World Academy of Science, Engineering and Technology
International Journal of Computer and Systems Engineering
Vol:11, No:6, 2017

IOT Based Process Model for Heart Monitoring Process

Dalyah Y. Al-Jamal, Maryam H. Eshtaiwi, Liyakathunisa Syed

***Abstract*—**Connecting health services with technology has a huge demand as people health situations are becoming worse day by day. In fact, engaging new technologies such as Internet of Things (IOT) into the medical services can enhance the patient care services. Specifically, patients suffering from chronic diseases such as cardiac patients need a special care and monitoring. In reality, some efforts were previously taken to automate and improve the patient monitoring systems. However, the previous efforts have some limitations and lack the real-time feature needed for chronic kind of diseases. In this paper, an improved process model for patient monitoring system specialized for cardiac patients is presented. A survey was distributed and interviews were conducted to gather the needed requirements to improve the cardiac patient monitoring system. Business Process Model and Notation (BPMN) language was used to model the proposed process. In fact, the proposed system uses the IOT Technology to assist doctors to remotely monitor and follow-up with their heart patients in real-time. In order to validate the effectiveness of the proposed solution, simulation analysis was performed using Bizagi Modeler tool. Analysis results show performance improvements in the heart monitoring process. For the future, authors suggest enhancing the proposed system to cover all the chronic diseases.

***Keywords*—**Business process model and notation, cardiac patient, cardiac monitoring, heart monitoring, healthcare, internet of things, remote patient monitoring system, process model, telemedicine, wearable sensors.

I. Introduction

IN reality, the patient monitoring system is one of the primary features provided to take care of patients. Measuring patient parameters such as heart rate and rhythm, respiratory rate, blood pressure and blood-oxygen saturation is necessary whether it is done in a continuous or an interval process. According to [1], the definition of patient monitoring can be "repeated or continuous observations or measurements of the patient, his or her physiological function, and the function of life support equipment, for the purpose of guiding management decisions, including when to make therapeutic interventions, and assessment of those interventions".

Since patient monitoring process is really critical and significant, a lot of research papers considered automation and improvement of this process. In reality, using Wi-Fi network for patient monitoring was considered since the 1970s. In fact, wireless patient monitoring system increases the mobility of the patient, improves the outcomes, allow for continuous monitoring by doctors, and because of the shared infrastructure in wireless the cost is reduced, hence it is a safe and reliable process for patient monitoring. Recently, heart issues and diseases spread among a huge number of people because of the improper eating habits and lack of the physical exercises. As the heart is the most sensitive part of the whole body which needs oversight all time, heart issues have been reported as the main cause of death. According to [12], "Cardiovascular disease is the leading global cause of death, accounting for 17.3 million deaths per year, a number that is expected to grow more than 20.6 million by 2030.

In this paper, many research papers regarding patient monitoring system have been investigated and analyzed to overcome the issues and limitations they have and to come up with an improved solution. A telemedicine IOT based patient heart monitoring technology is presented to produce high-quality care for patients, reduce the time and lower the cost. Moreover, the proposed process makes the patients feel more comfortable and enjoy their lives normally without worries as they are remotely monitored by the doctors.

II. Literature Review

Shifting the normal wired patient monitoring system to wireless technology is useful in monitoring older adults as it lowers the cost and enhances the reliability and the accuracy of the healthcare delivery. As mentioned in the research paper [2], the authors proposed wireless remote vital sign monitoring system that uses audio/video for data transmission. In fact, body temperature, blood pressure (systolic and diastolic), pulse, heart rate, oxygen saturation, blood glucose level and lung's air volume are the vital signs that are measured in this system using off-the-shelves medical devices. A special device called set-top-box is used for collecting the data from those different medical devices and transfer them to the associated PC-based software application in real-time without delays. This proposed technology is sufficient since it provides solutions to the interoperability, high cost, complexity and user acceptability issues found in the normal patient monitoring system. Furthermore, the system sends alerts for the abnormal events to the healthcare providers to take an action immediately. So, it is a safe and reliable technology to be used in monitoring elderly patients remotely.

