Implementation of Remote Patient Monitoring using Wireless Pulse Oximeter

T.J.Jeyaprabha, A.Abijith, Guru Prashanth, Chiranjeevraja.T

ABSTRACT--- A Pulse Oximeter is a device which is used to monitor the patient's vitals such as oxygen level in the blood and heart rate. The pulse oximeter can also be converted into a multi-parameter patient monitor by connecting it to an ECG monitor via cables. Now-a-days wireless battery-powered pulse oximeters are available which allows patients to have a constant check on their health. The main drawback of the current system is doctor/nurse has to walk all the way to the monitor to see the readings and make final conclusions. To make this process more reliable and bring advances in its operations, our primary goal is to produce a wireless pulse oximeter that presents its live feed in the doctor's/nurse's phone via mobile application.

Key terms: pulse oximeter, remote patient monitoring, heart rate, SpO2, Internet of Things

I. INTRODUCTION

Recent estimates reveal that around 4.4 lakh Americans die every year due to recklessness and negligence caused hospital errors that are preventable. After road accidents and murders, hospital errors are the leading cause of death in America; hence it is evident that hospitals should make patient safety their top most priority. Hospitals are causing death equivalent to the population of Miami every year from preventable medical errors. During a time when healthcare transformations are taking place at a rapid rate, it's important to find a solution to provide transparency to the patients and also the necessary details and tell the hospitals that the time for change is now. To view the hospital's safety efforts, data from the reputed data analysis firms are being analysed with which the current situation and gravity of the issue is much worse than expected [1].

To improve the current situation, use of Internet of Things is a major advancement. It can enable communication between devices by sending data to the cloud and retrieving necessary information from it. IoT applications exist in smart healthcare, smart city, industrial automation, smart home and much more [3], [4].

Making the current model of the pulse oximeter wireless will ensure that errors are reduced and anomalies are detected faster while measuring the patient's results. The various advantages of this solution are its customizable nature and smaller size. It is very robust and can be transported anytime and anywhere.

II. RELATED WORKS

The Pulse oximeter device is used to measure values such as heart rate and SpO2 [5]. These values are used to determine the patient's overall health and also in quick analysis of how well the patient is doing and data analysis is done by putting up charts to give an idea of overall well-being. This non-invasive device has been through cycle of changes with various proposals. First it began with evolving the ways of measuring the values. The oximeter has a concave structure to hold the optical sensor. With wireless transmission, device sends data to be viewed on a smart phone. The design allows the patient to wear it on a wrist until the values are required for analysis on a continuous basis. Before all this, the calibration curve was detected and checked before deploying for a full-time operation.

Instead of viewing the values on the conventional ECG monitor, transmission of this data was introduced. To enhance on wireless communication, bluetooth technology was introduced and also interfacing it with a smart phone to display the incoming values on an application [7]. The wireless transmission was limited as bluetooth had a certain disadvantage of distance coverage. The display monitor always needs to be close to the oximeter in order to display the results. To overcome this, the use of microcontroller is introduced. Beyond this to make the system robust and accessible remotely, Internet of things is introduced [8], [9]. MQTT is the recent trending protocol used to transfer data from STM microcontrollers to the cloud. The data is viewed on an android application with the help of publish-subscribe principle [10].

III. PROPOSED METHODOLOGY

This technological innovation is powered by the following components:-

i. Pulse oximeter
ii. Cypress CY8C21434
iii. Esp8266 Wi-Fi module
iv. Battery
v. Charging circuit with low battery indicator
vi. Cloud server
vii. Mobile application

The Sp02 and heart-beat readings are measured using a wireless pulse oximeter. Cypress CY8C21434, PSoC-1

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microcontroller is used to forward the data to the ESP8266 Wi-Fi module. The microcontroller makes use of a charging unit in order to recharge and also warn the users of low battery levels. The microcontroller instructs the Wi-Fi module to transmit the data to the CloudMQTT server via AT Commands. The coding is done using Embedded C in the PSoC Designer 5.4 software. Universal Asynchronous Receiver Transmitter (UART) is used for data transmission between the hardware components. The cloud receives and stores the data from the module. The mobile application subscribes to the required topic using Message Queuing Telemetry Transport (MQTT). The cloud server publishes these topics to the mobile application which then displays the readings.

