A Wireless Continuous Patient Monitoring System for Dengue: Wi-Mon

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***Abstract*— The improvements in the wireless networking technologies and the integrated electronic circuits have allowed the advancement in the Wireless Body Area Network. WBAN offers many applications in remote health monitoring and medicine. IEEE 802.15.4j and IEEE 802.15.6 are standards for the medical WBAN. It allows the integration of intelligent and miniaturized sensor nodes in or on a human body to monitor the human body functions. It has great potential to make a huge transformation in the future of medical industry. The WBAN concept provides plentiful new innovative ideas to enhance the health care systems. The paper presents a wireless monitoring system for patients who need continuous monitoring, using WBAN concept. This wireless monitoring system contains sensor network and remote monitoring application. It contributes to collection of the vital information of the patients such as temperature, pulse rate, ECG (electrocardiogram), oxygen saturation and blood pressure. Moreover, the system also provides management of information collected from the sensors, alert the administration in severe condition of the patients. The design and implementation of system are discussed in this paper.**

Keywords- Dengue, ECG, health-care systems, vital sign, wireless body area network, wireless monitoring.

I. INTRODUCTION

Health care expenses are rising with the increment of world population, which bring the technology based improvement in the health care systems nowadays. Advance technologies used in electronic devices and vast improvement in the wireless communication emerged to Wireless Body Area Network (WBAN). It consists of intelligent, tiny, lower power, micro and Nano technology sensor nodes which are placed in or around a human body. These sensors are used to send the data to personal server where it can be retransmitted, stored and analyzed. The usage of a wireless medium is to empower an application and is cost effective compared to wired connection [1]. WBAN applications are used in many fields such as military, sports, healthcare but it has a vast scope in the medical field. Nowadays, most of the doctors and engineers who are interested in bio medical engineering and wireless communication pay a lot of attention to WBAN. The standardization for medical WBAN, IEEE 802.15.6 desire to provide global standard for minimized power, and reliable wireless communication, with data rates from 75.90 Kbps in narrowband and up to 15.60 Mbps in ultra wide band [2], [4]. By using the facilities of WBAN, early detection and prevention and maintained optimum level to health even to chronic diseases, alternatively to the prevailing health system, in which health services are provided in crisis of the diseases. The most important purpose of the WBAN is developing the quality of life [5]. WBANs have transformed the future of the medical field by diagnosing life threatening diseases and giving real time monitoring for patients [6]. The value of WBAN is expected to build up health care systems to empower the effective management and early detection of illness, and reaction to crisis rather than just wellness [3], [7].

WBAN in medical applications, which allows for continuous monitoring of patients' vital signs such as blood pressure, temperature, pulse rate, respiration rate, ECG, and oxygen saturation. In cases where any vital sign threshold readings of the patients exceeded, the data being collected by the sensors send data to the personal server. Then from the server data delivers via internet to the remote location based on that the medical person can take necessary action for that situation [1], [8]. Continuous patient monitoring and providing medication to the patient whenever required are most advanced areas in WBAN. Among them continuous patient monitoring is the most required one in the medical field nowadays. It is mostly needed by cardiac attack patients, dengue severe condition patients and patients who are suffering from severe illness. Therefore, the Wireless Monitoring system (Wi-Mon) using WBAN is specially designed for the continuous monitoring purpose for patients who are suffering from dengue.

A. Dengue

Dengue is a neglected tropical disease that has become the fastest growing mosquito-borne disease, with almost half of the world's population now is at risk. The disease is one of the leading causes of serious illness among children and adults. Early detection of suspected case, access to proper medical care and disease management can help in dramatically

lowering the rate of fatal cases. Careful follow up of suspected cases and early detection of plasma leakage is very important to prevent shock or severe organ involvement. The use of the original world health organization (WHO) classification of dengue fever, dengue haemorrhagic fever and dengue shock syndrome that addresses on plasma leakage has proved to be very successful in reducing the case fatality rate of dengue (CFR). Therefore, patients need to be monitored continuously in the critical period of plasma leakage to reduce the CFR. The critical condition patient's body parameters such as blood pressure, heart rate, temperature, oxygen saturation and ECG needed to record in every 10 minutes since that can be used to determine the condition of the critical stage patients.

