Architecture Integrating Wireless Body Area Networks with Web Services for Ubiquitous Healthcare Service Provisioning

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Abstract—Recent advancements in sensor technologies and Wireless Body Area Networks (WBANs) have led to the development of cost-effective healthcare devices which can be used to monitor and analyse a person's physiological parameters from remote locations. These advancements provides a unique opportunity to overcome current healthcare challenges of low quality service provisioning, lack of easy accessibility to service varieties, high costs of services and increasing population of the elderly experienced globally. This paper reports on a prototype implementation of an architecture that seamlessly integrates Wireless Body Area Network (WBAN) with Web services (WS) to proactively collect physiological data of remote patients to recommend diagnostic services. Technologies based upon WBAN and WS can provide ubiquitous accessibility to a variety of services by allowing distributed healthcare resources to be massively reused to provide cost-effective services without individuals physically moving to the locations of those resources. In addition, these technologies can reduce costs of healthcare services by allowing individuals to access services to support their healthcare. The prototype uses WBAN body sensors implemented on arduino fio platforms to be worn by the patient and an android smart phone as a personal server. The physiological data are collected and uploaded through GPRS/internet to the Medical Health Server (MHS) to be analysed. The prototype monitors the activities, location and physiological parameters such as SpO_2 and Heart Rate of the elderly and patients in rehabilitation. Medical practitioners would have real time access to the uploaded information through a web application.

Keywords—Android Smart phone, Arduino Fio, Web application server, Wireless Body Area Networks.

I. INTRODUCTION

THE concept of healthcare is defined as prevention, treatment and management of illness and preservation of mental and physical well-being of people through medical services [3]. The healthcare system globally, currently experiences challenges of low quality service provisioning, lack of easy accessibility to service varieties, high costs of services and a continuous increase in the population of the elderly. The provisioning of high quality, easily accessible and cost-effective healthcare services are still challenges facing the current healthcare system globally [13].

Also, the continuous increase in population of the elderly in the past decade [14], has significantly contributed to an increase in the number of people suffering from age – related

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diseases. These healthcare challenges extend to the areas of resource management for prevention, treatment and control of diseases and in providing remote assistance services to patients [6]. These challenges are placing a strain on the existing healthcare services therefore they create the necessity to develop better, smarter, cost efficient and quality healthcare services at runtime. This will allow a large number of people, especially the elderly and those in rehabilitation to have easier access to important healthcare resources and quality – oriented healthcare services with limited financial resources. The demand for quality healthcare services is on the rise, individuals are becoming more health conscious and demanding for healthcare services that can be provided ubiquitously [8].

A ubiquitous healthcare system is an environment where quality healthcare services are available to everyone without time and location constraints. In [16], they noted that ubiquitous healthcare systems holds the promise of maintaining wellness, disease management, support for independent living, prevention and prompt treatment, along with emergency intervention anytime and anywhere as and when needed. Moreover, technologies that provide ubiquitous healthcare services will be assimilated flawlessly in our daily lives such that they become invisible [17]. Ubiquitous healthcare systems use a large number of environments and platforms including Wireless Body Area Networks (WBANs), mobile devices and wireless grid/cloud/web services to make healthcare services available, observable, transparent, seamless, reliable and sustainable. These systems can allow medical practitioners to remotely monitor, diagnose, access vital patient symptoms, offer advice to patients, facilitate real time interaction with patients, give patients control over their personal data and also allows patients access services anywhere anytime. The requirements for ubiquitous healthcare systems include; accessibility to various available services from an healthcare provider, flexibility, security and remote health data acquisitioning, service personalization, automatic decision making and response.

As an environment for ubiquitous healthcare, WBANs are characterized by the deployment of biomedical sensors around human body to proactively collect the body's physiological data measurements and transmit them wirelessly to the base coordinator for processing [20]. WBAN environment can continuously interact with the neighbouring network nodes and can access services from the web/cloud/grid environment to

provide new services at runtime. However, effective service provisioning continues to remain a challenge in a WBAN environment. By healthcare service provisioning we refer to providing cost – effective healthcare services in terms of ubiquitously monitoring patient's vitals, remote diagnosis, medical recommendation and prescription, access to view medical practitioner's daily routine and booking medical appointments online in certain cases.

