Design and Implementation of Smart E-Health System Based on Cloud Computing to Monitor the Vital Signs in Real-Time and Measurements Validation

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Abstract. Wearable devices used to monitor patients are classified as part of mobile health, one of the branches of e-health. They are widely used to monitor the vital signs of patients outside of the health institutions environment. The aim of this paper is to design a device that can be worn at low cost and of small size to provide comfort to the patient. The accuracy of this device should be high compared to the benchmark. Also, this study takes into account real-time remote monitoring based on the wireless sensor network and cloud computing where cloud computing is integrated with the Internet of Things to solve the problem of the flow of the huge amount of data. The Wearable Remote Vital Signs Monitoring System (WRV SMS) was manufactured by a printed circuit board, where the ESP01, MAX30100, NTC, OLED, and Li-ion battery were used. The WRV SMS was connected to the cloud server via the HTTP protocol where the data was stored and analysed. The WRV SMS works on basis the combining data of vital signs through which the stakeholders to whom the alert is sent will be assigned based on the patient’s case where the alert will be sent, which is short message to the stakeholders that are important in rescuing the patient when the patient's vital signs are outside threshold. The results showed that the device is 99.37% accurate and statistical analysis was performed to test the error.

Keywords: cloud computing; e-health; IoT; remote patient monitor; validation measurement; web applications.

1. Introduction
During the last few decades, a dramatic change occurred in the structure of the Internet. One of the major changes is the one that made a large number of things to be connected and communicated with each other autonomously over the Internet [1]. This is known as the Internet of Things (IoT). This term, the IoT, represents the technology that makes devices and things around us to be connected and communicate in order to achieve different goals [2], by sensing data from the surrounding environment, communicating and analyzing the sensed data, making decisions and doing an action [3].

A very large amount of data is generated by IoT devices, i.e. Things [4]. However, the number of connected Things is increasing rapidly. According to CISCO, around 50 billion of Things are expected to be connected in 2020 [5]. This makes handling such “big data”, i.e. storage and processing, as a real challenge that requires more resources (i.e., more cost). One of the solutions to handle this issue is to integrate IoT with cloud computing [6]. Cloud computing provides an efficient resource, by including...
multiple servers, such as processing units and storages, to work as a virtual infrastructure [7]. The integration of Cloud Computing would help to manage the “big data” that is generated by the IoT technology. Furthermore, it supports scalability, if it is needed [8]. Recently, there is a wide range of applications start using IoT technology, e.g., industrial applications, smart cities, electronic health (eHealth) applications, weather applications, and smart homes. However, eHealth is the field that we are interested in this paper.

The term “eHealth” introduced for the first time at the 7th International Conference on Telemedicine, that held in London on November 1999 [9]. The World Health Organization (WHO) defines eHealth as the 21st century ICT based system [10]. The use of computer and communication technologies in medical diagnosis and analysis is also known as eHealth. One of the goals of the eHealth is to improve medical care and diagnostics services to reduce the cost and to meet patients’ needs [11].

The research in these fields, eHealth, growth rapidly during the last two decades. This is especially after the emergences of wireless communication, which facilitate the data transfer between patients and healthcare providers [12]. More specifically, the use of wireless local area networks (WLAN), mobile networks (2.5G, 3G, 4G, and HSPA), and wireless personal area networks (WPAN), such as Bluetooth and ZigBee technologies, have greatly contributed in the promotion of eHealth [13, 14]. Furthermore, the combination of eHealth and IoT technology add more value to this field by supporting remote patient monitoring, especially in the cases of chronic diseases. It allows monitoring and alarming for patients at homes, elderly care centres, or at some other places [15].

This paper about enhancing the experience of remote patient monitoring, which is a demand by patients at homes, hospitals, and healthcare centres, especially for the cases of elderly patients. This is by proposing an enhanced (WRVSMS) that depends on the principles of cloud computing, wireless sensor network (WSN) and IoT. The proposed device job is to read and monitor some of the patient's vital sign remotely. More specifically, the device monitors the patient's health status by measuring a number of vital signs, namely: the heart rate, body temperature, and blood oxygen level (SpO2).

The communication between the WRVSMS and the cloud server is done using the Hypertext Transfer Protocol (HTTP). The collected data, by the server, could be monitored by an authorized doctor using a web interface. Furthermore, the data are processed and different actions will be done based on different conditions. For instance, alerting patient’s doctor and an ambulance if a patient emergency case happened. However, all data is stored in a database. The stored data could be used as a medical history of a patient and make it accessible by the healthcare provider through a web interface, i.e., to monitor patient data at any time.

