SEAMLESS ROAMING CONTEXT-AWARE IN REMOTE HEALTHCARE SYSTEM

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Abstract. In the health-care system, parameters of patients such as Electroencephalogram (EEG), Electrocardiogram (ECG), Electromyogram (EMG), Glucose, Blood pressure, motion, etc. are monitored in real-time that assist doctors to timely detect and treat unexpected risks of patients. Thus, it is critical for collected sensor data seamlessly roaming between various types of wireless transmission networks such as Personal Area Network (PAN), Wireless Fidelity (WiFi), Long Term Evolution (LTE). Moreover, congestion carrier frequency between multiple close-by PANs can cause high packet drop rates and useless energy consumption of sensors. From above reasons, we proposed a protocol for PAN-gateway to integrate many wireless communication standards (typically ZigBee, WiFi, LTE) and an optimal control network algorithm for Quality of Service (QoS). Flows of sensor data are seamlessly transmitted through many wireless interface standards in order to achieved the best average data rate; sensor energy used effectively and fairness/priority between many users.

Keywords. Healthcare, WBAN, QoS, roaming.

1 INTRODUCTION

Wireless Body Area Network (WBAN) includes number of body sensors (*i.e.* heart rate, temperature, motion, etc.) which are placed on around body human, collect data and send to medical center. There are many protocols and radio technologies provided for WBAN transmission, including Bluetooth, Bluetooth Low Energy, ZigBee/IEEE 802.15.4, Ultra-Wide Band (UWB) and IEEE 802.15.6 [1].

Among these radio technologies, ZigBee is still the most frequent choice for WBAN due to the efforts of ZigBee Alliance, which is an association of companies working together to develop standard and products for reliable, low bit-rate, low power networking solutions with cost-effective deployment. WBAN is a kind of Wireless Personal Area Network (WPAN) and among several type of WPAN, ZigBee network is a fine turn to apply in WBAN. Each ZigBee end device is integrated with body sensor and ZigBee network (star, tree or mesh network topology) helps to transmit data streams from body sensors to a coordinator in real-time [2].

In a typical ZigBee network for health-care, the body signal of a patient is first monitored by several wearable sensors called ZigBee end-devices, and then transmitted to a master node called ZigBee coordinator. Due to the characteristic of ultra-low power, only short-range communications are supported between ZigBee end devices and the coordinator, which leads to two disadvantages in a hospital scenario where a physician carries a mobile device to collect patient's data, *i.e., i)* the mobility of patient and physician is very limited to ensure the mobile device located within the radio range of the ZigBee coordinator, and *ii)* the physician cannot monitor remotely patients anytime and anywhere.

Beside ZigBee interface, there must has another interface (*i.e.* WiFi, Wimax, LTE, etc.) integrated to the coordinator to continue forward data streams far away to a medical server and/or to mobile devices of doctor, nurse for monitoring patient. In the health care system, the patient monitoring parameters continuously in real time to help a team of nurses and doctors detected the risks that may occur irregularly of patients, since doctors have treated timely action. In the context of a public health care area, a lot of patients wear sensors and transmit data through wireless interface to the data processing center (server). Conflicts of carrier frequency between different users lead to high packet loss rates and useless energy consumption of sensors. In addition, in the context of patients moving between care rooms, or moving outside of the hospital area, the data on the patient's sensor must be continuously connected to the server. Thus, data should be seamlessly roaming between various types of wireless transmission networks such as

PAN, WiFi, LTE.

The study of roaming contexts can affect the quality of health care services such as the context of patient mobility, the context of energy consumption of sensors, the context of transmission rate data of sensors, the context of congestion of transmission network system, and the context of service priority. To ensure that data from the sensor is sent to the server continuously in real time, the author proposes an algorithm to optimize the quality of network services by combining information or parameters from the above context.

The topic proposed to design the protocol for PAN-gateway, in which many wireless communication standards (typically ZigBee, WiFi, LTE) and algorithm to control the optimal quality of network services which is integrated into PAN-gateway. The algorithm for transmitting seamless information flows through many wireless connection standards enforces the best average data rate, uses energy efficiency, and ensures fairness and priority between many users.

