



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 11, November 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

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Remote Patient Monitoring using IOT

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ABSTRACT: IoT for medical applications is revolutionizing healthcare by enabling real-time monitoring and remote patient management. In this paper, an Android application is proposed for Remote Patient Monitoring using IoT, allowing patients to contact doctors remotely. In this work, an android application is proposed for Remote Patient Monitoring using IoT, enabling patients to contact doctors remotely. The system acquires vital parameters such as SpO₂, ECG, Respiration Rate, NIBP, and temperature from a patient monitoring device via Bluetooth. These physiological signals are processed using digital filters, and QRS complexes are extracted using the Pan-Tompkins algorithm for ECG analysis. To ensure secure data transmission, patient records are compressed to tar.gz format and sent to the server using Secure File Transfer Protocol (SFTP). The doctor can access the patient's medical information anytime and from anywhere through login credentials. Additionally, an SMS feature is provided to notify doctors in case of emergencies, and health reports can be emailed for further diagnosis or consultation. If any abnormal readings are detected, the patient's location can be tracked via GPS, and they can be contacted through live chat or live video for immediate medical assistance. This system offers an efficient, real-time, and secure solution for remote healthcare, improving accessibility and response time for both patients and doctors.

KEYWORDS: IoT in healthcare, Remote Patient Monitoring, Real-time health monitoring, ECG analysis, Secure data transmission, Telemedicine

I. INTRODUCTION

A lot of problem is involved with the conventional health care system as it is wired and paper based. The problem is more profound in the rural areas due to the unavailability of the doctors and lack of adequate facilities. Also, many patients in rural area die or remain untreated because of travelling long distance to consult doctors. Health economy states that many times patients are made to get admitted in the hospitals, just for continual monitoring [1]. This leads to improper utilization of resources, leading to shortage of hospital bed.

Investment in technologies that enable remote monitoring would lead to long-term gains both in terms of hospital finances and patient care. The benefits of such remote monitoring are wide-ranging; the patient can continue to live their normal life, their risk of infection is reduced, hospital expenses are reduced and clinician time is utilized more effectively. Hence, remote correspondence has turned out to be exceptionally in vogue and impressively increases patient comfort during data acquisition. Developing countries have seen rapid increase in the number of cell phone subscriptions over the past decade. Reports state that 77% of the urban users and 92% of the rural people use cell phone as their main source to access the internet [2]. Thus, use of cell phone in healthcare applications is becoming popular. Continuous monitoring of vital parameters is essential nowadays. Electrocardiograph (ECG) is considered to be the most important parameter for patient monitoring applications. A significant amount of work has been done in the past to extract important information from a noisy ECG signal.

In [3], digital Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters are realized in Android application for removal of noise in ECG. The artifacts in ECG due to baseline wander and power line interference is reduced efficiently. An ECG monitoring system based on Bluetooth Low Energy (BLE) technology using a two-lead sensor is implemented [4]. It transmits data to a smartphone for further processing and displaying of the ECG signals. The results show that the proposed system can be operated for a longer period of time due to BLE technology.

Accurate QRS complex detection in ECG is very important for analysis of heart conditions. Different algorithms are used for detection of QRS complex in ECG signal. In [5], a comparison study of three best QRS detection algorithms namely Pan Tompkins algorithm [6], Hamilton & Tompkins algorithm [7] and Phasor transform algorithm [8] is carried out. The results showed that the Pan Tompkins algorithm has better accuracy as compared to other two. A real-time

ECG monitoring system using Android devices is implemented for arrhythmia detection [9]. In this system, Pan Tompkins algorithm is used for feature extraction.

Along with the data acquisition, it is also important that the uploading of data on the server is secure and has minimum delay. Although File Transfer Protocol (FTP) is one of the basic protocols used for file transfer, it is not that secure. Secure Shell (SSH) and FTP both provide user authentication. However, the latter provides authentication over plain text only. Secure File Transfer Protocol (SFTP) not only provides encryption to the login credentials but also to the data which is shared on the link. Hence, it is more profoundly used in the industry. This makes SFTP a more suitable choice in the Android application [10].