1.1 Wearable Remote Monitoring System

One of the interesting subfields of eHealth is the wearable technologies that help to monitor patients vital sign and activities. For instance, we mention the: Wearable remote vital signs monitoring system (WRVSMS), which is part of the area of interest of this paper.

The WRVSMS consists of two main parts. The first one is the wearable patient device, which is the device that sense and monitors the patient's vital signs and transmits the sensed data to a server using the Internet. The second part is the Cloud web server, which is used to process, manage and store the patient data that is sensed and transmitted by the wearable device.

The adoption of cloud in eHealth is not only about maintaining and managing patients’ data, but it is also a way to provide the collected data for researches in order to study and analyze to server education purposes [16], i.e. it is another source for open data that relate to the eHealth sector. Note that there are many studies indicating the positive impact of cloud computing in eHealth, which show the effectiveness of cloud in the delivery of health care [17, 18].

1.2 Cloud Computing and E-Health

The idea of cloud computing goes back to 1960 by Joseph Carl and John McCarthy, and it was limited to processing census data and financial transactions [19]. As a brief history, we mention a number of famous cloud based servers that are started at the end of the 20th century. In 1999, Salesforces developed
one of the first cloud computing web servers and offers a wide range of cloud-based services. Later in 2002, Amazon launched its first Cloud Amazon Web Service (AWS). And in 2006, Amazon built the second cloud server used for commercial service, that is called the Elastic Compute Cloud (EC2). However, in 2009, Microsoft delivered the Windows Azure, which is another cloud service that offers a number of services to the customers of the company [20].

The integration of cloud computing with eHealth brings many benefits for health institutions and patients [21], among them, we mention: improving patient care, reducing cost, increasing resources efficiency, and improving quality.

Improving patient care includes facilitating healthcare provider processes through patient electronic records. In this case, a patient will obtain a unified identifier, and his/her data will be available anywhere and anytime across all health care processes. This would allow healthcare providers to have a comprehensive view of the patient’s data, which means providing more suitable treatments [22].

The cost is reduced by the use of cloud computing. This is as cloud computing creates a collaborative economic environment. More specifically, the overhead cost of a process is shared among different customers. Furthermore, cloud computing allows payment for the only utilized resources not for everything. This feature allows small and medium-sized health care providers to utilize an advanced computing infrastructure to support their healthcare services without facing a high initial cost, and there will be no potential costs later. However, reducing cost is an important feature, More specifically, the cost is one of the major restrictions imposed on electronic health systems [23]. Not using the cloud means more investments in equipment, software and training, which leads to high cost. A proprietary system that is installed locally makes health care institutions, hospitals and health care centres pay a lot of time and effort due to the demand of extra-human resources that are responsible for managing and maintaining the system, which is indeed an extra cost [23]. Moreover, regarding the cost reduction, making medical records available globally would reduce the required cost of manual data exchange, especially between different countries.

2. Related Work
This sub-section presents a number of recent patients monitoring systems, methodologies, and constraints of previous studies. 20 research papers have been selected to be studied and analyze. This is in order to get sufficient knowledge about what other researchers are doing in this field, and also help us to craft the problem statement of this paper.

Khalifeh et al.[24] designed and implemented patients fall detection system through a set of sensors and a precise microcontroller that communicates with the cloud through the Ethernet shield. This device uses an accelerometer module in order to detect patients’ movement and generates alert in the case of patients’ falling. This is done by the use of an algorithm that is based on the three axes. The system has a smart algorithm in the cloud that is able to recognize if the falling alert is true or false. Furthermore, the system, with the help of cloud computing technology, monitors the patient in real-time. As advantages of this system are the use the cloud computing, which provides a database and real-time monitoring. Furthermore, the cloud provides many advantages, including storage capacity, flexibility, and information security. However, as disadvantages, the movement of the patient is very restricted, as well as that the system does not generate alert to the medical staff in the case of an emergency.