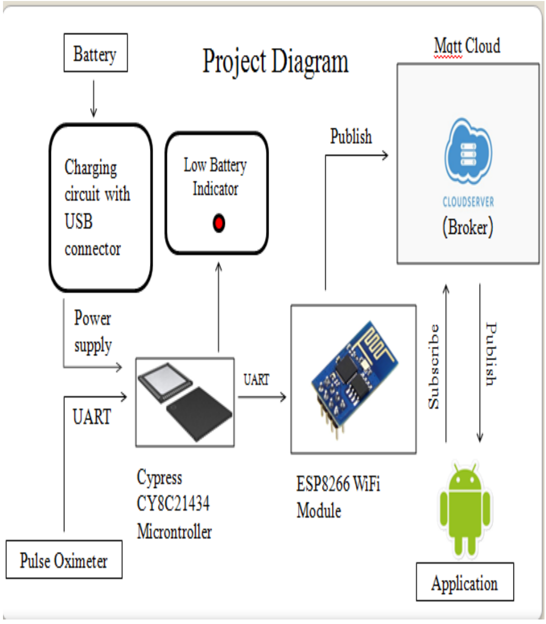

Fig. 1.Project diagram of proposed solution

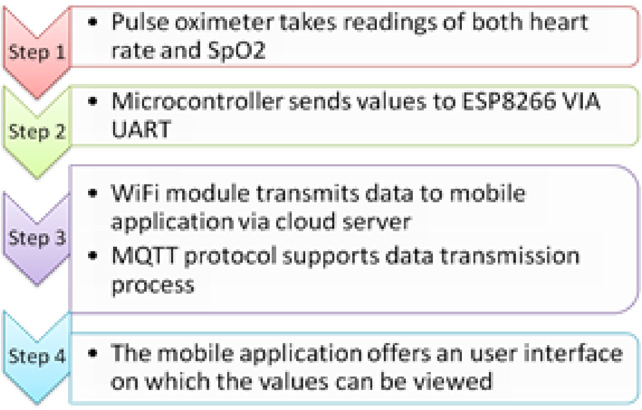

Fig. 2.Flow diagram to show the steps involved in the proposed system

This method eliminates the cumbersome process of doctors and nurses to be near the patients all the time to do the data analysis and make final inferences about their health. It improves the robustness of the system and also makes sure no more deaths happen due to hospital errors.

A. Pulse Oximeter

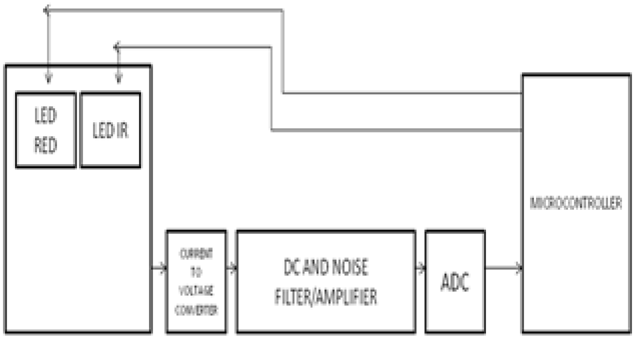

Fig. 3.Block Diagram of a Pulse Oximeter

Here in the proposed system, a Nellcor™ Flexible SpO_2 Reusable Sensor is used to obtain patient's data. Through UART the data is transferred to the microcontroller for further processing.

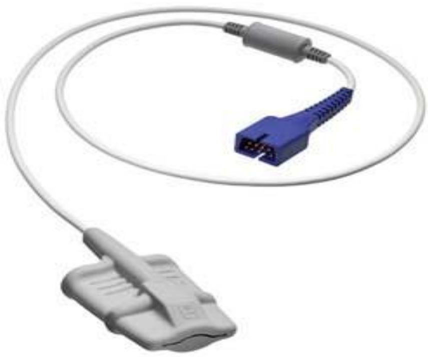

Fig. 4.Device diagram of pulse oximeter

On placement of the device on the finger or toe, small amount of pressure may be felt. The device is used until its service is required for monitoring. Either it is used on a continual basis or for just an instance to note the current value of both hear rate and SpO2 value.

There are actually 2 methods of measuring the values.

i. The transmission method is where both emitter and the detector are opposite to each other with the finger in between both. The LED rays pass through it.

ii. The reflectance method is where both emitter and the detector are on the same side. The LED rays bounce from the opposite side to the detector for further processing. Usually transmission method is used.