In this paper, a framework is proposed which attempts to provide a solution to the problems of existing healthcare system and facilitates remote patient monitoring. An Android application is designed for this purpose.

The paper has been organized as follows: Section 2 gives literature survey. Section 3 describes the basic and fundamental details of the proposed work. Section 4 presents the results and the work is concluded in section 5.

II. LITERATURE SURVEY

This systematic review analyzed 272 telemonitoring studies published between 2000 and 2018, highlighting a significant increase in publications from 2015 to 2018, with 76.8% reporting positive outcomes. Cardiovascular diseases were the primary focus in 47.8% of the studies, underscoring the effectiveness of telemonitoring in enhancing patient care and treatment efficiency [11].

This comprehensive study explored various aspects of RPM, including the use of sensors, wireless networks, and mobile health applications. The authors discussed the integration of IoT in healthcare, emphasizing its potential to improve patient outcomes through continuous monitoring and timely interventions [12].

This study investigated the use of Low Power Wide Area Network (LoRaWAN) technology for IoT-based health monitoring. The authors demonstrated that LoRaWAN could effectively transmit vital signs data over long distances with low power consumption, making it suitable for remote patient monitoring in rural areas [13].

This survey reviewed wearable sensor-based systems for health monitoring, focusing on their applications, challenges, and future directions. The authors highlighted the role of IoT in integrating these wearable devices for continuous monitoring and early detection of health anomalies [14].

The authors addressed the security challenges in IoT-based healthcare monitoring systems. They proposed a lightweight and secure data transmission protocol to protect patient data without compromising the system's efficiency [15].

This pilot study developed and tested an IoT-based remote patient monitoring system that collected and transmitted vital signs to healthcare providers. The system demonstrated potential in improving patient care by enabling timely medical interventions [16].

This paper explored the use of blockchain technology to secure Electronic Health Records (EHRs) in mobile cloud-based e-health systems. The authors proposed a blockchain-based framework to ensure data integrity and security in IoT-enabled remote patient monitoring systems [17].

This review examined the evolution of smart home technologies and their applications in healthcare. The authors discussed how IoT-enabled smart homes can facilitate remote monitoring of elderly patients, allowing for early detection of health issues and reducing hospital admissions [18].

III. METHODOLOGY

The system architecture comprises hardware and software components that facilitate real-time patient monitoring and remote data access. Fig. 1 illustrates the patient monitoring system block diagram, which outlines the flow of data from acquisition to storage and retrieval. On the patient side, the application collects vital parameters, including SpO₂, temperature, respiration rate (RR), non-invasive blood pressure (NIBP), and ECG, from a Patient Monitoring Device

via Bluetooth. These physiological signals are processed and stored in an SQLite database on the patient's smartphone for local access and record-keeping.

To ensure efficient storage and secure transmission, the patient record is compressed and uploaded to the server. The compression reduces data size, optimizing bandwidth usage and enhancing transmission speed. On the doctor's side, medical professionals can securely access patient records through a web interface, allowing them to review vital health parameters remotely. This remote accessibility improves the efficiency of healthcare services, enabling quick diagnosis and timely medical intervention.

Additionally, the system integrates ECG processing, which involves filtering noise and extracting key features such as QRS complexes for detailed cardiac analysis. The combination of IoT, database management, and secure data transfer makes this system highly reliable for real-time Remote Patient Monitoring (RPM) applications.