He et al [25] designed and implemented an effective system in detecting a fall of a patient. It is also capable of distinguishing between the fall and normal activities of the patient. The system device uses a tri-axial acceleration and a gyroscope for detecting patients’ fall. And it uses Bluetooth technology in order to communicate with an Android smartphone, where the device sends data to the phone, which in turn sends alerts in the form of SMS or phone call to patients’ family or healthcare providers for the purpose of assisting. The results showed that the system was 95% accurate, as the Kalman filter was used. The advantages of this system include a low cost and a lighter weight device. However, the disadvantages include that it does not use the cloud as well lacks a database and it does not support real-time monitoring.
Sendra et al [26] designed a smart system to monitor children with chronic diseases, allowing healthcare providers and parents to monitor the child’s health remotely using wearable sensors and smartphones. More specifically, the system uses the temperature sensor and heart rate sensor as well as using a smart algorithm to detect whether the parameter has exceeded the threshold or not and classifies patients into a natural or emergency situation based on algorithm output. The results showed that the system has sufficient accuracy in detecting chronic cases in children and also contributes to reducing the number of children staying in the hospital. The advantages of this system include low-energy consumptions, effective system for detecting cases in children, and reporting of hazardous cases. However, the disadvantages include: cloud computing is not used, and it is one of the systems applied on a personal level.

Miramontes et al [27] created a health care system using a platform known as plalm-OS to monitor vital signs of a patient, such as ECG, temperature, oxygen, skin response, respiratory rate, and fall detection. The system focuses on elderly patients to monitor and transmit their data in real-time. Data transmission is done using multiple communication technologies such as Bluetooth, ZigBee, and Wi-Fi to the web server and mobile phone. System advantages include low-cost, low power consumption, small size, and efficient database. The disadvantages are restricted patient movement and weaknesses in alerts provided to healthcare provider staff. As well as the system measurement is not validated.

Yang et al [28] proposed a method in ECG monitoring, by transmission patients’ data to the Internet. This is done by the use of IoT technology, the HTTP protocol, and the Message Queuing Telemetry Transport (MQTT) protocol. The structure of this system contains three main parts. First part is the patient’s device that includes a wearable ECG sensor (ECGAD8232), an Acorn RISC Machine (ARM) controller module, and a Wi-Fi module. The second part is the IoT and cloud services that include the storage cloud, hypertext mark-up language. Finally, the GUI part that is responsible for displaying data to doctors. Experimental results show that the system good for collecting and presenting ECG data in real-time and helps in the basic diagnosis of certain heart diseases. The main advantage is the system efficiency in terms of speed and database. However, as a disadvantage, it does not give sufficient accuracy.

Prakash et al [29] suggested a system that works on the alert of patients’ falling with the aim of improving the lives of patients who live on their own. The system consists of a two wearable sensor: Temperature and Accelerometer, which could be used to improve the lives of patients or people living in isolation from others. The system uses GSM communication technology in order to send alert messages to health care providers when an emergency case happened. The experimental results showed that the proposed system contained a very effective energy consumption algorithm. For instance, battery life longs about one year. The sleep algorithm was also applied to reduce the energy consumption level. System advantages include efficiency in terms of falling detection and also it has a nice feature of low-voltage warning. As for disadvantages, the system cannot display patient data in real-time and the system performance is not verified.

Spanò and Giuseppe [30] designed and implemented a wearable ECG monitoring system based on the IoT platform. The system uses an ECG sensor as well as multiple communication technologies: ZigBee, WIFI, and Bluetooth. In this model, the ZigBee technology was used for data communication. The ARM7 microcontroller and the Internet server were also used. The system uses the messaging protocol, data management, and storage unit. Furthermore, the user could use a computer or a smartphone to monitor data. The experimental results showed that the system consumes low power and gives monitoring in real-time. As advantages, we mention the low power consumption and low cost, also the small size and low weight of the device. As a disadvantage, low reliability coupled with the restriction of patient movement.

Based on these features analysis, we proposed to design and implementation of a system with specifically selected features, which we believe that it would add value and contribution to the literature. This is as the selected features contain the best experience features of the state of the Art. Generally, the proposed system is based on a wearable device that reads three important vital signs of patients, namely: temperature, heart rate, and SpO2. This system will take advantage of IoT technology to perform an
autonomous machine to machine communication. Furthermore, it will get the benefits of Cloud computing service. More specifically, the Infrastructure as a Service (IaaS) service module of the Cloud. However, the preferred wireless communication protocol to be used for data transmission is the Wi-Fi, since it is widely available. There are alerting technologies used in the case of emergency SMS. This in order to notify ambulance, doctor and patients’ family (i.e., the patient helper) the alert is made after for the patient data combining. Also, the measurement accuracy of WRV SMS gets large attention from this paper.