The prototype Service Oriented Wireless Body Area Networks (SOWBAN) reported in this paper is an effective service provisioning mechanism in ubiquitous healthcare environment, designed to be used by patients in rehabilitation and to monitor the elderly, with the help of a 3 axis accelerometer and a wireless pulse oximeter (SpO_2). The accelerometer monitors body movements to determine the patient's activities i.e., running, resting, walking and dangerous activities such as falling, as we know a fall not quickly detected experienced by a recovering patient or the elderly can be fatal. The SpO_2 is used to measure blood-oxygen saturation levels (SpO_2) and Heart Rate (HR) [19]. The continuous monitoring of physiological parameters has the potential to greatly improve the quality of life of patients [14]. The hardware components of our prototype comprises of WBAN nodes (hereafter referred to as BS nodes or Body Sensor nodes), implemented on arduino fio platforms to collect physiological data and transmit it wirelessly to the Central Intelligent Node (CIN). From the CIN, Patient's physiological data is then uploaded to the Medical Health Server (MHS). Physiological data received on the MHS would be equivalent to that obtained at the medical facility, if the patient were to go there for a medical check-up.

The prototype SOWBAN shows a system that implements fully the concept of ubiquitous healthcare service provisioning. Our prototype architecture provides another solution to the telemedicine technology, which is high in cost in implementation and maintenance. Through smart designing methods, we have integrated certain services in our prototype and make them accessible at the users' ends (patients and medical practitioner). All events and processes within our prototype are designed as services. Such service oriented design gives our prototype the advantages of: interoperability, reuse, efficiency and scalability. This current study aimed to describe our system architecture to integrate WBAN with WS for effective healthcare service provisioning. Our objectives are the following:

(a) To enable the seamless integration of wireless body sensors with web service architectures.

(b) To support the ubiquitous provisioning of quality and cost – effective healthcare services.

(c) To allow for real time diagnosis of the healthcare conditions of remote patients, irrespective of their locations.

(d) To enable an effective healthcare service provisioning in a distributed service provisioning environment.

The remainder of this paper is succinctly summarized as follows. In Section II, we discuss the related work. In Section III, we discuss the prototype SOWBAN system architecture looking at its different layers to feature all hardware and software components. In Section IV, we present the live implementation of the prototype SOWBAN architecture. Section V, concludes the paper and highlights its contributions as well as our future work.

II. RELATED WORK

A lot of research has been put into remote vital signals acquisition using WBAN technologies. Reference [8] provides a comprehensive survey of WBAN applications. In particular, [5] developed the OnkoNet architecture to support any-time and any-place access to healthcare services using mobile computing technology. The OnkoNet architecture was implemented as a mobile agent to support knowledge intensive cooperation among humans and software agents to produce, deliver, control and consume healthcare services in a virtual community supporting the cooperation of actors involved in cancer diagnosis and therapy. A wearable health system using WBAN for patient monitoring was presented in [3] the system is made up of 3 levels. The first level consists of physiological sensors, second level is the personal server, and the third level is the health care servers and related services.

A ubiquitous Healthcare System (UHS) was developed by [4], the system consists of vital signs devices and environment sensor devices to acquire context information to monitor and manage health status of patients anytime anywhere. The framework targeted the development of four healthcare applications including self-diagnosis, remote monitoring, exercise management and emergency services. Reference [22] proposed WBAN to support medical applications and the necessity for design concepts of the hardware and network protocols in a multi-patient monitoring environment were highlighted.