According to the research [3], moving to remote healthcare monitoring technologies is considered since the aged population is growing. In fact, those technologies are easier and cheaper especially in the case of monitoring elderly and infirm who cannot easily leave their homes. In this research,

Dalyah Yahya AlJamal, Software Engineering Student, Maryam Eshtaiwi, Software Engineering Student, and Dr. Liyakathunisa Syed, Assistant Professor, are with the Prince Sultan University, Saudi Arabia (e-mail: dalyah_se@outlook.com, eng.maryam.94@hotmail.com, lsyed@psu.edu.sa).

the authors provide an effective and flexible solution to monitor elderly patients remotely. The proposed system is based on linking a mobile monitor (PDA) with the ability to connect to the Internet to access the information remotely. In fact, this monitoring prototype uses Motes (coin-sized sensors) to sense sound and light. The sensed data is received using the mobile monitor (PDA) and then sent through the internet to be presented in MRTG website. In fact, the prototype was performed on a big-sized sound and light sensors (Motes) since they were the only sensors at the time the research was conducted. The authors suggested improvement in implementing the proposed prototype to measure patient vital statistics and to consider the privacy of patient's information issues.

According to [4], monitoring patients remotely is a difficult and critical task for doctors especially in dangerous conditions. Therefore, developing a specialized system that uses the network technology and the associated sensors to monitor patients' vital parameters is needed. In fact, the technology presented in this paper consists of three sensors attached to the patient's body to measure three parameters: ECG, heart rate, and body temperature. Moreover, an alarm for detecting noticeable variations from the sensors' results and ATMEGA328 microcontroller to convert the analog signals outputted from the sensors to digital signals are used in this proposed technology. The data obtained from the sensors is sent through the Bluetooth to an Android based smartphone. The data then is stored in an online database to be accessed remotely from different devices. In reality, this system is meant to simplify and accelerate the patient monitoring process. It also reduces the cost of the equipment that is used normally for this process. The authors suggested improvement in the proposed technology as a future work to allow responsive interactions from the doctors to the remotely located patients rapidly.

In [5], the authors studied the magnetic characteristics of the antenna. To ensure the antenna performance when it works close to the human body, the antenna is simulated in the phantom model. Since the antenna is a magnetic type, it generally does not change the antenna parameters significantly, especially in terms of bandwidth, frequency, pattern, and gain.

The author focuses on the antenna of magnetic wearable multi-band that is working for biomedical applications, especially for wireless patient monitoring, which works on multi-band frequency. The proposed antenna is simulating in free space and on a 3-layer phantom model to evaluate its basic performance in monitoring. Research has evaluated the magnetic field properties of the antenna, which the result shows that at close field the magnetic field is a higher value rather than the electric field value. In general, the simulated results show that the antenna characteristic meets the requirements those are the antenna operates it, and the required gain according to every technology at each operating band.

According to [6], it is too hard for one person to take care of patients especially the elderly people by manual monitoring. Some of the systems such as elder care system, monitor elders by video systems in around to monitor their activities continuously. However, this system does not measure any of the vital parameters. The proposed design mentioned in this research can show vital parameters and fall detection along with tilt monitoring for the bed-ridden patients. The system proposed is applicable for patients and elders for activity monitoring and fall detection also sports athletes' measurement and pattern analysis. The design interface consists of a vital parameter sensing and measurement block, a storage space, central controller, GSM Modem and a GUI block.

The human heart generates electrical signals with each heartbeat. In fact, this signal is what causes the heart to expand blood to the whole the body. Therefore, it is used to follow the patient's case under heart attack or the effect of any medicine doses. This application will be responsible for all communications that happen to the Control unit and the mobile device, using Bluetooth facility of the mobile for communication. Therefore, the users are provided with different options like critical heart rate, temperature value, oxygen, and content. This will display the actual status of the elderly people giving in the current physical parameter values. The monitored data is stored in the mobile phone database, so whenever the users ask and request to display the details, the Data Display option will display the whole parameter data, till that point of time.