3. Methodology
This section describes the structure of the proposed system, the methodology that contributed to the achievement of the research objectives, and the main circuit designs used in the proposed system. In addition, effective methods will be used to calculate the accuracy and reliability of data in order to calculate the accuracy of the proposed device. On the other hand, the best techniques used in the IoT were studied to store, analyse, and review the data in real-time. The proposed development device was linked to the cloud after completing the design of the main interface of the site, where the data is presented in real-time. In addition, to be able to register patients. Also, a send alert will be made in the event of an imbalance in the vital signals of the patient. It was done in three stages in order to reach the patient helper, doctor, and ambulance, alerting them by sending messages in the case of signs indicating the current health instability of the patient, by a proposed algorithm called data combining.

3.1 Circuit Design of Wearable Remote Vital Signs Monitoring System
In order to provide greater comfort to the patient while wearing the device, where the device is worn in the hand in the wrist, the device needed to be small and worn easily without obstructing the movement of the patient, so the size was reduced by Two-layer circuit design. The circuit was designed by the free online software EASY-EDA [31]. This circuit was manufactured by using fibreglass with a thickness of 1.6 mm, a length of 4.6 cm, and a width of 3.7 cm. This circuit consists of many electronic pieces compacted into one electrical circuit and the pieces were installed on both sides of the circuit to minimize its size. The heat-gun called Pro’sKit Hot Air helped to install the pieces. This circuit is lightweight, small, suitable for wearing on the wrist as shown in Figure 1, and comes at a low cost and gives reliability to data received from the sensors. It is was also made of one piece, which and this was not possible in the prototype. The device has an NTC temperature sensor in addition to the MAX 30100 sensor to read the heart rate and blood oxygen level, as well as consists the device the screen to display readings and wireless protocol Wi-Fi (ESP 01).

The WRV SMS measured was compared with the benchmark devices used in the hospital (i.e., Rossmax thermometer and Schiller patient monitor), as shown in Figure 2.

Figure 1. WRV SMS during data measuring.
3.2 Cloud Web Server
A cloud server is a virtual server running on the resources of several clustered servers. That makes these clustered servers act as one server with huge resources. Thus, cloud servers handle data processing and data traffic better than typical individual servers. This raises the dependency on cloud servers by lowering server failures or data loss. The cloud-based web server is a cloud server that is organised to act as a web server which responds to HTTP requests and sends the desired web data.

The proposed system was built on the Amazon EC2 cloud service, which gives a secure and resizable computing capacity IaaS. The Amazon services were chosen among all other services due to their reliability, which includes a server availability of 99.99%[32]. This is because E-Health requires high reliability where any error can cause a severe threat to the patient’s life. To take the mobility of the patient or the doctor as an advantage, the cloud-based web server was published by using a feature called Elastic IP provided by Amazon. That Elastic IP was bounded with a free domain name from a provider called Freenom. The website was developed locally, then it was uploaded onto the cloud server.

3.2.1 Website Design
The proposed website was developed by using two programming languages, which are Hypertext pre-processor (PHP) and JavaScript, with Hypertext mark-up language (HTML) as a mark-up language and Cascading style sheets (CSS) to style the webpages. Finally, a database to store all the information of users and patients. The proposed system as illustrated in Figure 3 works as follows: the data is received from the proposed WRV SMS on the live PHP file. The live PHP file acquires the patient’s information that has been stored in the database and attached with the device, and then the data is saved to the vital data table with the patient’s name, the date, and time it has been received. After that, the last 10 vital data are acquired to find their average. Then the system takes action an action based on that average. The average ignores any sudden rise or fall in the vital data unless it stays above or below the normal range. In that case, the website takes proper action; the system takes proper action in a fast and safe time frame to avoid severe threats to patient life. If the patient has not suffered any dangerous symptoms, the saved data can be used as a medical record for the patient who helps the doctor in his or her work. In addition, the patient can be monitored remotely at real-time from anywhere and at any time by the authorised person. This provides many benefits as follows:

• The hospital beds are only for severe cases.
• The psychological state of the patient is improved by moving him or her out of the hospital unless needed.
• The doctor can move anywhere to do his or her
• Work without losing contact with the patient’s medical state.
3.2.2 Web Page

WebPages are basically made by using HTML, which describes the content of that page (i.e., buttons, input fields, texts, and many other features).

The user's webpage monitors the patients remotely. By logging in with a username and with the regular user’s privilege, a webpage with the attached devices will show the device IDs and state whether the devices are live and sending data or not. If the device is live and sending data, a button labeled ‘show live’ will appear. If that button is clicked, the webpage will show the live data of that device with an update rate of five seconds as shown in Figure 4. The live data contains the vital data, the time it was received from the WRVSMS, and the normal ranges of the vital data. Also, a download button in front of each device is available for downloading the medical record of the patient.