The main content of this paper needs to be done to achieve results as follows.

   i.   The PAN-gateway protocol has integrated many wireless communication standards.
   ii.   Optimal control of network algorithm for seamless roaming network to satisfy Quality of Service (QoS).
   iii.   Network designs and results on OPNET simulation software.

The remainder of this paper is organized as follows. In Section II, we review related works. We present the PAN-gateway with multiple wireless interfaces proposal in Section III. Section IV describes our network architecture simulation and verify simulation results. Finally, Section V concludes this paper.

2   RELATED WORKS

A number of QoS metrics requirements for BAN is described in detail in [2]. Related to network, a lot of important parameters are summarized such as: delay, delay jitter, throughput, packet error rate, energy efficiency and interoperability. The ZigBee technology and the IEEE 802.15.4 standard are created to address the unique needs of sensors and control devices [3].

Sensors and control devices do not require the high bandwidth that other wireless network standards provide (such as WiFi and Bluetooth). Therefore, the ZigBee protocol was designed with reliability, cost-effectiveness, and low power consumption. The application bubble of this WPAN technology ranges from industrial monitoring and control, home automation, sensor networks to gaming, medical and automotive solutions [4]. The ZigBee Alliance, a non-profit consortium of companies, is responsible for the development of the technology, which defines the network and application layers upon the IEEE 802.15.4 physical and MAC layers. Additionally, the protocol provides security, inter-operability and conformance testing specifications [5]. As ZigBee is intended to become the global standard for sensor and control networks, it has been designed with the following primary features to suit the specific needs of those networks:

   i.   *Low cost:* The cost for the device, installation, and maintenance are all relatively low. The chipset itself is cheap to buy and the technologies simplicity allows for easy installation and maintenance for little cost.
   ii.   *Low power consumption:* The device operates at 1 *mW* Radio Frequency (RF) power, and has the ability to sleep when not in use. A ZigBee device can operate up to years without replacing of battery cells.
   iii.   *High density of nodes per network:* By making use of the IEEE 802.15.4 PHY and MAC layers, ZigBee is capable of managing a large amount of devices in a network.
   iv.   *Reliability:* By utilizing Direct-sequence spread spectrum (DSSS) with features such as the Carrier-sense multiple access with collision avoidance (CSMA/CA) transmission scheme in its MAC layer, which will be explained more thoroughly later in this paper, the technology ensures messages reach their destination nodes reliable.

3   PAN-GATEWAY MODEL

The OPNET Modeler simulation tool was used in this project to evaluate the performance of the ZigBee protocol and the IEEE 802.15.4 standard in PANs. OPNET Modeler is a popular tool for analyzing and designing communication networks, devices, protocols, and applications [6].

3.1.   The seamless protocol layer design

The ZigBee model suite offered in the modeler includes a discrete event simulation model to analyze the network performance of ZigBee PANs. The object code of the application and network layers are internally provided by the model and offer source code for protocol improvement, too. And it does include a model and the corresponding source code for the IEEE 802.15.4 MAC protocol [7].
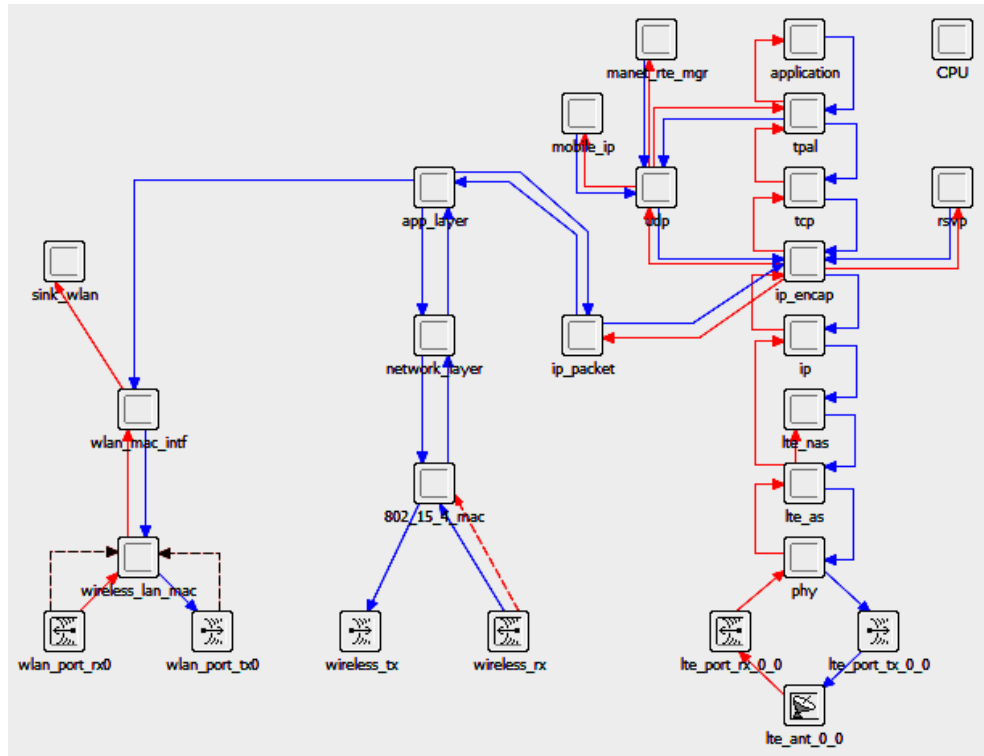