According to [7], monitoring health and taking care of people health is one major concern that people should take care of. Monitoring patient case is the magnificent way to know all information about the patient. The author describes how the technology especially mobile devices are helping in wireless monitoring, which patients need at most. The research came up with a block diagram wireless health monitoring system, that connecting between monitoring devices and the supervising devices with Bluetooth Low Energy. It is connecting to sensors so the electrical activities of the heart are collected which can give the signal to analog to digital converter. The prototype of the monitoring health system consists of the monitoring device, a supervising station and an optional personal computer installed in the chest belt. The prototype of the monitoring health system consists of the monitoring device, a supervising station and an optional personal computer installed in the chest belt. By the adapter, the monitoring device is plugged into the chest belt. The device has carried out service and diagnostic interface that allows communicating and connecting with the device via a personal computer.

The above literature review captures some of the proposed wireless patient monitoring systems. In fact, those systems meant to simplify, reduce the cost and lower the time associated with the normal patient monitoring process. The main goal is to telemonitor the patients especially elderly patients as it is difficult to continuously visit the doctor for the purpose of follow-up. However, there are some issues and

limitations in those presented systems. In reality, many devices are needed for the normal check-up process which complicates the process and requires a specialized nurse or a family member to do the check-up for the patient. Moreover, not all of the presented systems used the real-time monitoring feature which allows the doctors to be updated about their patients' health status. In fact, no responsive interaction from the doctors to their remotely located patients is presented in those systems. Therefore, if the doctor gets a notification that the patient is in danger, the doctor cannot responsively interact with the patient for treatment and medication. Bluetooth technology is used for connecting wearable sensors with some monitoring applications which is not applicable since it covers only short distances. As a result, there is a huge demand for a reliable, automatic and responsive monitoring system.

III. Research Problem

A. Cardiac Disease

There are a lot of risk factors that cause the development of cardiac disease. Many people nowadays have cardiac diseases because of a combination of factors such as poor diet, lack of workout and physical activities and addicting smoking, and more other causes. According to [15], the number of people having the heart disease increases a lot recently. The statistics say that over 616,000 people died of heart disease, heart disease caused almost 25% of deaths—almost one in every four, every year about 785,000 Americans have a first coronary attack. In 2010, the treatment cost of coronary illness alone was anticipated to cost the United States $108.9 billion [15].

In order to help the world to tackle this huge dangerous issue, and to help save people's lives, researchers investigate the current heart monitoring process to suggest some improvements. In reality, this research aims to find a final solution that facilitates and enhances the cardiac patient monitoring process, and reduce the time and the cost.

B. Cardiac Monitoring Process

In the real time, the current cardiac monitoring processes are quite complex with a lot of limitations. Different technologies and processes are used in different hospitals and centers. In reality, doctor visits for the check-ups are the usual process for monitoring cardiac patients. Basically, the doctors focus on three signs to check the patient's heart condition, which are heartbeat rate, cholesterol, and blood pressure. Based on the response of the distributed survey among cardiologists, in the case of cardiovascular disease, the patient shall visit the doctor twice a month for the purpose of the check-up. In fact, it is considered as an overhead for the patient and the doctor as well. Lots of time, cost and efforts are wasted in this process especially when the heart disease signs are stable at the inspection time. On the other hand, the high increase in heart rate or blood pressure may happen accidentally or due to eating too much fat while the patient is unaware of the risks. Therefore, the patient would not take the necessary care at the time the patient needs it.