4. Experiment of WRVSMS

This section will show the main work done in the laboratory for the device and the main algorithms used in the software. The measurement of accuracy. In addition, the combining of data and how actions are taken will be explained. Furthermore, the characteristics and specifications of all the work that is done will be shown.

4.1 Measurement Parameters Performance

This subsection will show the performance metric of the device and compare the WRVSMS with the benchmark (BM) according to the specification of the device and the accuracy for both of them. In addition, statistical and graphical methods will be used to show the accuracy of the device.

4.1.1 Validation between Proposed WRVSMS and BM

Tests of measurements were carried out to confirm the correctness of the proposed system work, where the following readings were obtained from the device, about 9000 samples in total: 3000 heart rate
samples, 3000 SpO2 samples, and 3000 temperature samples. This depended on two medical sensors, the MAX30100 to calculate the SpO2 and heartbeat and the NTC to measure temperature. These readings were displayed on an OLED screen in addition to uploading these readings onto a database on the cloud, where they were stored and analysed to take necessary action.

Experiments were conducted at the Center for Heart Disease Iraq- Karbala Health Department. The study was carried out with the help of six volunteers aged between 12-69 years old, three males and three females. The measurements were taken from the volunteers for over 10 days, with 50 readings each day shown in Figure 5 for the volunteers.

4.1.2 Statistical analysis

Statistical analyses were conducted. The error test of the data was obtained from the proposed system compared to the BM to verify the accuracy of the proposed system. Two types of statistical operations substantiated the reliability of the proposed device: Where the numerical methods that used were the mean absolute error, and the root mean square error. Absolute error is the absolute value of the difference between the estimated value and the actual value. Where the estimated value was obtained by the proposed device. The mean absolute error was calculated for each of the data types from the proposed system data with BM data. After that, each negative error number should be converted to a positive number; this was achieved by taking the absolute value of each error. Finally, the mean value of all recorded absolute errors (the average of all absolute errors) was calculated. This method was calculated by using Equations 2. The mean absolute error (MAE) detects average errors, whether small or large, since it takes the average for all errors weighted.

$$ E_i = X_i - Y_i $$  

$$ MAE = \frac{\sum |E_i|}{N} $$

Where $X_i$ refers to estimate value, $Y_i$ refers to the actual value and $N$ to the number of samples.

RMSE was used to detect the errors that represent outliers, where the RMSE works to neglect the small errors that have been evaluated as less than one and shows the large errors. This process is very useful for verifying the performance of medical devices, focusing on the outliers regardless of the quantity of the data. This method is not possible for comparing two different types of data because it depends on the difference between the values in two different cases for the same data, as these results are better when closer to zero. This is an ideal case and it is difficult to achieve unless the system is perfect. The negative solutions well are neglected and this solution is presented as a positive value because this method depends on the values of square error, and will reduce the effect of the small errors while enlarging the effect of the large errors. This clarifies how far the system can error. This type of measurement can be calculated by using Equation 4.

$$ MSE = \frac{\sum (E_i)^2}{N} $$
\[ RMSE = \sqrt{MSE} \]  

(4)

4.2 Analysis and Action Data in Cloud Webserver

The proposed system has been developed to take action according to the given vital data, which are sent from the wearable patient device to the server. The cloud server processes the data based on three variables being merged. The purpose of this process is to determine the patient's health status based on a set of vital signs where the temperature is classified into four levels (high, very high, normal, and low) as well as heart rate into five levels (high, very high, normal, low, and very low). The SpO2 is classified into three levels (very low, low, and normal). It has been categorized by a specialist doctor. After the data combining process, and taking the average of the last 10 readings, the alert is sent to the appropriate party, making it more accurate in making the right decision. This makes the action more robust because it will never give a false alarm or bother the doctor or the hospital in every single case of data instability.

The action will be taken only when it needs to by merging the vital data and splitting the actions into three cases according to the actions algorithm shown in Figure 6. These three cases are the ambulance, the doctor, and the patient helper.

