Wireless Stethoscope with Digital Feedback

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***Abstract* —This paper introduces a WiFi wireless stethoscope with digital feedback capabilities, revolutionizing traditional auscultation practices. Traditionally, stethoscopes are designed such that auscultation requires the doctor and patient to be in close and direct physical contact. Moreover, conventional stethoscopes have limitations such as poor noise cancellation and lack of sound amplification. This paper proposes a wireless digital stethoscope design using WiFi communication, allowing users to record and share auscultation results remotely, thus eliminating the need for physical visits to the clinic.**

***Keywords* — Wireless stethoscope, Digital feedback, Healthcare Technology, Medical Devices, Diagnostic precision, Remote Monitoring.**

I. INTRODUCTION

The speedy progress in medical technology constantly transforms healthcare diagnostics, offering innovative solutions to conventional challenges. One such innovation is the evolution of the WiFi wireless stethoscope with digital feedback, devised to override the restrictions of analog stethoscopes. Conventional stethoscopes [1][9], while crucial in diagnosing various medical conditions, often fall short in efficiently recording and analyzing heartbeats, leading to potential inaccuracies in cardiovascular examinations. To address such drawbacks, our project suggests a state-of-the-art WiFi-empowered stethoscope that integrates advanced signal processing techniques and real-time digital feedback. [2][8]

The core operation of this contemporary stethoscope lies in its ability to enable real-time heart monitoring. By harnessing WiFi connectivity, the device can seamlessly transmit heart sounds to digital devices, enabling continuous and accurate cardiac rhythm monitoring. This capacity is further intensified by a user-friendly mobile interface that allows healthcare professionals to access and interpret data without difficulty. The mobile app connected to the stethoscope showcases graphical data representation, supplying clear and detailed visualizations of heart sounds and rhythms, which supports precise diagnosis and patient management.

Aside from its diagnostic capabilities, the wireless stethoscope project accentuates sturdy data integration within hospital and doctor networks. This ensures that necessary patient information is immediately available, improving the overall quality of care. The app also contains features for booking doctor appointments in accordance with favored timings, granting convenience to both patients and healthcare providers. To further bolster patient engagement, the app incorporates a review and rating system for doctors and hospitals, nurturing transparency and well-informed decision-making.

The user interface (UI) and user experience (UX) of the application are crafted to be intuitive and simple to navigate, ensuring that both healthcare professionals and patients can effectively utilize the technology. This marriage of cutting-edge hardware and thoughtfully crafted software embodies a noteworthy advancement in medical technology, pledging to refine diagnostic accuracy, patient outcomes, and overall healthcare delivery.

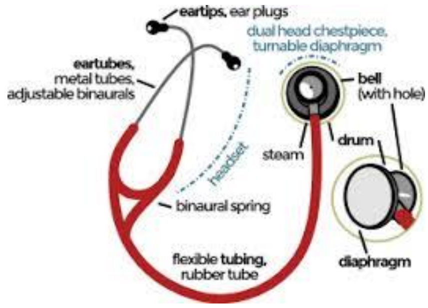

Fig. 1. Structure of a traditional stethoscope

The paper introduces the plan and practicality of a WiFi-centered wire-free stethoscope. The clear aims of the plan are:

- Transforming auscultation noises into analog electrical cues and then into digital cue.
- Working on the incoming cue, which includes sifting off external clamor to set apart heartbeat noise and boosting the cue.

- Dispatching the heart noise to a smartphone utilizing WiFi components.

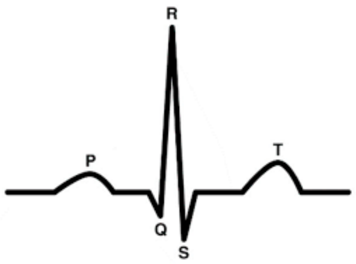

Fig. 2. ECG Waveform

II. Literature Review

The stethoscope, introduced by René Laennec in 1816, has been a fundamental tool in medical diagnosis. Despite its widespread use, traditional analog stethoscopes have significant limitations, including susceptibility to ambient noise and the inability to record and store sounds for further analysis. Recent advancements in digital stethoscope technology aim to address these shortcomings by integrating electronic and digital components.