Fig. 1. PAN-gateway with three interfaces: ZigBee, WiFi and LTE.

A ZigBee protocol standard includes four layers [8] as shown in fig. 1. The physical (PHY) layer operates on or off radio communication; it supports functionalities for channel selection, link quality estimation, energy detection measurement and clear channel assessment. The medium access control (MAC) layer defines three types of nodes: network coordinator, network router or network end-device. Each PAN only has one coordinator node and it is recognized by the identification (ID) number; this number is called PAN-ID. Child nodes are known as end devices or routers needing to have the same PAN-ID as the coordinator.

At the network (NWK) layer, the topology of the PAN network is configured. Beside the star topology that naturally maps to the corresponding topology in IEEE 802.15.4, the ZigBee network layer also supports more complex topologies such as tree and a mesh structures. The network layer is in charge of organizing and providing routing over a multi-hop network (built on top of the IEEE 802.15.4 functionalities).

An application layer (APL) provides a framework for distributed application development and communication. The application profile framework allows different developers to independently build and sell ZigBee devices which can interoperate in a given of application profile. Based on the characteristics of the application layer, we can build up the gateway component from the point of view of the application profile. We propose the seamless integration and Interaction of ZigBee and TCP/IP protocol inside the

ZigBee coordinator device. Fig. 1 illustrates the layer connections in detail. To the best of my knowledge, this article is the first paper proposes data packet seamless via three wireless interfaces, that are zigbee, wifi and LTE. In the previous studies, only wifi and 3G interfaces are considered in the healthcare system.
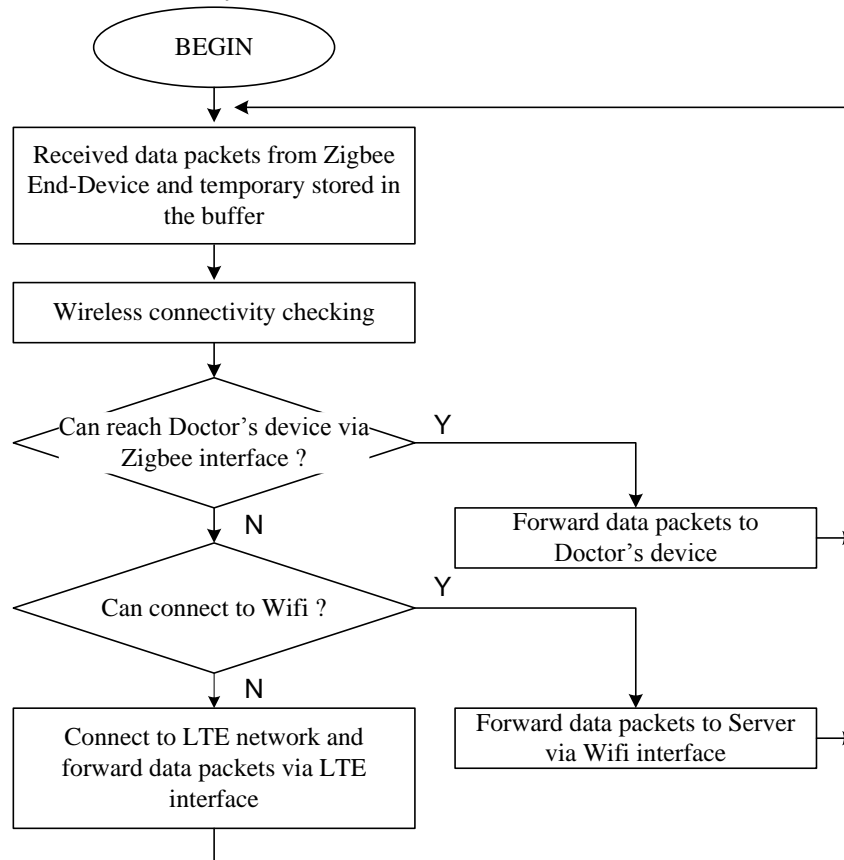