The vital data combining will cover 60 situations. Only one of these situations is normal, in which no action will be taken. The remaining 59 situations will be distributed between the three cases depending on the severity of the situation. For example, if the average of SpO2 level is under 88% but above 80%, assuming that the rest of vital data are normal, then there is no need to call the ambulance. The only action needed is to raise the patient’s oxygen level. So, the system will tell the patient helper to raise the oxygen level without bothering the doctor or the hospital. But if the average SpO2 level is under 80%, the patient helper may not be able to handle this situation, and the ambulance should take the patient to the hospital. The only thing that the patient helper can do in this situation is to prepare the patient to be taken by the ambulance. So, the system will tell the ambulance to go to the patient’s address, and it will tell the patient helper to prepare the patient. Additionally, the responsible doctor of the patient will be informed of the patient's situation to do the necessary actions. These and other

![Figure 6](image-url)
5. RESULT

5.1 Measurement Validation of WVRSMS

In this section, a statistical analysis was calculated between the WRVSMS and the BM to know how accurate the system is. As shown in the previous chapter, 9000 samples were collected, 3000 each for temperature, heart rate, and SpO2, by using WRVSMS. Also, the same number was collected using BM. A small variance was noticed between the WRVSMS and the BM results when comparing them between each other, as shown in Figures 7a, b, and c, which compare WRVSMS and BM temperature, heart rate, and SpO2, respectively. Whether or not these differences are acceptable will be disclosed by using statistical analyses such as the error test and Bland-Altman, as follows.

![Figure 7](image7.png)

**Figure 7.** Measurement of (a) SpO2, (b) temperature, and (c) Heart rate for the WRVSMS and BM. An error test and an analysis were done for the 9000 samples, 3000 samples each for SpO2, heart rate, and temperature. MAE, Mean absolute percentage error (MAPE), and RMSE were calculated between WRVSMS and BM.

The absolute error calculations were done to calculate the MAE for each SpO2, heart rate, and temperature, as shown in Figure 8 a, b, and c. Figure 8a shows that the absolute error of SpO2 was in the range of 0 up to 8, while the MAE of SpO2 was 0.99. Figure 8b shows that the absolute error of heart rate was in the range of 0 to 27 with an MAE of 3.9, and Figure 8c shows that the absolute error of temperature was in the range of 0 to 2.9 with an MAE of 0.47. That shows there is a small error value between the WRVSMS and the BM when taking the whole errors as the same weight.

![Figure 8](image8.png)

**Figure 8.** Absolute error and mean absolute error for (a) SpO2, (b) Heart rate, and (c) temperature between WVRSMS and BM.

As mentioned before, the MAE calculates the errors as the same weight; this way of calculation regrades the outliers. And to take the consideration of these outliers, the RMSE must be calculated. Where the RMSE gives most of the weight to the big errors to expand the sight of view on it while reducing the weights of the small errors. In this way, the system will be tested to know where the system is giving a large error frequently or not. Figure9a shows the absolute error and the RMSE of the SpO2 where the RMSE was 1.56. Figure9b shows the absolute error and the RMSE of the Heart rate where the RMSE was 4.93. Figure9c shows the absolute error and the RMSE of the temperature where the RMSE was 0.62.
The MAE and the RMSE together can give a view of what the type of error actually is. If the values of these two parameters are the same, that means the system has a constant error, whereas if there is a large difference between the MAE and the RMSE, that means the system gives a large variance between the errors. This means the system is unstable. If there is a slight difference between the MAE and the RMSE, that means the system has a small variation in the errors which are considered acceptable.

Figure 10a shows the MAE, RMSE, and the absolute error of the SpO2, which shows that the MAE is 0.99 and the RMSE is 1.56. Figure 10b shows the same parameters for the heart rate with an MAE of 3.9 and an RMSE of 4.93. Also, Figure 10c shows these parameters for temperature with an MAE of 0.47 and an RMSE of 0.67. This shows very little difference between the MAE and the RMSE, which means that the outliers in the WRVSMS are non-recurring and the system has a small and stable error, which makes the WRVSMS and BM nearly identical.

5.1.1 Accuracy Comparison
A comparison was made between the WRVSMS and related works [33-39] in terms of accuracy. This comparison showed the superiority of the system with an accuracy of 99.34%, 99.85%, and 99.92% for SpO2, heart rate, and temperature, respectively. The accuracy of the WRVSMS can be calculated by calculating the accuracy of each vital sign individually by using Equation 6 and taking the average of the three measurements will give the overall accuracy. By taking the average of these three parameters, the overall accuracy was 99.37%. Figure 11 shows the comparison between the WRVSMS and other systems.

\[
Accuracy = \left(1 - \frac{\sum_{i=1}^{n} EST_i - \sum_{i=1}^{n} Actual_i}{\sum_{i=1}^{n} Actual_i} \right) \times 100\%
\]  

Where estimated value is the value extracted from the proposed system WRVSMS and Actual value is the value extracted from the BM and \(n\) is number of samples.
5.2 Data Combining and Actions