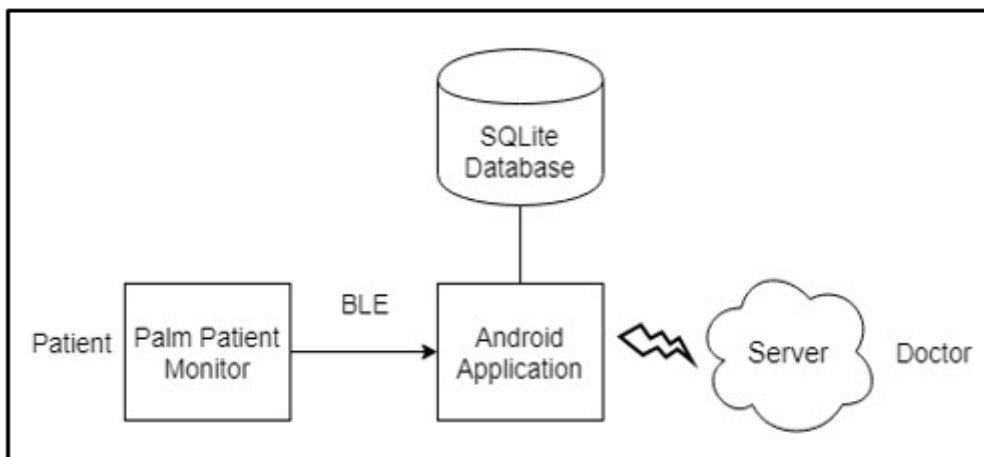


Fig. 1: Patient Monitoring System Block Diagram

A. Software and Hardware Specifications

For developing the application, Android Studio Integrated Development Environment (IDE) has been used. It is the official IDE for Google's Android Operating System (OS). PM6100 Palm Patient Monitoring Device has been used on the patient side to measure the vital parameters. It is a BLE module that allows the battery to last longer. The device has SpO₂, NIBP, Temperature and a three lead ECG sensor attached to it.

B. ECG Filtering and Parameters Extraction

ECG is the recording of electrical activity of the heart. It is used in analysis of health conditions of the heart [19]. ECG waveform and its important parameters are shown in Fig. 2. The ECG signal is acquired using bipolar Einthoven's triangle technique. Three leads of the sensor (Lead I, II, and III) are connected to the body as shown in Fig. 3. ECG signals are corrupted by various kinds of noise. The main sources of noise are: Power-line Interference (50 Hz pickup and harmonics from the power mains), Electrode contact noise, Muscle Contraction, Respiration and Perspirations and Electromagnetic Interference from other electronic devices [20]. These disturbances cause a drift in the baseline and motion artifacts.

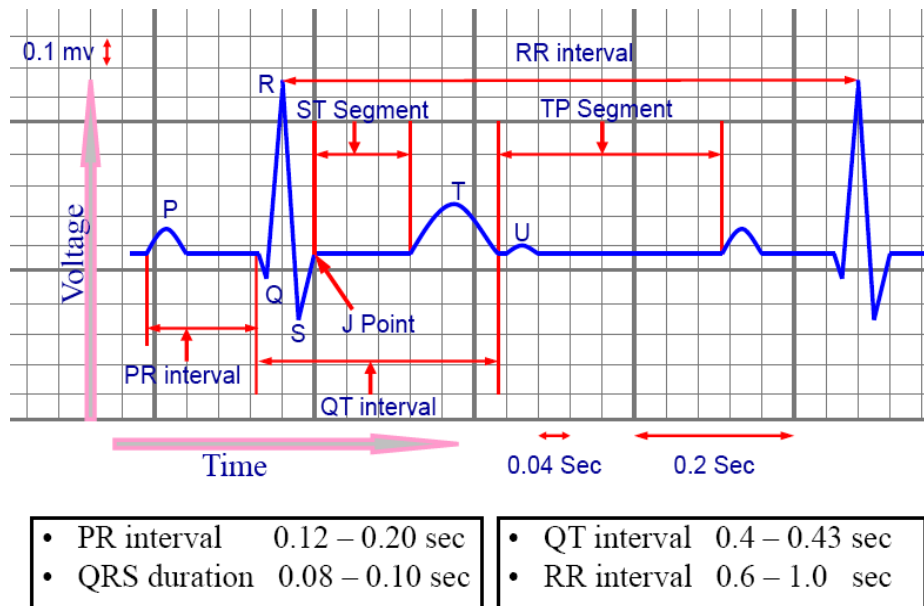


Fig. 2: ECG waveform [21]

To obtain the important information from the ECG signal, the raw ECG should be processed. The processing is divided into two stages namely, preprocessing and parameters extraction. In the preprocessing stage, digital low pass and high pass filters are used. The baseline wander which is a low frequency noise up to frequency of 1 Hertz (Hz) is removed using High pass filter. The motion artifacts are removed using Low pass filter. Then a Savitz Goly filter is used to smoothen the signal. In the next stage of parameters extraction, QRS complexes detection is done. Detection of these QRS is a vital step in ECG signal analysis. Since P and T waves are sparse and difficult to isolate from the ECG wave, many previous studies have focused only on QRS complex detection [22]. Pan Tompkins algorithm is one of the widely used methods for this purpose.