Fig. 2. Data packet seamless algorithm with wireless connectivity checking.

3.2.   Co-existing network

Radio collision is a critical problem in co-existing networks. The key physical parameters of ZigBee, WiFi, and LTE must be considered in determining the effects of radio interference between different kinds of networks [9]. Notably, carrier operation frequency is one of the most important specifications which we should initially consider. The 2450 MHz band is the industry, medicine and science (IMS) band, and is an attractive carrier frequency with unlicensed bandwidth.

However, radio interference easy occurs at IMS band if wireless users choose to use an improper communication system. Based on physical characteristics, we recognize that there is no radio interference between LTE radio and ZigBee radio but the radio collision will be happened if both WiFi and ZigBee uses IMS band. For this reason, the AP and WiFi devices should be configured in IEEE802.11a standard while ZigBee networks use IMS band.

3.3.   Energy model

How much power is needed to supply to WBAN? The propagation of wireless signals in WBANs experience shadowing and fading effects of the human body. Several more complex path-loss prediction models are available in the literature [10], [11], [12]. Because this article focuses on the mobility of patients, we use simple Link Budget model to compute power consumption for each type of end-device.

Let P_t is a power transmitted one symbol. For differential phase-shift keying (DPSK) modulation in ZigBee network, one symbol means one bit.

Let P_L is a free path loss; we have:

$$P_L = \left(\frac{4.\pi.d}{\lambda}\right)^2 \tag{1}$$

$$\lambda = \frac{c}{f} = \frac{3*10^8 [m/s]}{f[Hz]} \tag{2}$$

with: d is a distance between source and destination, λ is a wave length of radio propagation, f is a carrier frequency.

Let P_r is a received power, then we have

$$P_r[mW] = \frac{P_t[mW]}{P_L}$$
$$\Leftrightarrow P_t[W] = P_r[W] * P_L$$
$$\Leftrightarrow 10.\log_{10}(P_t[W]) = 10.\log_{10}(P_r[W] * P_L) \tag{3}$$
$$\Leftrightarrow 10.\log_{10}(P_t[W]) = 10.\log_{10}(P_r[W]) + 10.\log_{10}(P_L)$$
$$\Leftrightarrow P_t[dB] = P_r[dB] + P_L[dB]$$

Let E_s is a energy consumption for transmission one symbol, then we have

$$E_s[J] = P_t * \tau_s = \frac{P_t}{R_s} \tag{4}$$

with τ_s is a time to transmit one symbol and R_s is a data rate.

By using equations (1) ~ (4), we create Table I which sums up important parameters for the simulation.

For ZigBee network, the transmission power should be carefully adjusted to minimum due to following reasons, *i.e. (i)* a battery of ZigBee sensor is very limited in energy as well as physical size; and *(ii)* minimum wireless interference between different close-by WPANs. For WiFi and LTE networks, we don't need to adjust the transmission power to minimum WiFi and LTE energy because the energy of PDA devices is much higher than ZigBee sensor battery. The transmission power of them based on some manufacture specification [13].