The entity to send messages is determined by averaging the last 10 readings, which makes it more accurate in making the right decision. The program makes one of the following decisions according to the seriousness of the patient's condition:

1. **Ambulance**: This procedure is considered if the incoming readings represent a critical condition such as temperature rise to more than 40°C, a heartbeat greater than 120 beats per minute or fewer than 50 beats per minute, or oxygen saturation of less than 80%. In this case, a message is sent to the ambulance containing the name and the address of the patient. Another message is sent to the doctor who is told that the patient is in critical condition and who is advised to monitor the patient. The message contains the rate of another 10 readings of the patient. At the same time, the patient helper is informed that the ambulance is heading towards the patient to prepare the patient to be taken to the hospital.

2. **Doctor**: This procedure is considered if the incoming readings are abnormal but do not express a critical condition such as a pulse rate of more than 100 beats per minute or a pulse of fewer than 60 beats per minute. In such a case, an SMS is sent to the doctor which contains an average of 10 incoming readings so that the doctor can evaluate the situation and take the necessary action.

3. **Patient helper**: This is done when the patient's condition is not critical and there is no need to consult the doctor or the ambulance; for example, when the SpO2 is 88% or the temperature is a little high, the system will send a message to the patient's helper, either to give the patient oxygen or alert the helper to monitor the patient's temperature.

Figure 12 illustrates the importance of a data-gathering algorithm to make an accurate decision. The notification is sent after confirming the patient's condition after taking a rate of ten readings. In the case of readings outside the threshold limits, the system will make a decision on sending the notice to the stakeholders. Where the chosen samples of beats per minute (bpm) data for a period of 25 minutes. These data were recorded from a patient by using WRVSMS. As illustrated in blue, the bpm samples are in the normal range in the period of 0 to 400 seconds, and after that, the bpm values start rising to cross the doctor’s limit, which is near 500 seconds. However, the system will not take any action until the average, illustrated in the red line, crosses the limit. When the average crosses the limit, the system will take an action, marked as a circle, after 600 seconds. The average will depend on the last 150 seconds, which gives the system room for making sure that the patient's bpm truly crosses the limit. When certain data crosses its limits, the system will take into consideration all three vital signs and it will give the priority to the most critical vital sign between them. After taking an action, the system will wait five minutes. In this way, notifications will be less frequent, and the system will give the responsible person time to take action. After five minutes, the system will send the notifications if necessary. In such a way, the system makes sure that the notifications are sent to the most useful entity for the patient’s situation without bothering the other entities.
As the normal threshold systems take action directly after crossing the limit, WRVSMS waits until the average rises above the limit. This reduces false notifications that may occur due to external influences, outliers, or maybe even real values, but which soon return to the normal range and improve the patient’s condition. Maybe these values occur because of the patient’s psychological state and its impact on the heart rate or external factors that affect the temperature. Figure 13 of WRVSMS temperature data shows a rise in temperature but a return to the normal range in a few seconds, which means the action is not needed.

In case there is a need to take any action, the WRVSMS will send an SMS notification, which is divided into three categories. The first is the ambulance category, which will inform the ambulance, the doctor, and the patient helper, as shown in Figure 14. The second is the doctor category, which will inform the doctor and the patient helper, as shown in Figure 15. The last category is the patient helper category, which will inform the patient helper only, as shown in Figure 16. The patient helper category is used only in simple cases where there is no need to inform the doctor.
Figure 14. SMS message samples for ambulance action to notify (a) the ambulance, (b) the responsible doctor, and (c) the patient helper.

Figure 15. SMS message samples for doctor action to notify (a) the doctor, and (b) the patient helper.
6. Conclusion
The elderly patients were remotely monitored in real-time from anywhere in the world by using the proposed WRV SMS with mobility for the patients. The accuracy of the WRV SMS reached 99.37%, compared to BM. Where statistical tests were taken, showing that the WRV SMS error was small and the outlier values were rarely frequent, which means the error did not affect the accuracy of the system. A data-combining algorithm was developed to make an accurate decision about which entity was best for the patient’s situation when the patient needs help, with no false notifications and without bothering the responsible entities. Moreover, AWS EC2 cloud service was configured to host the web service to get the benefits of high availability, low cost per use, and high bandwidth of data flow. That reduced the server errors and server cost. The WRV SMS was connected as an IoT device to the cloud server. A database was maintained to store the vital data to act as a medical record for the patient, which helped the doctor to identify the patient’s situation. The device was designed to be small, with dimensions of 3.7 cm in length, 4.6 cm in width, and 1.2 cm in height, and with a weight of 15g, which was comfortable to be worn on the wrist like a watch. In addition can be adding other vital signs sensors in the future such as ECG, EMG, and ENG to the proposed system to be shown in real-time. In addition to using artificial intelligence classification methods to classify disease types based on vital signs.