Sometimes, when the doctor cannot diagnose the patient condition clearly, the doctor requires the patient to use Holter Monitor which is a continuous electrocardiogram (EKG) to record the heart condition for a continuous twenty-four hours [13]. It should be stuck to the patient's chest and the patient shouldn't shower or swim while the Holter Monitor is attached to the body. Then, based on the results obtained from the Holter test, the doctor can diagnose the disease accordingly [14]. According to Eshtaiwi, a biomedical engineer that was interviewed, the Holter Monitor is efficient as it accelerates the monitoring process and reduces doctors' efforts. However, it may cause cosmetic issues for the patients as the Holter device is quite huge and observed, so the patient hesitates to wear it in front of other people. In addition, sometimes it records wrong data when the device gets wet or when the patient is near to a high voltage electrical device. Moreover, this process does not offer the real-time monitoring as the doctor needs to check manually the records of the Holter Monitor after the test.

Some hospitals have a system called wireless heart monitor which monitors the patient heartbeat when doctors and patients are far away. This process of monitoring requires a sensor to be worn by the patient and should be fixed to the patient's clothes. Unfortunately, this technique bothers the patient and eliminates the freedom of movement. Also, sometimes it records wrong data when the patient takes the sensor off to take a shower or to sleep. Moreover, this technique may cause inaccurate recording of the data as the doctor records the data manually by hand.

To sum up, the processes used nowadays for heart monitoring are inefficient and not applicable all the time. As the technology has become an important part of every aspect of the modern life, the medical field is the most necessary aspect that a light should be spotted on. Therefore, an improvement of the current cardiac patient monitoring process is considered in this research.

IV. Methodology

A. Survey and Interviews

In order to understand the process used in most hospitals to monitor cardiac patients, a survey was distributed to cardiac doctors. In fact, one cardiac doctor gave a valuable response to the survey. To fully understand the process, two interviews with medical engineers in the field of patient monitoring were conducted. The interviewees were able to describe the current cardiac monitoring system clearly and identify its related issues.

B. Proposed Cardiac Patient Monitoring Model Using BPMN

This paper proposed a solution for the above issues and limitations in the current heart monitoring process. A telemedicine system is a very effective way of connecting patients with their doctors all the time and everywhere. In fact, IOT based technology is used in this proposed system. The system consists of a monitoring watch which has four impeded sensors to sense the pulse rate, blood pressure, body temperature, and respiration rate. In fact, the high increase in the pulse rate or the blood pressure, or the decrease in the

body temperature or the respiration rate are signs that the patient's heart is suffering. These signs make the cardiac patient's condition worse and controlling them is the best way to heal from the heart diseases. The watch's sensed data will be saved on a cloud server. The cloud server is connected to a user-friendly mobile application and a monitoring website used by the doctor to telemonitor the patient. Fig. 1 visualizes the idea of the system.