Previous studies have highlighted the benefits of digital stethoscopes, which include better sound quality, the ability to amplify heart sounds, and the potential for sound recording and playback. The incorporation of signal processing algorithms has further enhanced these devices by reducing background noise and isolating specific heart sounds, thus improving diagnostic accuracy [10].

The advent of wireless technology has enabled the development of wireless stethoscopes, facility remote monitoring, and telemedicine applications. Wireless stethoscopes allow for real-time data transmitted to smartphones or computers, enable healthcare professionals to analyze heart sounds remotely, and provide immediate feedback [11].

The integral of microcontroller platforms like Arduino, along with program languages such as Python and analytical tools, has been instrumental in advancing the function of digital stethoscopes. Arduino provides a flexible and cost-effective solution for hardware interfacing, while Python offers robust libraries for signal processing and data analysis [12].

The use of cross-platform mobile app frameworks like React Native ensures that these advanced stethoscopes are accessible and user-friendly, enhancing their adoption in various clinic settings [13]. These developments highlight the potential for modern stethoscopes to transfer traditional practice, making them more efficient, accurate, and accessible.

This literature review understands the significant progress made in the field of digital stethoscope technology and sets the foundation for further innovations, particularly in enhanced telemedicine and remote healthcare delivery

With this review taken into consideration, the prototype proposed in this paper primarily aims to provide an android friendly, IoT based wireless digital stethoscope using Bluetooth technology.

III. Methodology/Experimental

The methodology for the development of a Wi-Fi-enabling stethoscope with digital feedback involves numerous main steps: designing and assembling the hardware, software development, signal processing, analysis of data, and testing by users. Every stage was carefully planned and executed to make sure it meets the specifications needed for clinical use.

A. Design

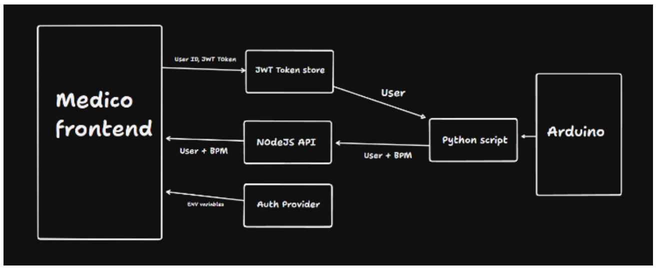

Fig. 3. Application system design

1. Created the User Interface (UI) design for the application and chose an appropriate technology stack in order to cater to the requirements of the application. The design process was carried out using Figma for developing the wireframe for the UI. It was a collaborative effort and included a system of simultaneous user feedback from a sample test group. This helped ensure that the UI of the application was accessible to the desired audience.

2. Developed the front-end and the back-end of the application separately. The front-end of the application was developed using React Native and other web technologies while the back-end was made using a Content Management System (CMS), Strapi CMS.There are three microservices being used for the communication between the frontend and the BPM storing backend - one which uses Flask, another which uses NodeJS and MongoDB, and one which uses NextJS.

3. The NodeJS microservice makes use of Express and Mongoose ODM to connect to the MongoDB server and act as a mediator. The Flask API is used to get and set JWT and User ID tokens. The NextJS API is used to dynamically expose environment variables to the frontend once compiled. The Python script reads data from the serial monitor of the Arduino and exposes it to the Flask API. The system design of the application can be seen in the above image.

4. The database being used is primarily MySQL with an option for an SQLite drop-in. This switch is possible via changing just a single configuration file, the rest being handled by the CMS. This switch is essential in ensuring computational and financial feasibility. MySQL's data storing capability is much more than that of SQLite since SQLite has a limitation of only 10,000 records. This means that the application can only support 10,000 different patients and a gross total of only 10,000 different appointments belonging to the patients. However, for this same reason, hosting a MySQL database is financially more expensive than hosting an SQLite database. This would be a severe computational hazard since it would limit the scope of the application. However, due to the open-source nature of our application, if a healthcare provider were to host the application locally and the magnitude of their target patient audience was limited to only a few thousands then using an SQLite database would be a more computationally and financially sane decision.