TABLE 1: RANGES OF MEASURING PARAMETERS

Parameters	Normal Range	Critical Stage
Blood Pressure(mmHg)	120/80	90/60
Heart Rate	80-60	Above 100
Temperature (ºC)	36.8	Above 36.8
SpO_2	95-100 %	Lower than 95%

II. EXISTING SYSTEMS IN THE MEDICAL FIELD FOR CONTINUOUS MONITORING.

There are many continuous monitoring systems available in the medical field such as lifescope Vismo PVM-2703, Mindray VS 600, Mortara s12 monitor, Comen NC5, vitalogik 4000, dyanascope 8001, carescope VC150, smartsigns compact 750, benevision N22 and etc. But lifescope vismo PVM-2703 is most widely used in the medical field due to its accuracy and less expensiveness compared to other systems.

Fig.1. Lifescope Vismo PVM-2703

A. *Lifescope vismo PVM-2703*

This machine enables to monitor ECG, pulse, respiration, SpO_2, NIBP (non-invasive blood pressure amplifier) temperature, IBP (invasive blood pressure). A large touch screen enables quick and intuitive operation. Some of the features are listed below:

- Simple operation
- It can be used to measure 7 parameters such as ECG, RESP, SpO_2, NIBP, CO_2/IBP
- Touch screen provides easy and intuitive operation
- 3 hours of continuous monitoring on battery power

Even though this machine provides good facilities to the health care system it contains some disadvantages too. It is very expensive compared to wireless monitoring systems. It costs around 5000USD and it is difficult for developing countries to have many machines in one treatment unit. The medical staff needs to manually record the parameters for every ten minutes which can cause human errors while recording.

III. WIRELESS MONITOR (WI-MON)

Wi-Mon is a new concept which combines sensor nodes with wireless networks and Wi-Mon software. It enables user to use the new emerging technology in the networks to be used in the medical field. Wi-Mon can be used to limit number of dengue patients who are at death risk and it enables the ease of using by giving a compact solution for the need of Doctors as well as the hospitals. Some of the features in Wi-Mon are mentioned below:

- Wireless Body Area Network is one type of wireless networks utilized for communication among sensor nodes and the personal server.
- Measures data of the patients automatically every ten minutes
- Measures crucial parameters such as temperature, blood pressure, pulse rate, SpO_2, and ECG.
- User friendly software interface with the remote access of patients details.
- Analyses the readings of the patients.
- Inbuilt alarming system to warn about critical patients.
- Small and compact.
- Comfortable for patients compared to the existing system.

Wi-Mon has the potential to provide better and less expensive health care services and provides more benefits to the patients, health care staffs and the society. Wi-Mon system

in the medical field gives a great advantage in remote monitoring purposes. This allows medical professions to access patient's data anywhere in a medical centre or even if they are away. This system is very suitable to be used in hospitals environment to reduce human errors and to reduce health care cost.