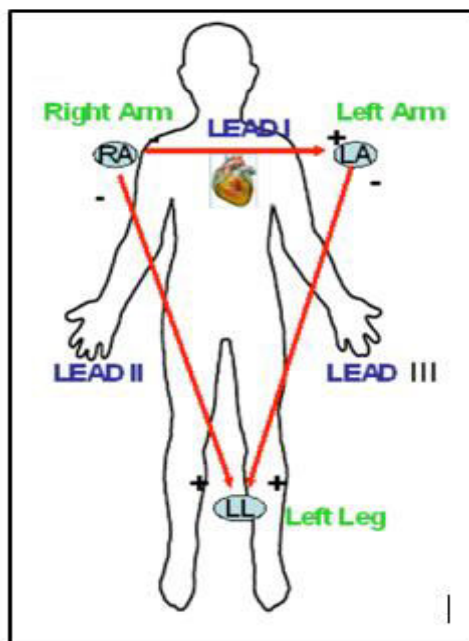


Fig. 3: ECG leads connection [23]

In this method, ECG is passed through a bandpass filter as QRS complex has a frequency of 5-15 Hz. A derivative filter followed by a squaring filter and a moving average filter is then applied. A threshold is used for detection of R peaks. On obtaining the R peaks, the Q peak is obtained by applying a window on the left side of each R peak. The minimum amplitude in the window gives the Q peak. Similarly, S peaks are detected by applying a window on the right side of every R peak. P and T waves are detected similarly by windowing technique and checking maximum amplitude location in the corresponding window. Location of all the peaks is used to calculate the different intervals. The R peak amplitude and R-R interval is also obtained. Heart rate in beats/minute (bpm) is calculated from the following formula:

$$\text{Heart Rate (bpm)} = \frac{60 * \text{sampling frequency}}{\text{R} - \text{R interval}}$$

C. Data upload on the server

The patient record that is to be sent on the server follows a pre-defined file structure so that the data is properly extracted at the server and the server database is updated properly. The entire record is compressed into tar.gz format since this format provides higher compression ratio and is more compatible with the operating systems than zip. Compression reduces the bandwidth requirement of the communication link and the time required in uploading the data, hence making the upload to the server faster. SFTP is used for uploading the record as file transfer is easy and faster. The feature of resuming the upload makes the file transfer more efficient, saving bandwidth and time.

IV. EXPERIMENTAL RESULTS

When the application is started, the home screen pops up as shown in the Fig. 4(a). The user needs to fill all his/her basic details. On the next screen, the application gets connected with the patient monitor device via Bluetooth and readings are acquired, processed and displayed as shown in the Fig. 4(b). The SpO2, Temperature, PR, NIBP and RR values are extracted from the corresponding headers using Palm Patient Monitor Communication protocol and the ECG values obtained are processed. On pressing the ECG button, ECG signal for a duration of 10 seconds is recorded and is seen live on the screen. It is stored and filtered to remove any noise using digital filters which are incorporated in the application. On filtering the ECG signal, the R peaks are detected using Pan Tompkins algorithm. Once the R peaks are detected, other peaks' location is obtained with reference to R peak using a windowing technique. Then different parameters like PR, QT, QTc, QRS intervals, R-R interval and R peak amplitude are calculated and averaged over duration of 10 seconds. The filtered ECG and the parameters are then displayed on the screen as shown in Fig. 4(b). The application can detect any abnormality in heart rate like Bradycardia if heart rate < 60 or Tachycardia if heart rate > 100.