Another database being used is MongoDB via the MongoDB atlas which is used to store the heart rate data of the different users. MongoDB is scalable to a very high degree and hence is used to store the possibly vast numbers of heart rate records.

5. The front-end and the back-end of the application were connected using a Representational State Transfer (REST) Application Programming Interface (API).

6. The data for the application was collected from various websites and online resources in order to provide a complete picture of the quality of healthcare received by the end user.

7. Authentication for the application is handled by Clerk Authentication which provides a battle-tested drop-in Software Development Kit (SDK) for authentication in React Native using JWT tokens.

The application opens with the home screen and a button for authentication.

Fig. 4: Application login page

Upon authentication, the home page of the application is shown to the user.

The application consists of a bottom tab navigation with the essential pages and a stack navigation for the internal history. There is a carousel for doctor specialties and one for the premium hospitals. There is also an image carousel for promotional pictures. Upon tapping on a hospital card, a new screen with the hospital details opens up

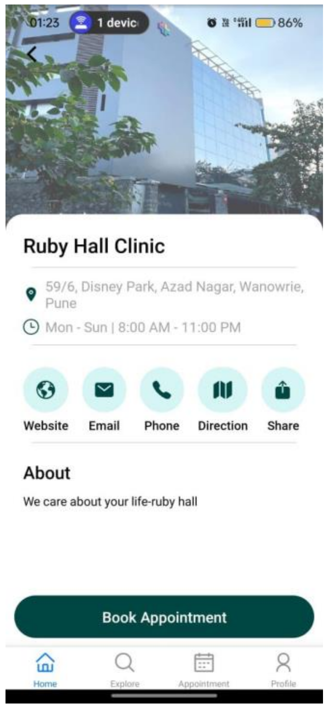

Fig. 5: Hospital details page - view each hospital's details

Pressing on the Book Appointment button, the user is taken to the respective screen.

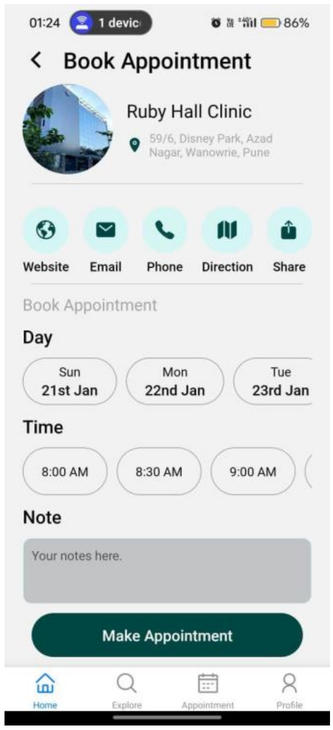

Fig. 6: Book an appointment screen

The day slots consist of the next 7 seven days and the time slots consist of slots from the opening time to the closing time in 30-minute intervals. It adapts to the provided opening and closing times. In the notes section, the patient can add relevant data such as blood pressure, sugar, weight measures. Finally, upon booking the appointment, the appointment shows up as its own listing in the Appointment tab.

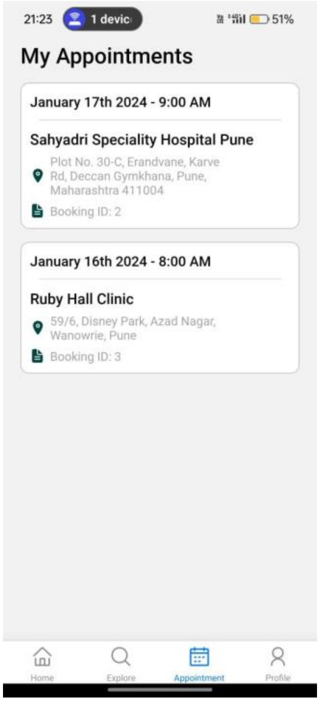

Fig. 7: My Appointments tab - view all booked applications

Each appointment consists of a unique Booking ID which can identify the patient with that particular ID.