A. Communication Architecture of Wi-Mon

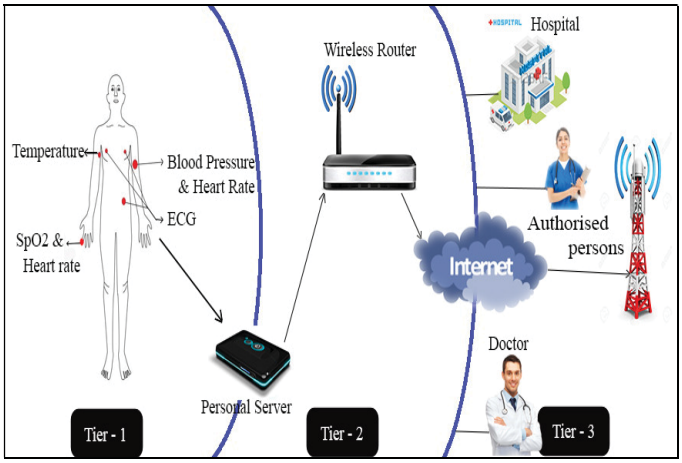

Fig.2. Communication architecture of Wi-Mon

Tier 1 characterise the network interaction of sensor nodes in the human body. Variable sensors are used to send body signals to personal server in the tier-1. The sensor networks incorporated with the raspberry-pi version 2 to accomplish the vital signs from the sensors to transfer them via Wi-Fi module to the wireless router in the tier-2. The network in the hospital and surrounded area is WLAN (wireless local area network). The router, which holds patients' information, is configured with IP address in order to interface the medical applications. After that it routes the all information to the internet via internet service provider. In tier -3 data are transmitted to hospital remote access point, and Doctor's personal computer through the internet.

B. Sensors using Wi-Mon

Fig.3. Sensors using in Wi-Mon

A Temperature, SpO_2, Blood pressure, pulse rate, ECG sensors are used in the Wi- Mon sensor network. Skin Temperature sensor used for temperature measurement with the accuracy of ± 0.4% ºC and the temperature sensor range is -40ºC to 100ºC. Pulse rate sensor essentially combines a simple optical heart rate sensor with amplification and noise cancellation. It has the measuring accuracy ±5%. Kodea blood pressure sensor is used for measuring the blood pressure with an accuracy of ± 3mmHg.

C. Wi-Mon Software

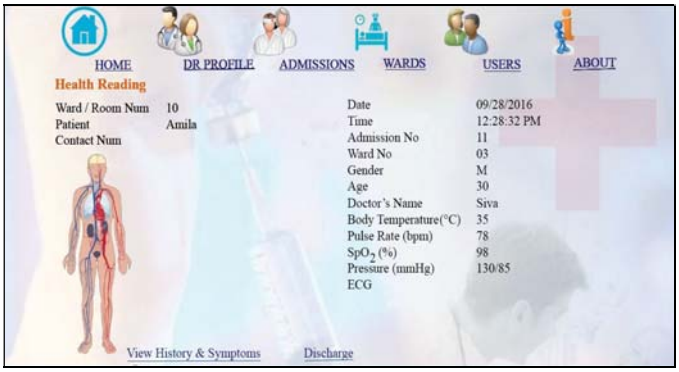

Fig.4. GUI interface of Wi-Mon software

Wi-Mon is specially integrated software to use the platform of the Wi-Mon device. It is the software that uses data from database to view it more conveniently and comfortably in a user-friendly manner. Wi-Mon software consists of features like admission of new patients, creating doctor profiles, doctor's ward lists, ward rooms, in-built alarming systems, password authentication privileges which are limited to various kind of users, analyzing details of patients and as well as the patient's history. The privileges for doctors and the administrative officers will vary according to their job titles. Doctors have more privileges than the administrative officers but for an emergency situation the alarm will work for all the users of Wi-Mon software. The patients' vital readings from the sensors will be visible in the interface of the Wi-Mon software under labels. The analyzing part of these readings also can be accessed through the software and it can be saved as a portable document for future use and the in-built alarming system in the software will alert the hospital through alarming with a sound. There are some threshold values for each parameter and those limits are already fed to the software therefore, these limits are used to identify the critical behavior of a patient. Considered threshold values were defined by the WHO.

IV. Experiment and Results

For the purpose of testing the accuracy of sensor readings from Wi-Mon, the readings from Vismo PVM-2703 and the Wi-Mon were taken simultaneously for the dengue patients in the Clinical Management of Dengue and Dengue Hemorrhagic

Fever (DHF) at the Negombo Base Hospital, Sri Lanka. Vital signs such as temperature, pulse rate, SpO_2, blood pressure, and ECG were taken for two patients, who were suffering from dengue haemorrhagic fever.