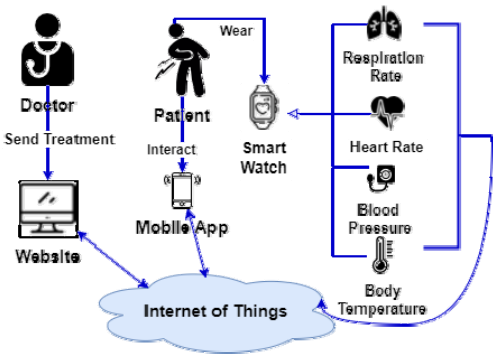

Fig. 1 Cardiac patient monitoring system

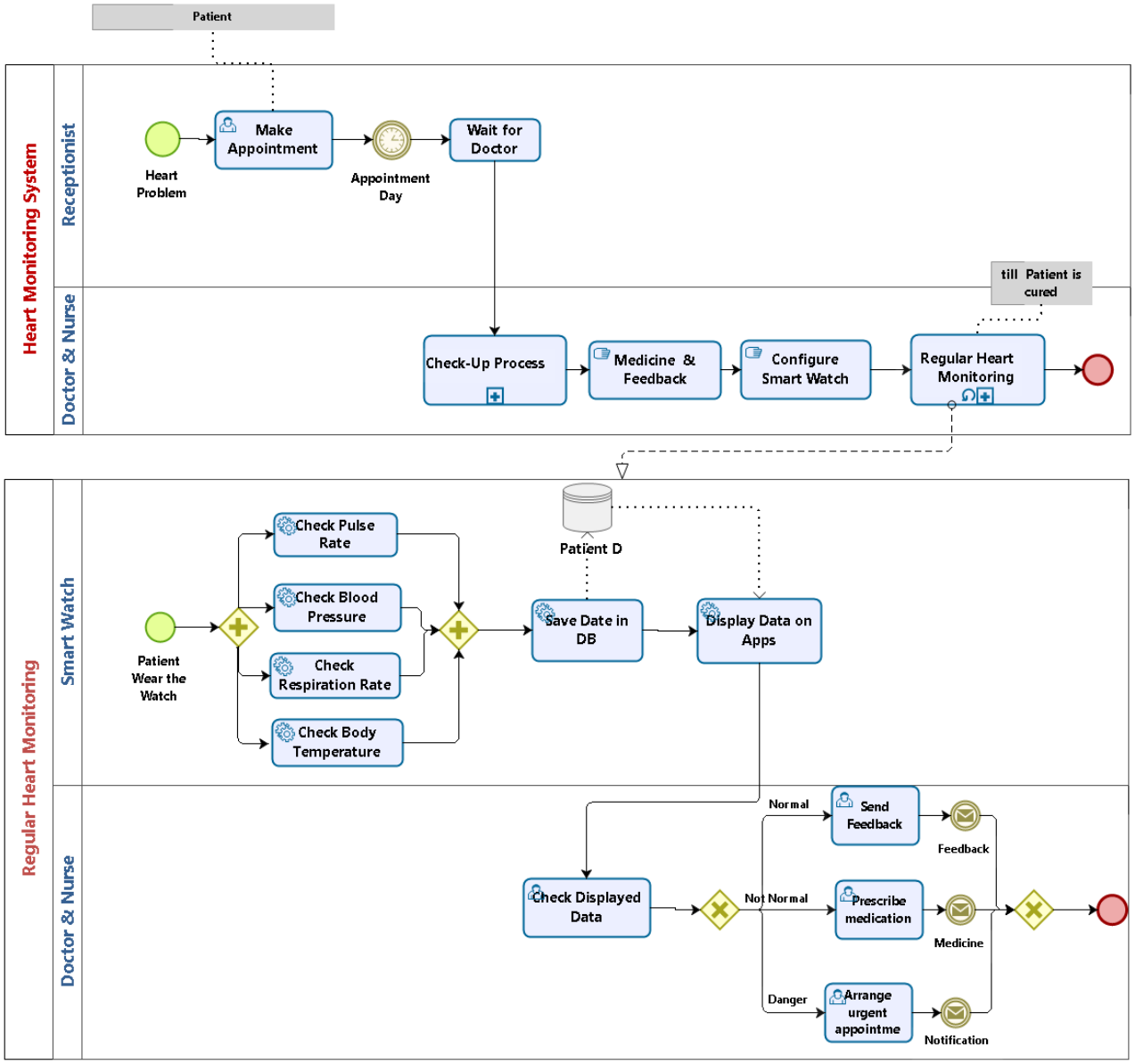

Fig. 2 IOT-based heart monitoring process model

After the patient's first doctor visit, the patient will be required to wear the monitoring watch most of the time and download the associated mobile application. Accordingly, the doctor will configure the watch and the mobile application

with the patient's normal readings of the heart rate, blood pressure, body temperature and respiration rate. As soon as the patient wears the watch, sensors sense the four signs to send them to the cloud server. As the cloud server is connected to the patient application and the doctor's monitoring website, the sensed data is then displayed on the screens of both the application and the website. Therefore, the patient will be aware of the heart condition and will be able to relate healthy lifestyle with the heart health. On the other hand, the doctor can follow-up with the patient remotely. The doctor will check the data presented on the website to send an appropriate feedback or medication as a message to the patient's application. Moreover, a notification message shall be sent to the doctor's phone if the patient is in a dangerous or critical situation and an urgent appointment will be set for the patient to visit the doctor for further treatment. In fact, a standard BPMN has been used to model this process. According to [8], BPMN is an effective and a flexible tool for modeling as it uses graphical notations which make the process easier to be understood by all the involved actors. Fig. 2 shows the Improved Heart Monitoring System modeled using BPMN standards with Bizagi Modeler Software [9].