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References
[1] Hussien Z A, Jin H, Abduljabbar Z A, Hussain M A, Yassin A A, Abbdal S H, Al Sibahee M A, and Zou D 2016 "Secure and efficient e-health scheme based on the Internet of Things," In: 2016 IEEE International Conference on Signal Processing, Communications and Computing (ICSPCC), pp. 1-6.
[2] Bhat M I, Ahmad S, Amin A, and Ashraf S, 2017 "e-Health with internet of things," International Journal of Computer Science and Mobile Computing (IJCSCMC) vol. 6, pp. 357-362.
[3] Azimi I, Rahmani A M, Liljeberg P, and Tenhunen H, 2017 "Internet of things for remote elderly monitoring: a study from user-centered perspective," Journal of Ambient Intelligence and Humanized Computing, vol. 8, 273-89.
[4] Niranjana S and Balamurugan A, 2015 "Intelligent E-Health Gateway Based Ubiquitous Healthcare Systems in Internet of Things International," Journal of Scientific Engineering and Applied Science (IJSEAS), vol. I (9), pp. 284-290.
Making use of cloud computing for healthcare provision: Opportunities and technologies.
[25] He J, Bai S and Wang X, 2017 "An unobtrusive fall detection and alerting system based on Kalman filter and Bayes network classifier," Sensors, vol.17, pp.1393.

[26] Sendra S, Parra L, Lloret J and Tomás J, 2018 "Smart system for children's chronic illness monitoring," Information Fusion, vol. 40, pp. 76-86.

[27] Miramontes R, Aquino R, Flores A, Rodríguez G, Anguiano R, Ríos A and Edwards A, 2017 "PlaIMoS: A remote mobile healthcare platform to monitor cardiovascular and respiratory variables," Sensors, vol. 17, pp.176.

[28] Adnan H. Ali, Farhood, A.D. 2019 Design and Performance Analysis of the WDM Schemes for Radio over Fiber System with Different Fiber Propagation Losses. Fibers, 7, 19.

[29] Prakash R, Ganesh A B and Girish S V, 2016 "Cooperative wireless network control-based health and activity monitoring system," Journal of medical systems, vol. 40, pp. 216.

[30] Spanò E, Di Pascoli S and Iannaccone G, 2016 "Low-power wearable ECG monitoring system for multiple-patient remote monitoring," IEEE Sensors Journal, vol. 16, pp. 5452-5462.

[31] EASY-EDA. Available: https://easyeda.com/account/user (accessed on Feb. 2019).

[32] Server A W. Available: https://aws.amazon.com (accessed on Feb. 2019).

[33] Roh T, Hong S and Yoo H-J, 2014 "Wearable depression monitoring system with heart-rate variability," In: 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, pp. 562-565.

[34] Kakria P, Tripathi N and Kitipawang P, 2015 "A real-time health monitoring system for remote cardiac patients using smartphone and wearable sensors," International journal of telemedicine and applications vol. 2015, pp. 8.

[35] Nosrati M and Tavassolian N, 2017 "High-accuracy heart rate variability monitoring using Doppler radar based on Gaussian pulse train modeling and FTPR algorithm," IEEE Transactions on Microwave Theory and Techniques vol. 66, pp. 556-567.

[36] Crema C, Depari A, Flammini A, Sisinni E, Vezzoli A and Bellagente P, 2017 "Virtual respiratory rate sensors: An example of a smartphone-based integrated and multiparametric mHealth gateway," IEEE Transactions on Instrumentation and Measurement, vol. 66, pp. 2456-63.

[37] Baba E, Jilbab A and Hammouch A, 2018 "A health remote monitoring application based on wireless body area networks," In: 2018 International Conference on Intelligent Systems and Computer Vision (ISCV), pp. 1-4.

[38] Fakhri A B, Gharghan S K and Mohammed S L, 2018 "Statistical validation of patient vital signs based on energy-efficient wireless sensor network monitoring system," ARPN J. Eng. Appl. Sci, vol. 13, pp. 8258-8270.

[39] Gharghan S K, 2017 "Energy-efficient remote temperature monitoring system for patients based on GSM modem and microcontroller," Journal of Communications, vol. 12, pp. 433-442.