Fig.5. A patient monitored with Wi-Mon and Vismo

One hundred and eleven samples from pulse rate, SpO_2, and ECG were taken from both Wi-Mon and Vismo PVM-2703. Variations were studied with time. Results obtained are summarized in Fig.6 to Fig.9.

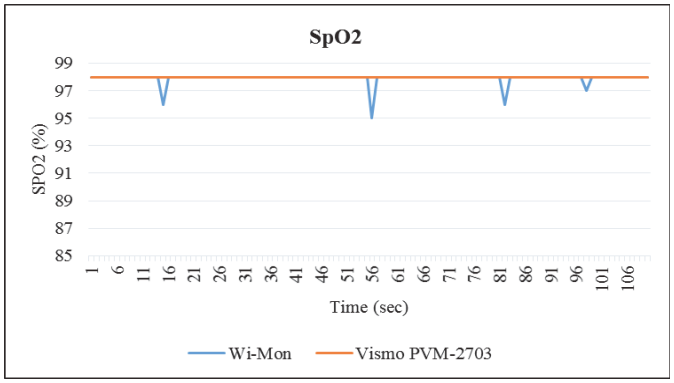

Fig.6. SpO_2 Vs Time with Wi-Mon and Vismo PVM-2703

By analysing the results shown in Fig.6 it can be seen that the saturation of oxygen level from Wi-Mon slightly varied with Vismo PVM-2703. According to the results maximum error rate, and minimum error rate are 3.06%, and 0.00% respectively.

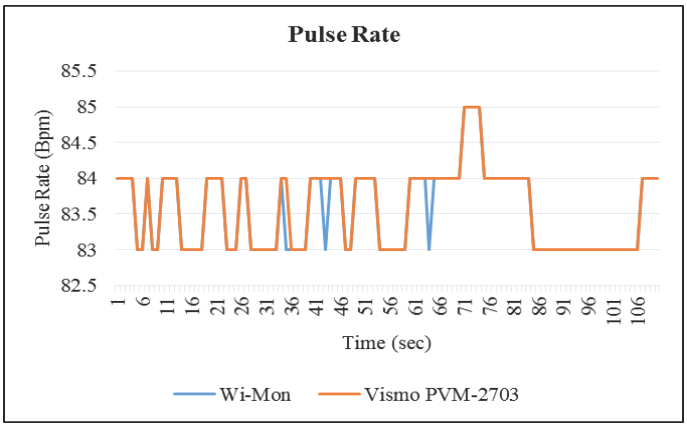

Fig.7. Pulse Rate Vs Time with Wi-Mon and Vismo PVM-2703

By analysing the results shown in Fig.7 it can be seen that the pulse rate from Wi-Mon is slightly varied with Vismo PVM-2703. According to the results obtained from the hospital maximum error rate is 1.19% and minimum error rate is 0.00%.

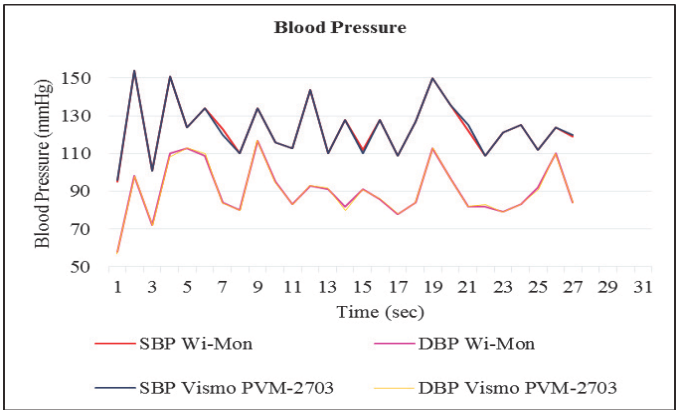

Fig.8. Blood Pressure Vs Time with Wi-Mon and Vismo PVM-2703

Twenty-seven blood pressure samples were taken from both Wi-Mon and Vismo PVM-2703. Systolic blood pressure (SBP), and Diastolic blood pressure (DBP) were taken for each blood pressure reading. According to the results maximum error rate and minimum error rate for systolic blood pressure are 2.50% and 0.83% respectively and for diastolic blood pressure maximum error rate is 2.50%, and minimum error rate is 0.91%.