An information based sensor system presented in [20] focused on the problem of constructing information gain model stroke prevention in U-health Wireless Body Area Networks (WBANs). Here, an information-based probabilistic relation model among the key indicators which sequenced their data gathering priority and precedence in the WBAN was constructed. They further constructed a cost function over the energy expenditure involved in their data gathering, and expressed the relationship between utility gain and energy loss as a constrained optimization problem. Reference [18] gave a case study providing the fundamentals of how WBAN can be used for remote data acquisition and information fusion was given. Wireless devices from different technologies were made to work together in a distributed way in a smart environment. This system uses a distributed approach to add new components in execution time. To enable real time collection of healthcare data from the WBAN, [11] proposed a Secure Ubiquitous Healthcare System Architecture (SUHSA). The collected data is converted into a Clinical Document Architecture (CDA) format, digitally signed, encrypted and securely transmitted over the Internet protocol Multimedia Subsystem (IMS) and Health Level 7 (HL7) messaging standards to a central hospital for patient health condition to be

accessed by doctors. The IMS provides internet services with Quality of Service (QoS) and it integrates different services.

Reference [13] in improving on their earlier work on grid-based Healthcare Service Broker (HSB) for remote vital signs management [12] proposed a new grid enabled framework for ubiquitous healthcare service provisioning. Their work gave a comprehensive discussion of the roles of telemedicine, wireless body area networks and wireless utility grid computing technologies to address the challenges of the conventional healthcare system. They integrated these technologies to realise the gFrame framework for ubiquitous healthcare service provisioning. The study integrated Mobile Dynamic Virtual Communities (MDVC) of healthcare services into health grid through a proxy based approach for performance benefits. The framework allowed for remote vital signs acquisition and personalized grid services discovery through a metadata and fuzzy logic based intelligent context engine. The gFrame is promising because of its vision to integrate MDVC into the health grid for ubiquitous, quality and cost-effective healthcare service provisioning. This current study reports on life prototype implementation of SOWBAN, which is a component of gFrame for remote vital signs acquisition. The implementation was tested on people who volunteered for the project.

III. SOWBAN SYSTEM ARCHITECTURE

The prototype SOWBAN is a component of gFrame designed to enable effective healthcare service provisioning by integrating WBAN with WS. Fig. 1 shows the SOWBAN 3 layer system architecture. These layers are: BS Arduino Layer, Central Intelligent Node Layer (CINL), and Medical Health Server (MHS) Layer which is made up of the SOWBAN applications (the web application server) and the database.
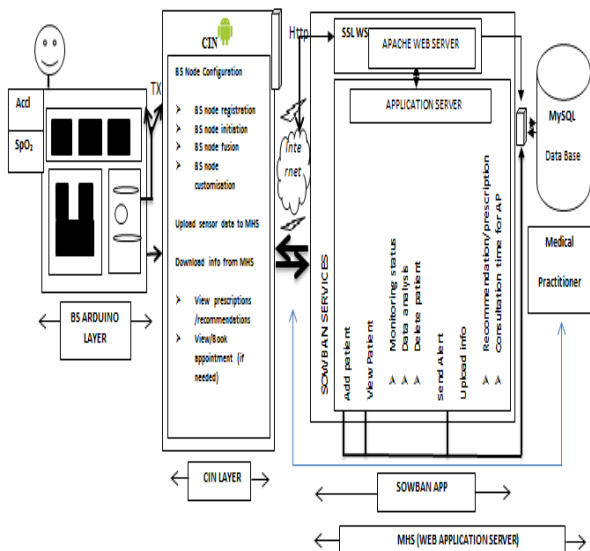

Fig. 1 SOWBAN Architecture

A. The BS Arduino Layer

The BS Arduino layer consists of the BS nodes i.e., 3 axis accelerometer and pulse oximeter, implemented on arduino fio platforms to be worn on the patient's body. We developed the BS node hardware as shown in Fig. 2. The BS nodes gather physiological data from patients and transmit the data through an attached WiFly radio over a Wi-Fi wireless network to the CINL. The BS nodes have the intelligence to sense, sample, process and communicate physiological data. They also satisfy design requirements of minimum weight, greatly reduced form factor, low – power consumption through configuration (which allows for prolonged ubiquitous healthcare monitoring), seamless integration into our prototype, standard based interface protocols and patient – specific customization. The BS nodes receive configuration instructions and responds to commands from the CIN which is more superior in terms of intelligence [2].
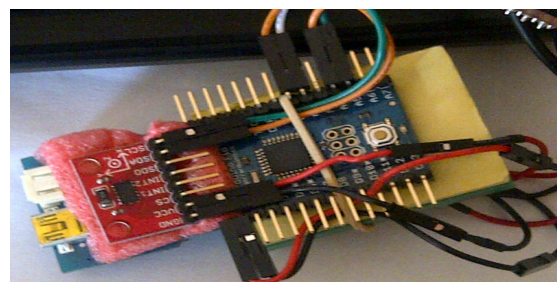