C. Simulation Analysis

In order to measure the improved performance in the proposed process, a simulation for validating the process and analyzing the time and the resources was performed using Bizagi Modeler software. In fact, there are three resources needed in this process: a cardiologist, a nurse, and a receptionist. Cardiologist and the nurse are responsible for manually examining the patient at the beginning of the process and to continuously telemonitor the patient later on. Furthermore, the receptionist is the one responsible for making the appointment for the patient at the very early stage of the process and to organize the urgent appointment in the case of danger. Based on PayScale research in the US [10], the average hourly rate for a Cardiologist is $50, for a Licensed Practical Nurse (LPN) is $ 18 and for a Medical Receptionist is $ 13. Therefore, those salaries were considered during the simulation. Moreover, the waiting time for the appointment was given as 28 days according to the survey [11].

V. Results and Discussion

Figs. 3 and 4 show the time and the cost analysis after running the simulation analysis using Bizagi Modeler for one patient. As it is clear from Fig. 3 that represents the Regular Heart Checkup Process in the proposed system, most of the activities have zero processing time as they are automatically performed by the sensors and the associated applications. The other activities in this process are user tasks which make the total average time for the Check-Up process approximately 10 minutes per patient diagnosis. Thus, the proposed system is fast compared to the traditional Check-Up process.

From Fig. 4, the cost per the resource is quite clear. The cost was calculated based on the salary for each resource and the amount of time the resource spent during the process. The total cost per patient is $ 38.5 covering the first manual visit and the automated follow-up check which is not high compared to the cost of a normal cardiologist visit with a follow-up visit.

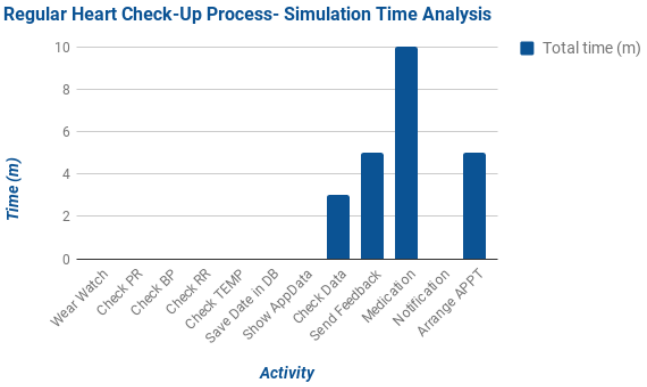

Fig. 3 Time analysis of the heart monitoring process

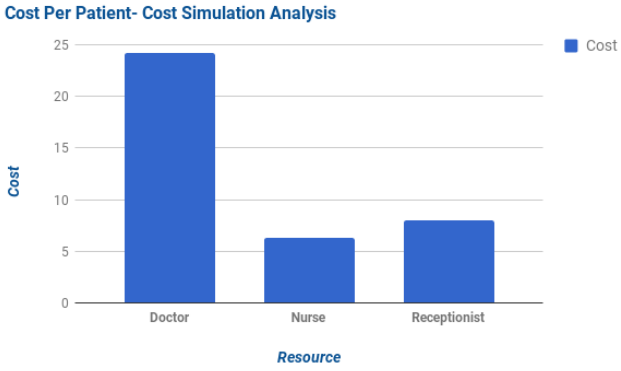

Fig. 4 Cost analysis for the heart monitoring process

As it is clear from the previous analysis, the regular check-up process does not require so much cost and time. The huge time and cost are required only in the patient first visit as the receptionist will use some time in making the appointment, the doctor will use also some time for the check-up and the patient will waste a couple of time waiting for the appointment. In reality, this proposed IOT-based heart monitoring process is a cost and time efficient compared to the normal heart monitoring process where the patients need to visit the doctor multiple times for the check-up purpose.