Table 1: Sum up important parameters for the simulation.

| Network Types	Symbol	Value	Explanation
ZigBee network	d	2 m	A high of human being
	f	2.4 GHz	ZigBee carrier frequency
	P_r	-85 dB	Sensitivity power received
	λ	0.125 m	Wave length
	P_L	46.067 dB	Free path loss
	P_t	-38.933 dB	Transmit power
	R_s	250 kbps	ZigBee data rate
	E_s	$6*10^{-10}$ J	Energy cost to transmit 1 bit
	E	0.005033 J/MByte	Energy cost to transmit 1 MegaByte
WiFi network	f	5.0 GHz	802.11a carrier frequency
	λ	0.06 m	Wave length
	P_t	20 mW	Transmit power
	R_s	6 Mbps	802.11a data rate
	E_s	$3.3*10^{-9}$ J	Energy cost to transmit 1 bit
	E	0.028 J/MByte	Energy cost to transmit 1 MegaByte
LTE network	d	2000 m	Cell diameter
	$f\,(UL/DL)$	1920 / 2110 MHz	LTE carrier frequency
	BW	20 MHz	Bandwidth
	$R_s\,(UL/DL)$	75 / 300 Mbps	Peak data rate
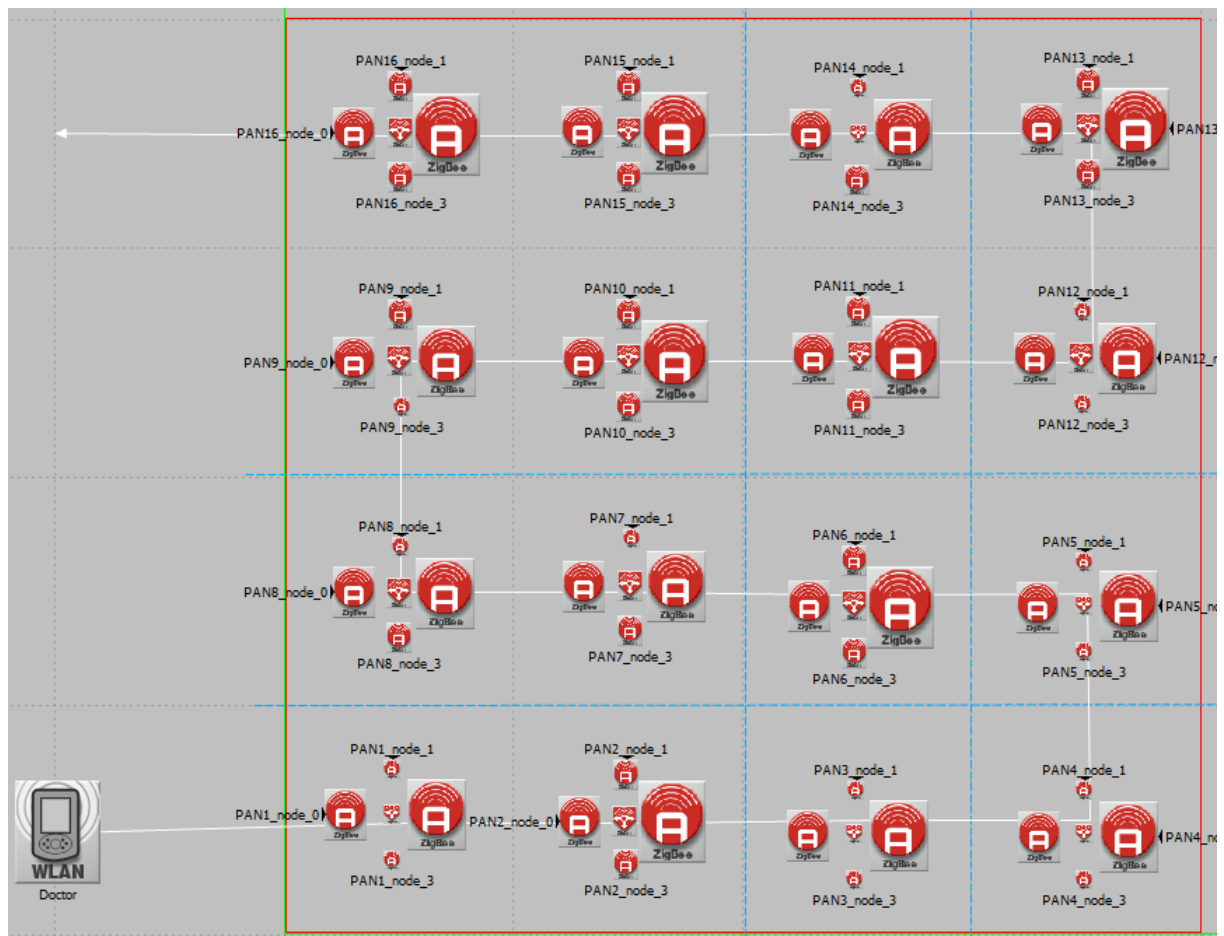
Fig. 3. Network simulation model inside a room for 16 patients and Doctor moving to collect data.