In the current device, transmission method is used as shown in the following diagram. The working principle of the pulse oximeter is defined by how it measures the values of heart rate and SpO2.

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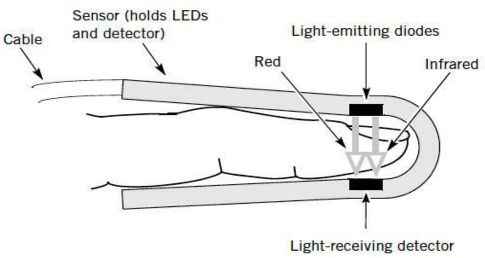

Fig. 5.Working diagram of pulse oximeter

B. Charging Circuit

The circuit is connected to the microcontroller to recharge the device and also keep account of the battery levels. The peak voltage is 3.7V. The circuit consists of BQ21040dbvt IC, USB 2.0 connector and low battery indicator with ADC. This is an integral part of the system which ensures the continuous functioning of the device. This avoids the requirement for batteries and the dependency on it. The low battery indicator is bi-colour LED which shows:

i. Blue color while charging.
ii. Blinking red colour when it reaches 2.7V.
iii. Rapid blinking and turns off on reaching 2V.

The USB connector is used for charging the device.

1. BQ20140 IC

The BQ20140 IC is the part which is responsible for running the charging circuit. It is used to program the low battery indicator and also controls the power supply.

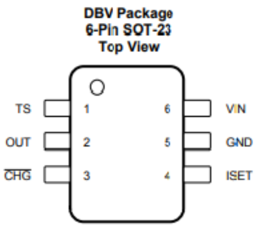

Fig. 6.Pin Diagram of BQ20140

2. Low Battery Indicator

The Low battery indicator works on the principle of ADC which is present in the micro-controller. The converter is configured on PSoC Designer 5.4. The ADC maps the analog voltage values to digital. The converter has a 10-bit resolution. Therefore with 3.7V maximum voltage, 0 to 3.7V is mapped between 0-1023 values. The step size is defined by 3.7/1024=3.6mV. Therefore at 2.7V, i.e. in digital at 750 (2.7/0.0036), the LED will start to blink and at 2V, i.e. in digital at 555.55 (2/0.0036).

3. Power Supply

A 3.7V 800 mAh Lithium ion polymer battery is used to supply power to the microcontroller.

Fig. 7.Image of Battery

C. CY8C21434 Cypress Microcontroller

The micro-controller is the brain of the project which controls each and every component based on coding. Pulse oximeter, charging circuit, low battery indicator and WiFi module are connected to it. To give the basic functionality to the micro-controller, it is programmed on a software PSoC designer 5.4.

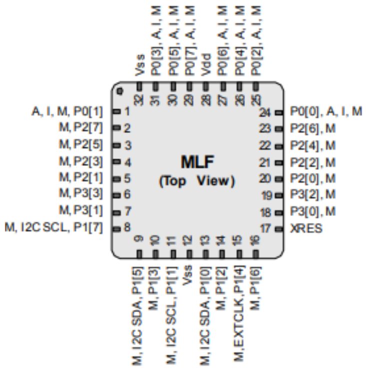

Fig. 8.CY8C21434 Pin Diagram

1. PSoC Designer 5.4

PSoC Designer™ 5.4 is the Integrated Design Environment (IDE) that is used to design the circuit for implementing the project. The environment offers flexibility in programming and setting up input and output ports for the microcontroller. The microcontroller can be configured for the developer's needs.

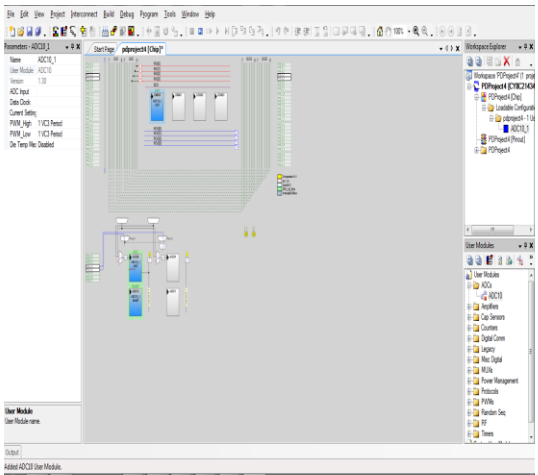

Fig. 9.Overview of PSoC Designer 5.4

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D. ESP8266 WiFi module

The ESP8266 is a low-cost Wi-Fi module which is used to transfer data to the cloud server using MQTT. The module operates in the station mode in order to connect to the internet to make the data transfer. The microcontroller passes instructions to the Wi-Fi module via AT commands.