Fig. 2 BS Node Hardware

B. Central Intelligent Node Layer (CINL)

The CINL holds the CIN which is responsible for collecting and processing of physiological data received from BS nodes, providing a Graphical User Interface (GUI) for the patient to view his/her data in real time and uploading patient data to the MHS. It communicates with the MHS via GPRS/Internet. The architecture uses an android smart phone with operating system (OS) 2.3v as the CIN. Android OS serves as a great choice for this architecture allowing for sophisticated real time data processing and increasing processing power. Integrating an android smart phone with certain sensors e.g., an accelerometer provides a way to determine mobility and Global Positioning System (GPS) for location determination. This makes them more suitable for a fully integrated BS node ubiquitous monitoring system and is a benefit to our prototype SOWBAN. We have deployed a service on the CINL to enable configuration of the BS nodes, in terms of: node registration, node initialization, node fusion and node customisation. We have also deployed services to enable patients upload physiological data to the MHS, download information (recommendations/prescriptions) from the MHS and view the medical practitioner's consultation times or routine, if uploaded to the MHS. This will enable patients' book medical appointments when needed.

Using a simple comparison algorithm the CIN compares changes in data received from the BS nodes to determine whether to send data to the MHS or not. Data from the BS

nodes are sent only when the CIN detects a change in the received data (SpO$_2$ parameters, activities and location). This will help save cost for the patient by reducing the number of data transmissions made. Fig. 3 shows the basic data flow algorithm of the CINL.

```
Do
If (bsData1 == 0)
        bsData1 = readValue ()
        bsData2 = bsData1
Else

        bsData1 = readValue ()
        // compare with previous and decide
                If (bsData1 != bsData2)
                Send new Val
                bsData2 = bsData1
                Endif
Endif
```

Fig. 3 CINL basic data flow algorithm

C. Medical Health Server (MHS) Layer

The MHS stores the electronic medical records of registered users and provides various services to the patients, medical practitioners and healthcare providers. It is the responsibility of the MHS to authenticate users, accept health monitoring session uploads, format and insert the session data into corresponding patient medical records, analyse the data, determine serious health situations in order to contact emergency healthcare providers, and forward new information to the patients, such as recommendations, prescribed drugs and exercises. These operations are performed autonomously, without human's intervention by comparing the latest patient's physiological data updates with already existing ones in patient's medical record as well as comparing recommendations and prescriptions by the patient's medical practitioner or healthcare provider. The MHS consists of the web server and application server forming a web application server which can be accessed through a web browser. The application component of the web application server holds the MHS's business processes and is responsible for communications between the CIN, web server/web services and the database.

Our developed web application server is deployed on Tomcat with Apache and MySQL is used as a database. On the application component, Add patient, registers and initializes a new patient record on the database. View patient, checks the existing patient medical record i.e., monitoring status/monitoring history, received data analysis and if a patient record no longer exists on the database, delete patient. Send alert, creates an alert when data analysis results in a potential medical condition. With the Upload info, patient recommendations, prescriptions and medical practitioner's consultation slots can be uploaded to the MHS. Patients can view this uploaded information through the download info service on the CIN over the web.

Two main services offered at the web server component are *enterData* and *collectData*. To access these services the medical practitioners have to login first. Using the *enterData* enables data to be entered into the database while *collectData* helps retrieve data. These services give the medical practitioner access to the patient's record on the MHS over any public network provided the correct authentication details are used. Authentication login details ensure the privacy of the patient's medical records. Privacy involves the confidentiality of patient's data and the assurance that no information leakage from the medical records is feasible.