4   SIMULATIONS AND RESULTS

4.1.   Doctor moving to collect data

Figure 3 shows the first scenario of network simulation. In a room with $20m$x$20m$ dimension, there are 16 patients at their treatment positions. And there are WiFi access point serving for this room and a data central to store all data sensors from patients. If patients are required to remain in bed or move slowly indoors, a tree or mesh ZigBee structure network is used. In cases where patients are outdoor and enjoy high mobility, a star structure network must be used. However, the peak data rate of the ZigBee network is limited to 250 *Kbps*, the star structure will be used in most cases to achieve maximum data rate with minimum end-to-end delay. All sensor data are collected by the ZigBee coordinator (also known as a PAN-gateway).

As shown in Fig. 1, the coordinator includes two interfaces: ZigBee and WiFi. As normally, coordinator collects data from sensors via ZigBee interface and send all data to database central via WiFi interface. When a Doctor enters a room, he reaches to each patient (for example in five minutes) and collects data to his portable device. At that time, the coordinator within the ZigBee coverage range only send data to Doctor to minimize the transceiver energy. So that, when a Doctor's device received data from patients, his device continues forward all data to database central via WiFi interface.

There are two schemes for Doctor's devices: the first scheme is sensors data received via ZigBee interface directly from patients and the other scheme is data retrieved via WiFi interface from data center. Fig. 4 presents the simulation results when Doctor received data via Coordinator ZigBee interface. The results figure out the time of Doctor get reach to patients and collect data. They also indicate that data from
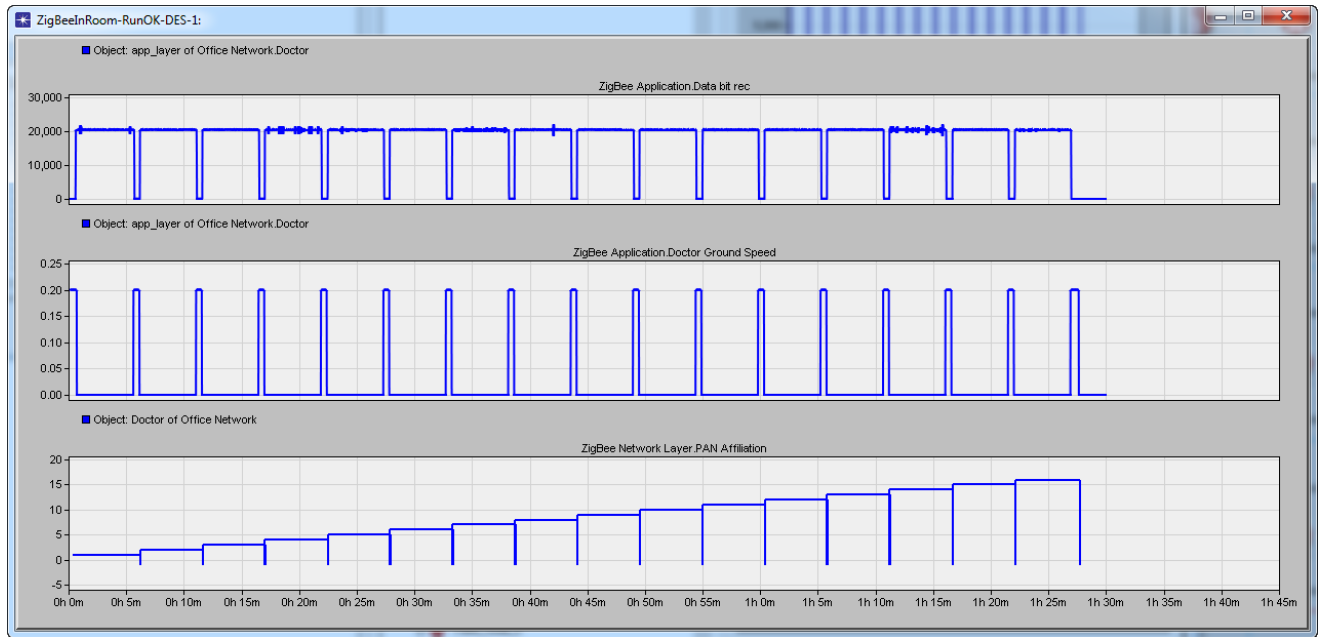
different patients are separated by PAN ID.