VI. Conclusion

Since heart problems are increasing rapidly, cardiac patients need special care and monitoring. Although there are some improved systems to facilitate the heart monitoring process, the existing heart monitoring systems still have a lot of limitations for both the patients and the doctors. This paper proposes a reliable heart monitoring process that facilitates the patient follow-up process, allows for telemonitoring, reduces the cost and decreases the treatment time.

As for the future, the authors suggest expanding the system to cover most of the spread chronic diseases. For example, the system might be customized and enhanced to telemonitor diabetic patients as they need continuous monitoring. Moreover, the system could be used locally by the parents to monitor and keep track of the health of their children.

Combining the sensors used in the process with sports watches such as Apple or Google watches is considered as a future enhancement to make patients feel normal and comfortable while wearing the smart watch.

ACKNOWLEDGMENT

The authors thank Dr. Hassan Eshtaiwi, the biomedical engineer, for his valuable feedback about the current patient monitoring system.

REFERENCES

[1] Gardner, R. M., & Shabot, M. M. (2001). Patient monitoring systems. In Medical Informatics (pp. 443-484). Springer New York.
[2] Baig, M. M., & Gholamhosseini, H. (2013). Wireless remote patient monitoring in older adults. 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). doi:10.1109/embc.2013.6610030
[3] Lubrin, E., Lawrence, E., & Navarro, K. (n.d.). Wireless Remote Healthcare Monitoring with Motes. International Conference on Mobile Business (ICMB'05). doi:10.1109/icmb.2005.115
[4] Sneha, B., Bhavana, V., Brunda, S., Murali, T. S., Puneeth, S., & Ravikiran, B. A. (2015). A wireless based patient monitoring system using Android technology. 2015 International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT). doi:10.1109/icatcct.2015.7456851
[5] A multiband magnetic type wearable antenna for wireless patient monitoring applications. (2016, August 11). Retrieved from http://ieeexplore.ieee.org.ezproxy.psu.edu.sa/stamp/stamp.jsp?arnumber=77 35382&ta
[6] MediSuit: Wearable Health Monitoring System for Elders and Bed-ridden Patients. (2016, January 7). Retrieved from http://ieeexplore.ieee.org.ezproxy.psu.edu.sa/stamp/stamp.jsp?arnumber=77 27091
[7] (2015, July). Retrieved from http://ac.els-cdn.com/S2405896315008289/1s2.0-S2405896315008289-main.pdf?_tid=5532a250-b3cb-11e6-a66200000aab0f01&acdnat=1480159837_a473a0196ed18118af41e2c7996ff8d1
[8] Object Management GroupBusiness Process Model and Notation. (n.d.). Retrieved December 20, 2016, from http://www.bpmn.org/
[9] Bizagi Modeler (Version 3.1.0.011) (Computer software). (n.d.). Retrieved September 22, 2016.
[10] Hourly Rate by Job for Mercy Hospital Employees. (n.d.). Retrieved December 20, 2016, from http://www.payscale.com/research/US/Employer=Mercy_Hospital/Hourly_Rate/by_Job .
[11] (Rep.). (n.d.). doi:https://www.merritthawkins.com/uploadedfiles/merritthawkings/surveys/mha2014waitsurvpdf.pdf
[12] Heart Disease and Stroke Statistics – At-a-Glance. (2014, December 17). Retrieved from http://www.onebraveidea.com/submissions/ucm_470704.pdf
[13] Holter Monitors: A Tool to Detect Heart Disease. (2009). Retrieved December 31, 2016, from http://www.everydayhealth.com/heart-health/holter-monitor.aspx
[14] Holter Monitor: Uses and Expectations. (n.d.). Retrieved December 31, 2016, from http://www.heart-health-guide.com/holter-monitor.html.
[15] Heart Disease Statistics. (n.d.). Retrieved December 31, 2016, from https://www.cardiosmart.org/Heart-Basics/CVD-Stats