IV. SOWBAN IMPLEMENTATION

The process of monitoring a person's health condition requires a large amount of information. Our developed BS nodes implemented on arduino fio platforms has the capacity to collect large amount of physiological data and transmits these data continuously. Fig. 4 shows the diagrammatical description of the data transmission process of our prototype.
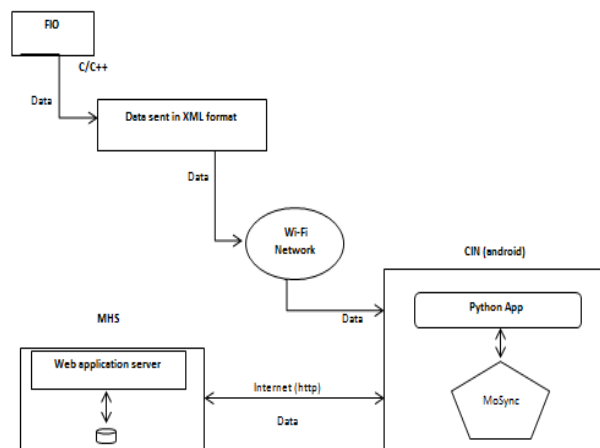

Fig. 4 Prototype SOWBAN data transmission process

The accelerometer is worn around the patient's waist, either using a waist belt or modified mobile-phone carry-case. The accelerometer gives the continuous monitoring and transmission of the patient's angular force on the X, Y and Z axis. These movements are translated into motion states which corresponds to the activities of the patient with the following states existing; resting (ID - 1), walking/general movement (ID - 2), running (ID - 3) and falling (ID – 4). The measurement of the motion is determined by using the maximum recorded values from the accelerometer within a 1- second cycling period and based on these values, the respective states were determined. We describe the work flow process of the accelerometer as this: initially, the accelerometer is set to an inactive state. Its timer is configured with a 1-sec cycling period to wake the accelerometer up at intervals to record both low measurement range (e.g., ±2g) and high measurement sensitivity on the X, Y and Z axis. Waking up at intervals

minimizes power consumption when patient is in a resting state (ID – 1). If the measured value exceeds a certain threshold value, the inactive state is disabled as this signifies patient is now in an active state. The normal frequency of human activities is at ranges between 1 – 18Hz [1]. Due to this our data sampling rate is set to be in the range of 10 – 100Hz. The accelerometer's measurement ranges allows for highest sensitivity outputs on the X, Y and Z axis. If measurement shows inactivity for a period of time (e.g., 6mins) the accelerometer returns to an inactive state and restarts the work flow process all over. This work flow process ensures automatic activity monitoring, power conservation and alertness to changes in patient activities.

To carry out measurement test, our accelerometer sampling at a frequency of 50Hz on all axis is worn around a person waist using a modified mobile-phone carry-case as shown in Fig. 5.

Fig. 5 Accelerometer worn by a patient

Fig. 6 shows the test measurements for the ID – 2 and ID – 3 states. We use AcclX, AcclY and AcclZ to represent the front, side and vertical accelerations, respectively. Due to the earth's gravitational force, there is always an output of +g present if a person is in a vertical position and vertical measurement AcclZ is taken. During test measurements, ID – 1 and ID – 2 showed acceleration movements mostly on the X and Y axis while the Z axis showed less acceleration movement. Also measurement tests for ID – 3 and ID – 4 showed acceleration movements mostly on the Z axis while the X and Y axis showed less acceleration movement.
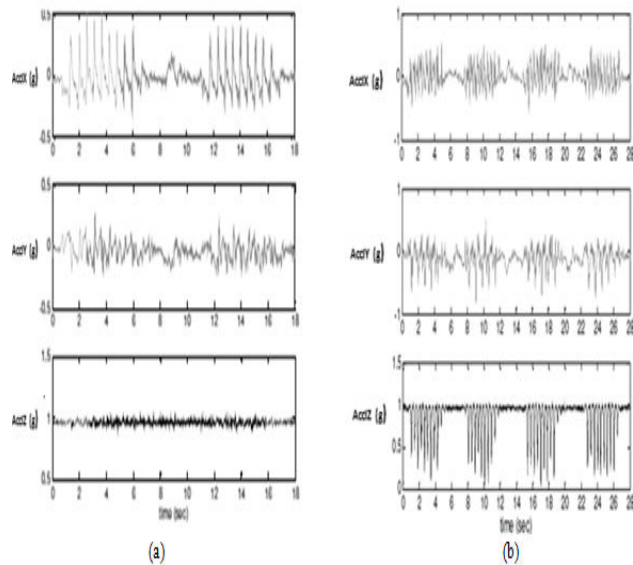