Fig. 4. (a) Data collection from each patient via ZigBee interface; (b) Moving speed of Doctor; (c) PAN ID of patients.
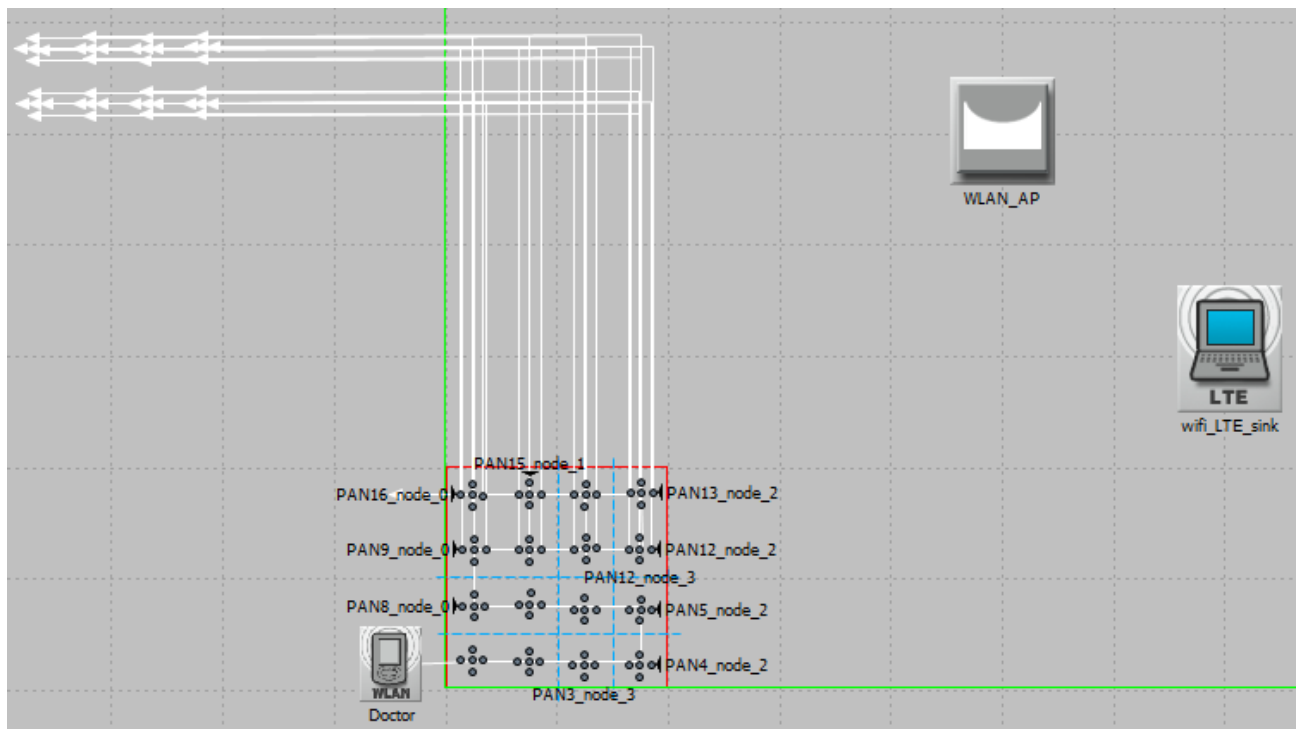

Fig. 5. PAN-gateways seamless roaming between multiple wireless area networks.

4.2.   Patients mobility indoor and outdoor

Figure 5 illustrates the second scenario of network simulation. In this scenario, we would like to show out that all coordinators can auto switch between three interfaces. A scheme likes that: all patients are static from the beginning of the simulation. After Doctor got in a room and collected all data (the same with the first scenario), all patients move around indoor with 100mx100m dimension, and all coordinators can

continue to send data to data center.