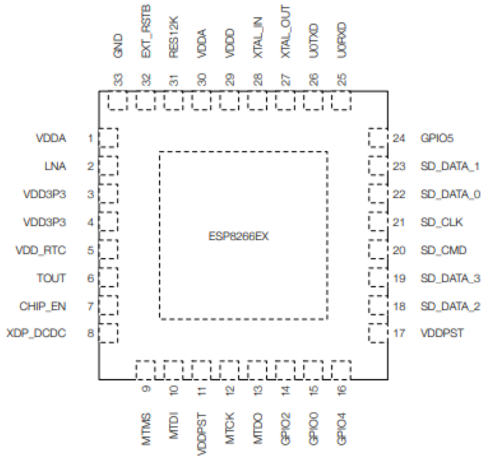


Fig. 10.Pinout diagram ESP8266

1. Message Queuing Telemetry Transport

MQTT is a lightweight messaging protocol that is used to transmit the SpO2 and heart beat values from the Wi-Fi module to the cloud server and from the cloud server to the android application. The "CloudMQTT" server will subscribe to specific topics which will be PUBLISHed by the WiFi module. The mobile application will SUBSCRIBE to these topics and in return the cloud will PUBLISH the data to the application.

E. Application Development

Developing the app is an integral part of this project as this is used to create the interface on which the patient's details can be viewed. The app subscribes for the patient details from the CloudMQTT server and in return it publishes on the app. The details that are being subscribed are the patient's SpO2 and heart rate values. The application is developed with the help of Android Studio and is programmed for better access of patient details. The languages used to develop the application are: Java -> used to configure the app for shifting from page to page, MQTT operations etc. XML -> used to develop the user interface for the doctor to access the details.

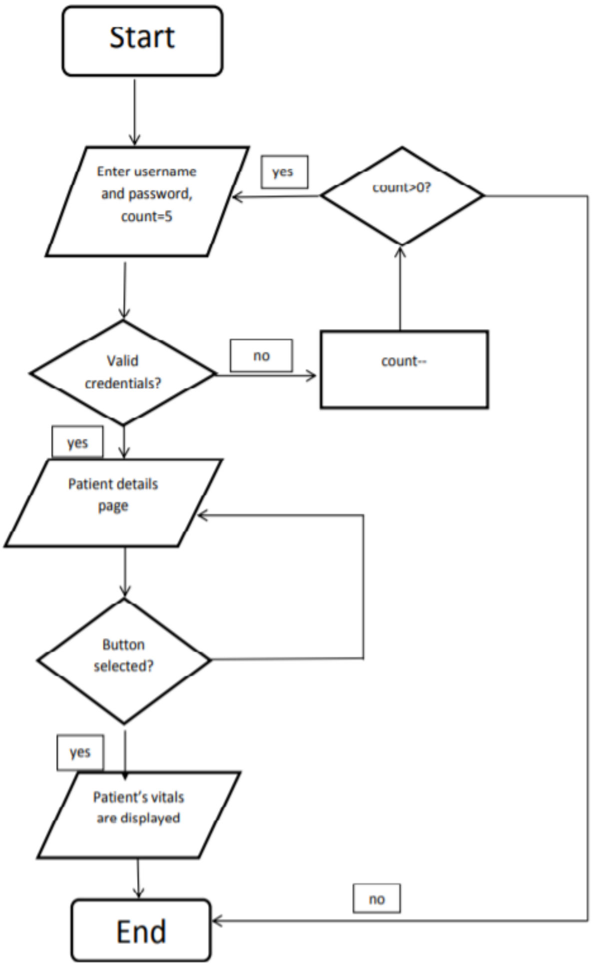
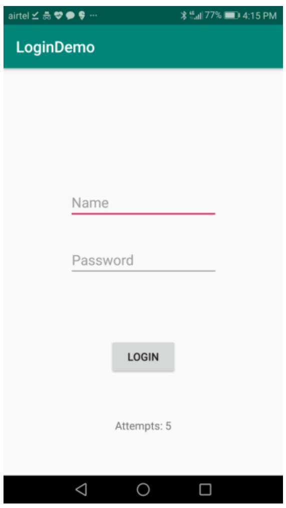