Fig. 6 Accelerometer measurements showing (a) walking (ID – 2) and (b) running (ID – 3)

The measurement tests in Fig. 6, shows different human activities generate different patterns in acceleration readings. With this, it is possible to group different human activity through the analysis of the recorded acceleration data and warn against abnormal activities such as increased energy expenditure and falling. Moreover, once an abnormal activity is detected through the acceleration reading, the health status can be verified with inputs from other sources, e.g., by checking the heart rate from a SpO_2 or heart activity from an ECG sensor.

The wireless pulse oximeter measures blood-oxygen saturation levels (SpO_2) as well as heart rate (HR). Measurements are based on Lambert Beer's law of spectral analysis which relates the concentration of absorbent in solution to amount of light transmitted through the solution [9]. Knowing the intensity, the path length and extinction co-efficient of a substance (here, oxyhemoglobin or reduced hemoglobin) at a particular wavelength, we determine oxygen saturation by measuring the light transmitted at two different wave lengths through the fingertip. This method capitalizes on the fact that, at the red region of the light spectrum around 660nm reduced hemoglobin (Hb) has higher extinction co-efficient compared to oxyhemoglobin (HbO_2). While in the near – infrared region of the light spectrum around 940nm, the extinction co-efficient of Hb is low compared to HbO_2. With the differences in extinction co-efficient, the light absorbed by Hb and HbO_2 can be determined and used to calculate a ratio R, which correlates to oxygen saturation. Using lambert's law, we obtain an expression for the ratio for light absorbed given by Equation 1.

$$R = \frac{\log_{10}\left(I_1/I_{in1}\right)}{\log_{10}\left(I_2/I_{in2}\right)} \tag{1}$$

I_1 and I_2 are the light intensity at different wave length calculated by Equation 2 and Equation 3.

At wavelength λ_1, $\quad I_1 = I_{in1}10^{-(\alpha_{o1}C_o + \alpha_{r1}C_r)l}$ (2)

At wavelength λ_2, $\quad I_2 = I_{in2}10^{-(\alpha_{o2}C_o + \alpha_{r2}C_r)l}$ (3)

where

C_o is the concentration of oxyhaemoglobin (HbO$_2$)
C_r is the concentration of reduced oxyhaemoglobin (Hb)
α_{on} is the extinction co-efficient of HbO2 at wavelength λ_n
α_{rn} is the extinction co-efficient of Hb at wavelength λ_n
From Equation 1 we show that:
Oxygen saturation (SpO2) =

$$\frac{C_o}{C_o + C_r} = \frac{\alpha_{r2}R - \alpha_{r1}}{(\alpha_{r2} - \alpha_{o2})R - (\alpha_{r1} - \alpha_{o1})}$$ (4)

By measuring the elapsed time between peaks of the infrared light signal we get a value for heart rate using Equation 5. The infrared light signal is used to calculate for heart rate because it has low noise and can be used in different environments [21].

$$\text{Heart Rate (BPM)} = \frac{60}{Period(\sec)}$$ (5)

Our pulse oximeter test calculations report hearts rates in the range of 30 – 245bpm and SpO$_2$ values from 0 – 97%. In developing our wireless microcontroller based pulse oximeter, we made use of available off the shelf products that provide self-contained logics for driving LEDs (red, infrared, silicon photodiode) and performing SpO$_2$/HR calculations. The pulse oximeter performs all required calculations and transmits physiological data via a WiFly radio module over the Wi-Fi network to the CIN.