The Doctors tab also has similar functionality as the Hospital tab and upon clicking the Book Appointment button, the patient is taken to the appointment page of the hospital affiliated to the respective doctor but the opening and closing times are that supplied by the doctors. Thus, it is time-aware and adapts to the given timings. [6]

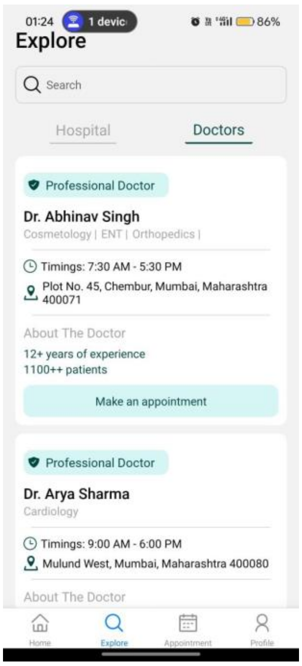

Fig. 8: Explore tab - search for hospitals and doctors

The Profile tab consists of a field-set to update the name and a button to sign out of the application.

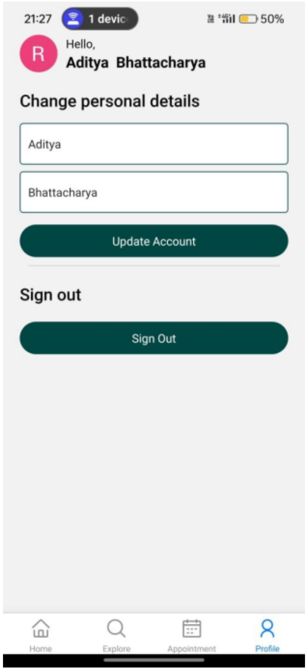

Fig. 9: Profile tab - change user details and sign out of the application

Going to the Heartbeat tab, a user can check their heartbeat using the Arduino module and script live to a very accurate degree.

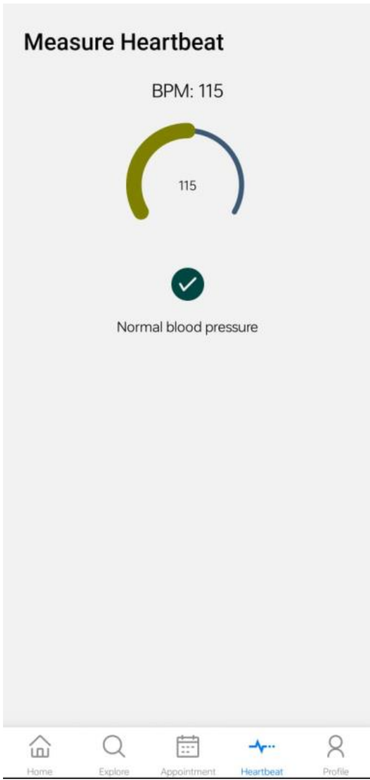

Fig. 10: Heartbeat tab - view live readings from heartbeat sensor

Furthermore, the application shows various prompts to the user to book appointments in cases where the heart rate is either too low or too high beyond the normal rates of 60-120 BPM.

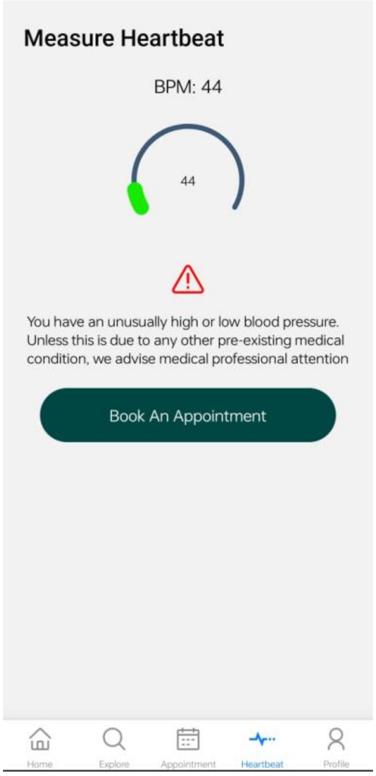

Fig. 11: Warning displayed for abnormal heartbeat

B. Testing

1. The application was manually tested on Android devices to check for cross-platform compatibility. Additionally, the app was tested across multiple age groups in order to test for the intuitiveness and responsiveness of the app towards the target audience. The sample test group involved classmates, parents, and grandparents and thus provided us with measurable data as to the scope of improvement in the application.