As shown in fig. 6, the simulation results are clear that all coordinators auto switch from ZigBee interface to WiFi interface. That is to say, when patients do not move in a small room and a Doctor gets reach very close to them, coordinators use ZigBee interface to transfer data to Doctor's device. When a Doctor stays outside a small room or when patients moves around inside a large room, coordinators use WiFi interface to upload information packets to data center. Moreover, in this scenario, a half of patients move from indoor to outdoor, then coordinators auto switch from WiFi interface to LTE interface. The simulation results in fig. 6 show that, when patient is inside room, coordinator uses WiFi interface, otherwise LTE interface is used to transfer data to data center.
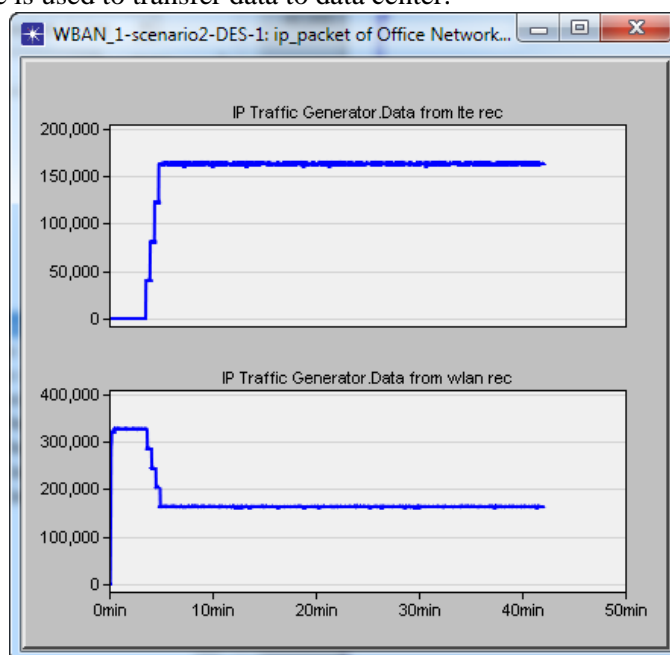

Fig. 6. Received data from mobility patients at server.

5   CONCLUSIONS

WBANs play an important role in the deployment of wearable/mobile pervasive computing systems. In this work, we presented a new type of WBAN with multiple interfaces integrated to Coordinator. All patients can keep in touch with Doctor or Database in any time and any place. We also analyze how much power transmission is needed to supply to ZigBee sensors. Coordinators switch interfaces based on their locations. The proposed model is useful for many applications, such as wearable computing, home entertainment, and health monitoring.

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CÁC BỐI CẢNH CHUYỂN VÙNG LIỀN MẠCH TRONG HỆ THỐNG CHĂM SÓC SỨC KHỎE TỪ XA

Tóm tắt. Trong hệ thống chăm sóc sức khỏe, việc theo dõi thông số người bệnh như Electroencephalogram (EEG), electrocardiogram (ECG), electromyogram (EMG), Glucose, Blood pressure, motion, v.v. một cách liên tục theo thời gian thực giúp đội ngũ y bác sỹ phát hiện và có hành động chữa trị kịp thời các nguy cơ xảy ra đột xuất của bệnh nhân. Như vậy, dữ liệu người dùng cần được chuyển vùng (roaming) liền mạch giữa nhiều loại hình mạng truyền dẫn không dây như Personal Area Network (PAN), Wireless Fidelity (WiFi), Long Term Evolution (LTE). Xung đột về sóng mang truyền dẫn giữa nhiều người dùng khác PAN có thể gây ra tỉ lệ rớt gói dữ liệu cao và làm tiêu hao vô ích năng lượng các sensor. Tác giả đề xuất giao thức cho PAN-gateway tích hợp nhiều chuẩn giao tiếp không dây (điển hình là Zigbee, WiFi, LTE) và giải thuật điều khiển tối ưu chất lượng dịch vụ mạng. Các luồng thông tin từ sensor được truyền dẫn liền mạch

thông qua nhiều chuẩn kết nối không dây; tốc độ dữ liệu trung bình đạt được tốt nhất; năng lượng sensor sử dụng hiệu quả; tính công bằng/ tính ưu tiên giữa nhiều người sử dụng.

Từ khóa. Chăm sóc sức khỏe, WBAN, chất lượng dịch vụ, chuyển vùng.