Fig. 7 shows the WiFly radio module hardware. The WiFly is attached to the arduino fio platforms to enable radio transmission. The WiFly can connect to any router whenever the necessary security protocols are correctly configured. Once connected, the module will create a server and listens on IP Address – 192.168.0.68 and Port – 60000.
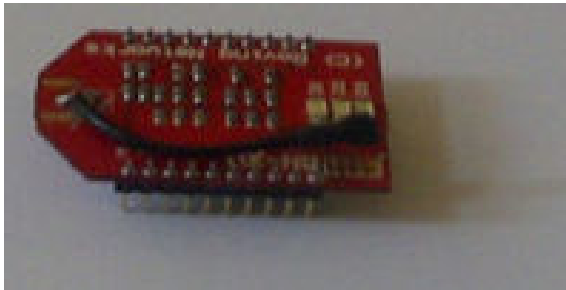

Fig. 7 WiFly radio module hardware

The performance of the wireless network is important in ubiquitous healthcare service provisioning. We set up our Wi-Fi wireless network to ensure efficient transmission of patient physiological data because medical practitioners can only assess patient's status correctly by the medical information they receive. To achieve this, we configured an Access point (AP) to set up a wireless connection and deployed TDMA schemes to operate on the Wi-Fi's existing MAC protocols. Our TDMA schemes results in: a scheduled data transmission process, reduction in network congestion, power conservation and extended battery life of BS nodes.

We developed a MoSync python application to run on the android smart phone. Python for MoSync is a very effective programming language with efficient high-level data structures that delivers a simple but effective approach to object-oriented scripting programming [10]. The MoSync python application gathers data sent from the BS nodes. The CIN uses the python APIs (Application Program Interfaces) to manage the AP's processes i.e., setting up wireless connections to both BS nodes and the MHS. On receiving data from the BS nodes, the CIN uses comparison algorithms to compare data received with the last data sent. The comparison algorithm is programmed to send data to the MHS only when there is a difference in data just received from the last data sent. The CIN also enables the patient view his/her medical status in real time through its GUI. Fig. 8 shows screenshots of the GUI interface on the CIN.

Fig. 8 Screenshots of the CIN's GUI showing (a) patient walking (ID – 3) on accelerometer monitoring and (b) an alert message in case of an emergency on pulse oximeter monitoring

To upload patient data to the MHS, the CIN connects with the upload info service on its GUI and sends to the web application server in TCP/HTTP over GPRS/Internet. The web application server mines data received and determines health risks using logistic regression. Functionality on the web application server is implemented in HTML/PHP. Fig. 9 shows a section of the PHP program on which the web application server runs.
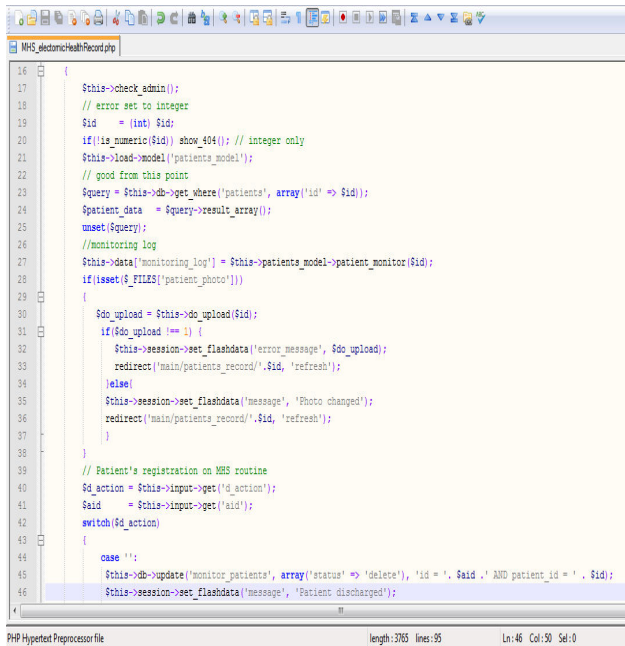
Fig. 9 A section of the Web application server PHP program

The medical practitioners can see the patient's activities and SpO₂ health status in real time through a web application over a web browser. An abnormal condition triggers the alert signal which is received by both patient and medical practitioner and in high risk situations the GPRS on the android can be used to determine the patient's location. Our implementation of various off the shelf components and Open Source Softwares (Python, PHP, MySQL and Apache Tomcat) helps reduces overall cost of the prototype SOWBAN. Fig. 10 shows the prototype's output at the medical practitioner's end on a browser.