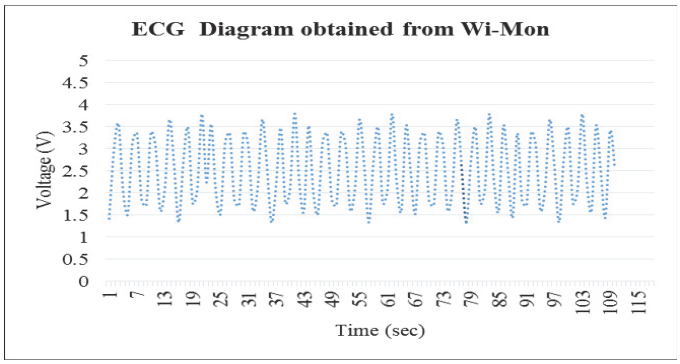

Fig.9. ECG diagram obtained from Wi-Mon

Fig.10. ECG diagram obtained from Vismo PVM-2703

By analysing the results shown in the Fig.9 and Fig.10 it can be seen that the ECG diagram of from the Wi-Mon is similar to ECG shown in Vismo PVM-2703.

Temperature readings were taken manually by the medical professions using a digital thermometer meanwhile in the hospital since Vismo PVM-2703 does not provide the facility to get the temperature reading.

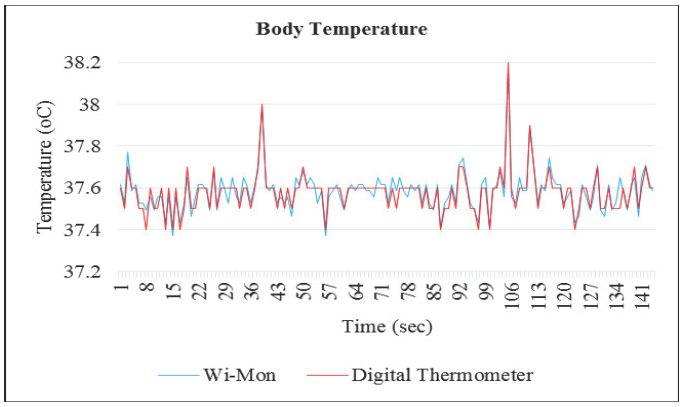

Fig.10. Temperature Vs Time with Wi-Mon and digital thermometer

Hundred and forty-five temperature samples were taken from both Wi-Mon and digital thermometer. According to the above analysed data, the variance between the temperature reading from Wi-Mon and vismo PVM-2703 is very less and the maximum error rate and minimum error rate are respectively 0.15% and 0.01%.

V. CONCLUSION

The paper has reviewed the detailed literature on WBAN and the Wi-Mon device which is used to monitor some of the human vital information. It is different than the existing systems in the medical field because of the various advantages and the continuous monitoring of the patients' vital information through the use of the advanced software like Wi-Mon. This system can be used to monitor many patients' physiological signals simultaneously in the real-time hospital environment. The challenges faced by the Wi-Mon are also addressed with future implementations. The real time testing and the results of the Wi-Mon with the existing system simultaneously in the Clinical Management of Dengue Hemorrhagic Fever (DHF) at the Negombo Base Hospital had proved that the Wi-Mon has less error percentage. Therefore, Wi-Mon is a better replacement for Vismo. The future improvements such as GSM based real time monitoring and with the mobile application will be a great challenge to implant the Wi-Mon with all the hospital environments.

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