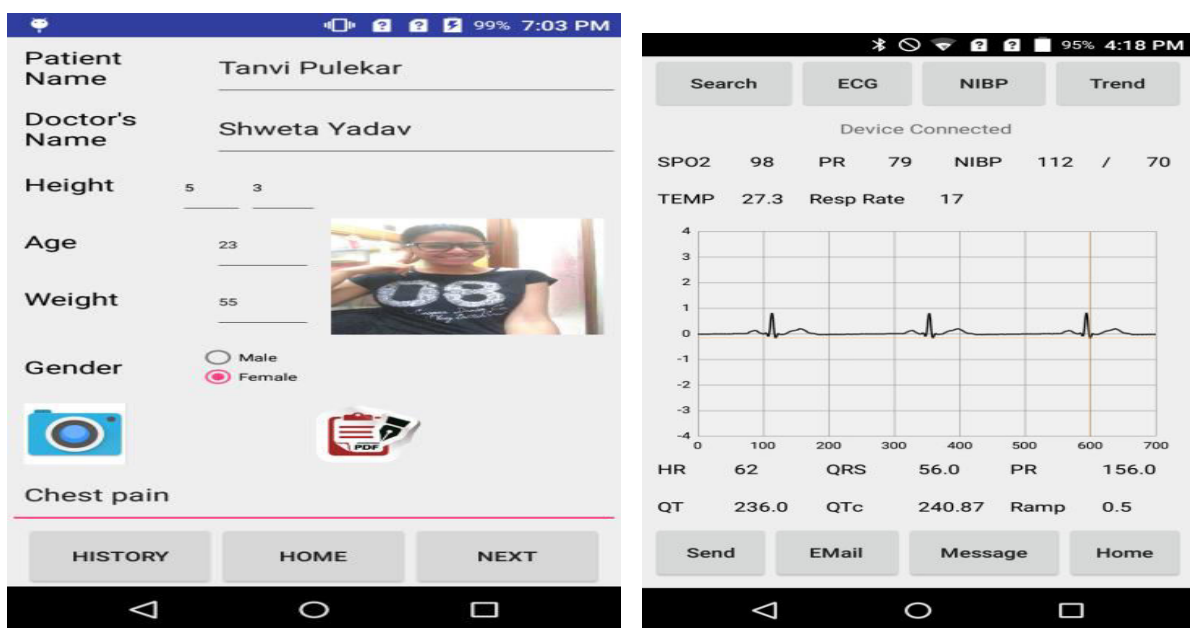


Fig. 4: Home screen and Patient readings screen



When the send button is pressed, the record obtained is compressed to tar.gz format and is uploaded to the server using SFTP along with which a Short Message Service (SMS) and Email is sent to the doctor. The application is able to provide a compression ratio of 23:1. Additionally, a SMS can be sent in case of emergency to other doctor or relatives using the Message button. Similar is the case for email button. A snapshot of received email is shown in Fig. 5(a). The email report is generated in the application itself in the background whereas the SMS report is generated on the server as the SMS comes from a third-party service and has bandwidth constraints.

When the history button on the home screen is pressed, a list of the previously acquired records is displayed as shown in the Fig. 5(b). The red color indicates that the corresponding record is not uploaded in the server due to weak or no data connection. The record is held in the queue and whenever the data connection is established, they are uploaded automatically and require no user involvement. When a record is selected from the list the detail patient report can be seen.