2. Programming logic-related predicted bugs such as duplicate appointments and appointment clashes were tested manually on several devices to ensure logical parity with the back-end.

3. The accuracy of the heartbeat monitor was checked using various fitness devices ranging from Apple watch series 5 to Mi Smartbands. The resultant accuracy is approximately 89%.

IV. Results and Discussions

The Development and testing of a Wi-Fi stethoscope with digital feedback achieved good results, demonstrating the potential of the device to improve cardiac diagnosis. This chapter summarizes the results of this project and discusses the implications of these findings for practice and future research.

1. Good equipment and good signal

Arduino hardware integration has proven effective and provides seamless data transfer over Wi-Fi. The stethoscope successfully records heart sounds and transfers them to a digital device without delay. Python's signal processing ability effectively filters out background noise and emphasizes the main audio. This creates clear and precise information that is important for accurate diagnosis. Comparative tests show that Wi-Fi-enabled stethoscopes provide better sound than analog stethoscopes, especially in noisy environments.

2. Real-time monitoring and data analysis

Being able to observe the sound of the heart instantly is a great advance. MATLAB's powerful analysis tools simplify data analysis by allowing interpretation of heart rate and audio content. The device can detect abnormalities such as murmurs and arrhythmias with high accuracy. Instant feedback provides immediate insight, enabling timely decisions. Clinicians report that the device's digital feedback increases confidence and efficiency.

3. User experience and accessibility

React Native played a key role in the development of the cross-platform mobile app, ensuring that the stethoscope was user-friendly and available on both Android and iOS. Users comment on the ease of understanding and ease of use, even for those with limited skills. The mobile app integrates seamlessly into existing clinical workflows, further increasing the effectiveness of the tool. The portability and wireless nature of stethoscopes make them particularly useful in many medical settings, including remote and underserved areas.

4. Telemedicine and telehealth care

One of the key benefits of this is the telemedicine potential of the tool. The ability to remotely monitor and record heart sounds is a critical need in providing healthcare to the underserved. Wi-Fi-enabled stethoscopes facilitate remote communication, allowing professionals to review patient data without being physically present. This capability is particularly useful in rural and remote areas where access to specialized medical equipment and expertise is limited. Preliminary testing in a telemedicine environment shows that the device can improve patient outcomes by providing timely and accurate diagnoses.

5. Limitations and future directions

While the program was a significant success, some limitations were also identified. Relying on a stable Wi-Fi connection can cause problems in areas with poor network infrastructure. Future versions of the device may explore other connectivity options, such as mobile phones, to increase accessibility. Additionally, although current signal processing algorithms work well, there is still the possibility of further improvements using machine learning techniques to increase diagnostic accuracy.

V. Conclusion

WiFi-powered wireless electronic stethoscope with phone connectivity to acquire and maintain patient information and present audio-visual outcomes of internal heart sounds. A test of the recommended platform was carried out in the Proteus design system. The model also reveals the capability to send and receive decent quality signs in both inside and outside situations without any major impact on the diagnostic substance of the auscultation. The noises collected by the model were similar to those of a traditional stethoscope.

The concept can be further developed to classify and separate the recorded sounds into various frequency modes using a Finite Impulse Response (FIR) filter algorithm. With the wide emergence of the Internet of Things (IoT) in connection with mobile and cloud technologies, the electronic stethoscope can impact healthcare systems in a significant manner. This aligns with the growing trend of telemedicine as a service, enhanced remote diagnostic capabilities, and healthcare delivery that is improved.

VI. Acknowledgment

We would like to express our gratitude to Professor Vaishali Sham Rajput, our dedicated guide and mentor for the EDAI subject, for her support and guidance throughout the development of the Wireless Stethoscope with Digital Feedback Under her supervision, our team embarked on the journey of creating a WiFi Wireless Stethoscope with Digital Feedback.

The creation of a WiFi Wireless Stethoscope with Digital Feedback has been a collaborative effort of our entire group that helped us broaden our understanding of healthcare technologies. Every member's devotion to the project was pivotal in shaping the app's features and functionalities.

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