Fig. 11.Flowchart for Mobile Application

IV. RESULTS



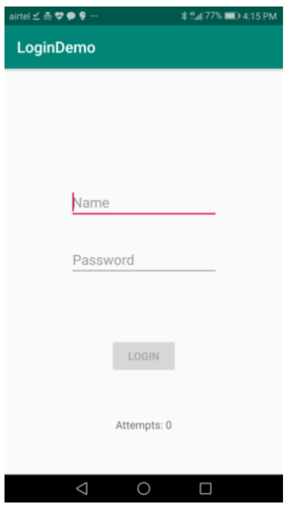


Fig. 12.Login interface (i) Fig. 13.Login interface (ii)

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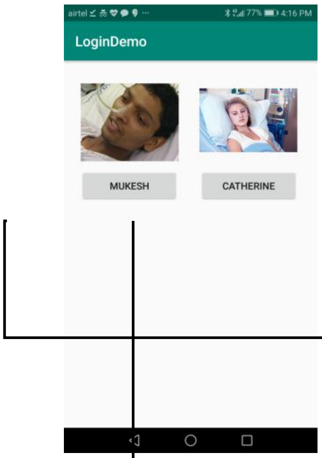

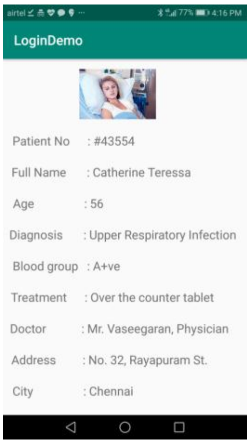

Fig. 14.List of Patients **Fig. 15.Patient 1 details**

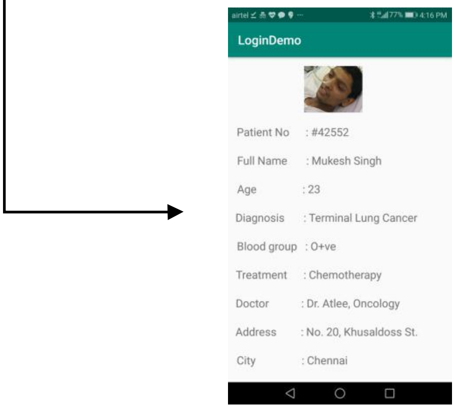

Fig. 16.Patient 2 details

Fig. 17.Hardware Implementation

Fig. 18.Charging phase **Fig. 19.Working of device**

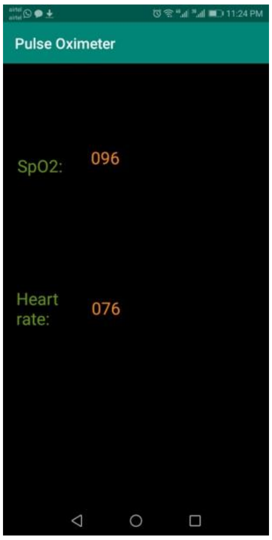

Fig. 20.Patient's vitals on the app

V. CONCLUSION AND FUTURE WORKS

The main aim of the project is to convert a successfully implemented wired device i.e. Pulse Oximeter into a wireless device with the help of IoT. This paves way to improve the flexibility of its usage and also overcome difficulties posed by the current solution. We are now able to view the live feed of the vitals of the patient i.e. SpO2 and Heart rate readings on a mobile application. This can be done by:

i. Integrating the Wi-Fi module with the broker.

ii. Connecting the broker with the mobile application.

iii.

With the help of PSoC designer 5.4, the microcontroller has been programmed and designed. The mobile application is an integral part as it act as the base interface for the user and with the help of Android Studio the application has been designed and programmed to implement the basic working. Further improvements to the proposed project could be

i. Enabling the reception of a message when anomalous readings are observed.

ii. Viewing the readings on a web page.

iii. Increase the connections to the cloud so that more patients can be managed.

iv. Implement the same working on different wired instruments.

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