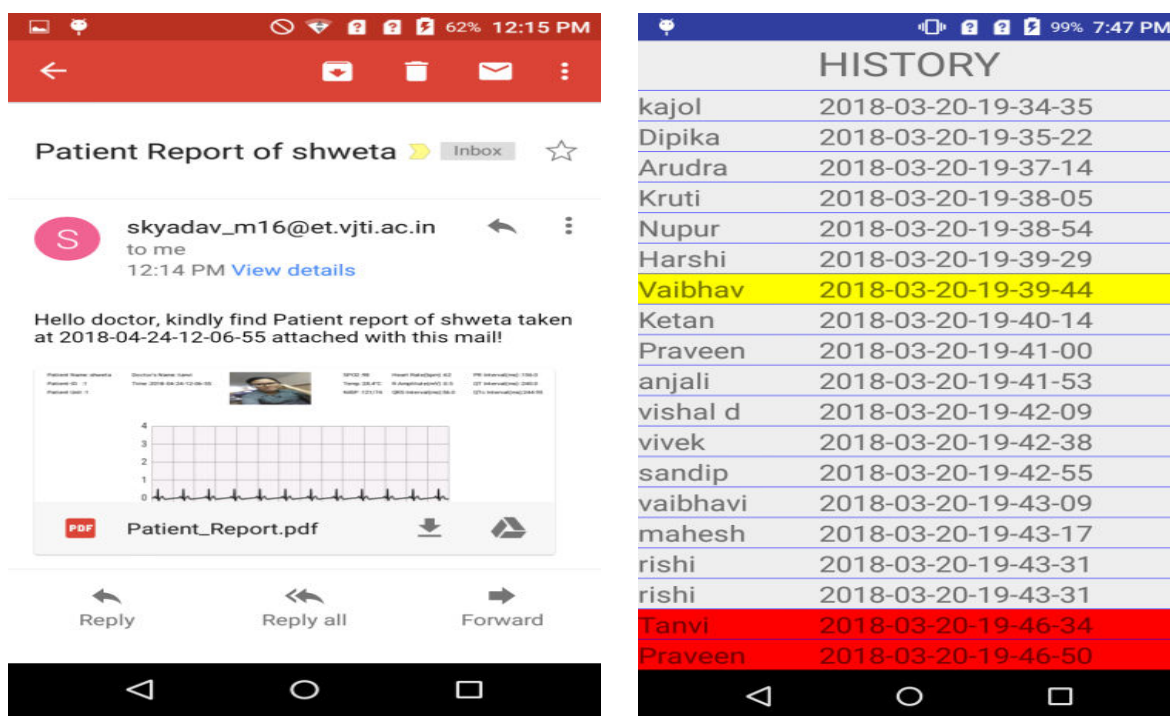


Fig. 5 Received Email and History

In Fig. 6(a), a graphical trend analysis of the monitored health parameters is presented. This trend analysis is crucial for both doctors and patients as it provides insights into the variations of vital signs over time. The application stores the acquired parameters in a structured database during each session. These stored records can later be exported in both graphical and tabular formats for better visualization and review. The trend analysis feature enables patients to monitor the progression or deterioration of their health conditions, making it easier to detect early warning signs of potential complications. By analyzing these trends, both the patient and the healthcare provider can make informed decisions about further medical interventions, treatment adjustments, or lifestyle changes.

An additional feature integrated into the application is the chat and video interaction module. This feature enhances doctor-patient communication by allowing direct interaction whenever necessary. If a doctor needs to interact with a patient, a request is initiated and sent to the server. The application is designed to ping the server every five seconds, ensuring real-time monitoring of incoming requests. Whenever a request is detected on the server, the chat or video screen automatically opens in the patient's browser, instantly connecting the doctor and the patient. The type of interaction, whether chat or video call, depends on the request initiated by the doctor. This seamless connectivity ensures that patients receive timely guidance, reducing the need for frequent in-person visits to healthcare facilities. The feature is especially beneficial for individuals residing in remote areas with limited access to healthcare professionals.



Furthermore, the application integrates Global Positioning System (GPS) functionality to track and share the patient's location. This feature becomes particularly useful in emergency situations where a doctor identifies abnormalities in the patient's health parameters but is located far away from the patient. By accessing the GPS-tracked location, the doctor can guide the patient to the nearest available healthcare facility or recommend a local physician for immediate consultation. This capability significantly enhances the efficiency of remote patient monitoring by reducing response time and ensuring that medical attention is provided when and where it is needed the most.