Fig. 10 Prototype SOWBAN's output on MHS

The power consumption and size for the major components in the BS Arduino Layer and CINL are listed in Table 1 to give a cost evaluation. The size of the entire BS arduino layer is limited to 90 *62* 22mm and powered by a Li-Ion battery pack which is selected due to its low cost and convenience in testing and recharging. With smart implementation power consumption is greatly reduced in the prototype development. The CINL has a more reliable and longer lasting source of power, therefore will not be an issue.

TABLE I
COST EVALUATION OF THE PROTOTYPE SOWBAN

Component	Current (mA)	Size (mm)
BS nodes i.e., accelerometer and pulse oximeter	0.023	3 * 5 * 1 90 * 60.5 * 22
Arduino Fio platform	40	27.9 * 66.0 *3.5
WiFly radio transmitter	38	27*18*3.1
Li-Ion battery pack	_	67.5*49.5*17

The cost to build the prototype SOWBAN (excluding the MHS) is around 1500Rands which is feasible for ubiquitously monitoring the elderly and patients in rehabilitation. Based on our implementation, we can evaluate our prototype in terms of:

(a) Safety – patient's conditions being monitored constantly and in real time guarantees early detection in patient's status and treatment can be administered early enough.

(b) Timeliness – with real time detection in the patient's status i.e., especially in critical conditions where the medical practitioner is notified in immediately and can contact the healthcare providers in closest proximity to the patient for immediate attention.

(c) Effectiveness – by monitoring patient's status and providing services ubiquitously, cost spent on healthcare is reduced, patients do not have to travel the distance to a health facility, wait in queues at the health facility before being attended to. Effectiveness also ensures that patient's conditions, prescriptions and recommendations are properly documented.

(d) Efficiency – this is experienced in the ability for the designed prototype to provide an overall outcome for the patients in days of survival, years of survival, improvement in status (especially in recovering patients) and reduction in disability (especially in some age – related illness).

V. CONCLUSION

This paper describes the implementation of an architecture that seamlessly integrates WBAN with WS for ubiquitous healthcare service provisioning. The prototype SOWBAN developed proactively collects body signals of remote patients to recommend diagnostic services. This prototype provides continuous physiological data monitoring capabilities with minimum intervention of medical personnel and ubiquitous

accessibility to variety of services allowing distributed healthcare resources to be massively reused for providing cost-effective services without individuals physically moving to the locations of those resources. By automating the physiological data monitoring process the most updated information of patient will be available at all times. The SOWBAN enables the monitoring of patients physiological data in real time, promising ubiquitous, yet an affordable and effective way to provide healthcare services. The developed SOWBAN is one of the first that successfully integrates body area networks with web services for ubiquitous healthcare service provisioning. The SOWBAN ensures interoperability between heterogeneous devices and technologies, data representations, scalability and reuse. The contributions of this paper are:

(a) It provides the effective provisioning of services within ubiquitous healthcare system. SOWBAN achieves this by seamlessly integrating the WBAN technologies i.e. sensor systems and networks, embedded engineering etc. with web services i.e. internet technologies, apache servers etc.

It allows health data monitoring, through activity information such as body positions and SpO_2 parameters, to know a patient's health status.

(b) It provides reliable and power efficient medical data transmission within the 802.11/Wi-Fi using developed TDMA schemes.

The SOWBAN also ensures privacy, integrity and authentication protocols by using passwords and encryptions because privacy is seen as a fundamental right of humans and is a sensitive issue in healthcare applications.

However, future works are required to improve the quality of service of body sensors wireless communication, reliability of sensor nodes, security and standardization of interfaces. In addition, further studies of different medical conditions in clinical and ambulatory settings are necessary to determine specific limitations and possible new applications of this technology.

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