The application has been tested across multiple devices, including smartphones and tablets, demonstrating flexibility in terms of screen size compatibility. The development team has ensured that the application adapts seamlessly to different screen resolutions without compromising functionality or user experience. Additionally, it has been coded in such a way that the architectural changes introduced in Android 6 (Marshmallow) and later versions do not interfere with the application's permission requests. Users can easily grant the required permissions without experiencing technical difficulties.

To enhance reliability, the application incorporates robust error-handling mechanisms. This ensures that any unintended user actions or mishandling of the app do not lead to application crashes. Instead, if an error is encountered, the system is designed to display a clear and user-friendly message that provides guidance on how to resolve the issue. This prevents frustration among users and ensures a smooth and hassle-free experience while using the application. In summary, the Remote Patient Monitoring (RPM) application combines real-time data analysis, secure and efficient doctor-patient interaction, GPS tracking for emergency situations, cross-device compatibility, and robust error handling to create a reliable healthcare solution. These features collectively contribute to enhanced patient care, timely medical intervention, and improved accessibility to healthcare services, making it a valuable tool for hospitals, health camps, and personal health management.

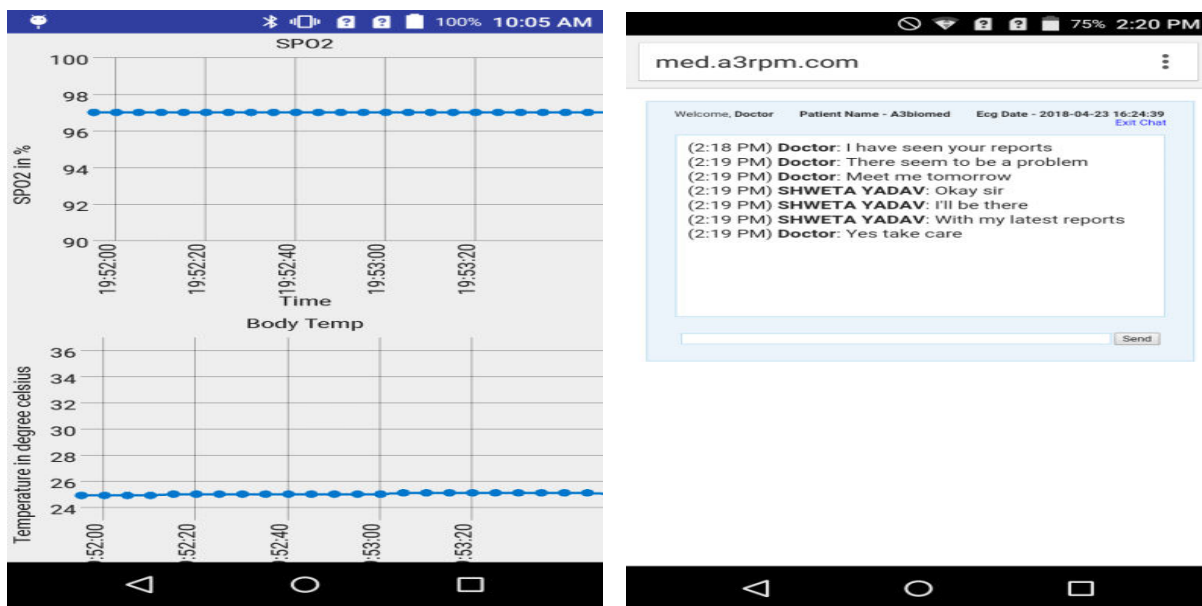


Fig. 6: Graphical Trend screen and Live chat screen

V. CONCLUSION

An Android application has been developed to enable patients to access doctor consultations remotely while detecting abnormalities in vital health parameters for timely medical intervention. Tested on both Android smartphones and tablets, the system ensures reliable performance with only a few seconds of delay in data acquisition and upload. Lightweight, portable, and user-friendly, it can be integrated into hospital management systems, deployed in health camps, or used for personal health monitoring. Its accessibility enhances healthcare delivery by improving response time for both medical professionals and patients. Future advancements could include continual and live monitoring, AI-based diagnostics, and cloud storage, further revolutionizing telemedicine and digital healthcare for both urban and remote populations.

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