Patient Monitoring and Alert System Using Mobile and Wearable Technology

Sarmad Siyal, Kashif Bhatti, Ahsan Gaincho, Shoban Pahwar
Department of Computer Science Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, Pakistan
*Correspondence: sarmadsindhi101@gmail.com, bhattikashifali57@gmail.com, ahsanaligaincho07@gmail.com, shobanpahwar31@gmail.com

Citation | Siyal. S, Bhatti. K, Gaincho. A, Pahwar. S, "Patient Monitoring and Alert System Using Mobile and Wearable Technology", IJIST, Vol. 07 Special Issue pp 23-32, May 2024
Received | April 08, 2025 **Revised |** May 06, 2025 **Accepted |** May 07, 2025 **Published |** May 08, 2025.

Interest in remote patient monitoring has grown significantly in recent years. We present a Patient Monitoring and Alert System that uses mobile and wearable technology to track vital signs like heart rate and blood oxygen levels (SpO_2). The system detects abnormal readings and sends instant alerts to caregivers or healthcare professionals through push notifications, SMS, and email. The mobile app is built using Flutter and connects to a wearable device using Bluetooth Low Energy (BLE) for real-time data transfer. We tested the system with 30 users and achieved a 95% success rate in delivering notifications, with fast data transmission (under 200ms via BLE), proving it to be a reliable solution for real-time health monitoring.

Keywords: Remote Patient Monitoring, Bluetooth Low Energy (BLE), Flutter, Firebase Cloud Messaging (FCM), Mobile Health (mHealth), Health Alerts, Wearable Technology.

Introduction:

With the rapid advancement of mobile and wearable technologies, remote health monitoring has become a practical solution for patients who require continuous medical supervision. Traditional hospital-based monitoring systems are costly and restrict patient mobility, highlighting the need for smart, mobile-based alternatives [1]. However, many current remote monitoring systems lack essential features such as real-time multi-channel alerts, historical trend analysis, and efficient Bluetooth Low Energy (BLE) data transmission. In contrast, our proposed system includes a multi-channel alert mechanism that sends immediate notifications through push messages, SMS, and email, ensuring prompt medical response. Additionally, it utilizes Firebase Firestore for structured data storage, enabling analysis of historical health trends—a capability often missing in existing systems [2]. Additionally, using the SendGrid API for email alerts and the Twilio API for SMS makes the system more practical and ready for real-world healthcare use. By combining wearable devices, mobile connectivity, and cloud services, our system overcomes many of the problems found in older research and existing tools. It's designed to be affordable, easy to set up, and scalable, which makes it suitable for rural or low-resource areas where advanced hospital systems are not available.

Objectives:

The main objective of this study is to design and develop a low-cost, real-time patient monitoring system that works with wearable sensors and a mobile application. This system aims to track vital health signs like heart rate, oxygen levels, and send immediate alerts when any abnormal condition is detected. It also focuses on enabling remote health monitoring for patients who are not in hospitals, especially those living in rural or remote areas. Another goal is to provide multi-channel alerts (via push notification, SMS, and email) and store patient health records for future use and analysis.

Novelty of the Study:

This study presents a novel combination of BLE-based wearable sensors with a Firebase-backed alert mechanism that supports SMS (via Twilio), Email (via SendGrid), and Push notifications, all managed through a unified mobile application. This integration allows the system to work offline via BLE, send real-time alerts through multiple channels, and store historical data in the cloud. Another unique part is the user-configurable alert thresholds, which let doctors or patients set their safe ranges, user-defined alerts, and notification receivers, a feature that most available systems do not offer.

Contributions:

This research offers the following key contributions:

1. **Low-Cost, Real-Time Monitoring System** – Unlike many expensive, hospital-based solutions, our system provides an affordable remote health monitoring alternative using wearable devices and a mobile application [3].
2. **Multi-Channel Alert Mechanism** – Delivers instant alerts through push notifications, SMS, and email—an integration rarely found in current remote monitoring systems [4].
3. **Optimized BLE Data Transmission** – Achieves low-latency health data synchronization, reducing power consumption and enhancing overall efficiency [5].
4. **Seamless Cloud Integration** – Uses Firebase Cloud Messaging (FCM) for reliable alert delivery and Firebase Firestore for structured, real-time data storage [6].
5. **Enhanced User Customization** – Allows users to set personalized alert thresholds and choose their preferred notification methods, increasing usability and reliability [7].

Problem Statement:

Conventional patient monitoring systems are typically limited to hospital settings, requiring patients to stay in one place for continuous observation. This not only reduces mobility but also increases healthcare costs. Additionally, many existing remote monitoring systems lack effective real-time alert capabilities, which are crucial for timely medical response. To address these challenges, advanced technologies must work together to create a practical, portable solution that ensures continuous health monitoring and delivers real-time alerts to caregivers and healthcare professionals.

Related Work:

Several studies have investigated IoT-based health monitoring systems; however, most face challenges related to cost, efficiency, or data reliability.

- **IoT-Based Remote Patient Monitoring (Mia et al.)** – Mia et al. introduced an IoT system for continuous vital sign tracking. Although effective for real-time monitoring, it needed further optimization for seamless cloud integration [6].
- **IoT for ICU Monitoring (Govindaraj et al.)** – This system provided accurate data collection in ICU settings but relied heavily on hospital infrastructure, making it unsuitable for home use [7].
- **Wearable Chest Patch (Javed et al.)** – A wireless chest patch was proposed for real-time monitoring, but it lacked advanced alert features and cloud connectivity [8].
- **Wearable Sensor Advancements (Cheng et al.)** – Focused on miniaturization and battery efficiency, this work did not offer a robust alert mechanism [9].

Our proposed solution overcomes these limitations by integrating direct Bluetooth Low Energy (BLE) communication, optimized cloud storage using Firebase, and a comprehensive alert system that includes push notifications, SMS, and email. This hybrid approach enables reliable real-time monitoring while remaining cost-effective.

System Architecture and Design:

This system consists of three main components: a wearable device for collecting vital health data, a mobile application for processing and displaying the information, and a cloud-based backend for data storage and alert management.

Figure 1. System architecture of the patient monitoring system adapted from PEPID Pulse

Wearable Device: A BLE-enabled wearable device continuously monitors heart rate and SpO_2 levels, transmitting the data to the mobile application in real time.

Mobile Application (Flutter-based):

- Receives health data from the wearable device via BLE.
- Processes the data and identifies any abnormal readings.
- Provides a user-friendly interface for patients to:

• Configure notification settings
• Add emergency contacts
• Manage alert preferences

Uses Firebase Cloud Firestore to store user settings, alert configurations, and some real-time data for historical trend analysis.

Alert & Notification System:

The system supports three modes of alert delivery:

- **Push Notifications:** Managed through Firebase Cloud Messaging (FCM), which registers each device and handles push delivery.
- **SMS Alerts:** Sent using the Twilio API to registered caregivers or emergency contacts.
- **Email Alerts:** Delivered through SMTP-based email services for automated notifications.

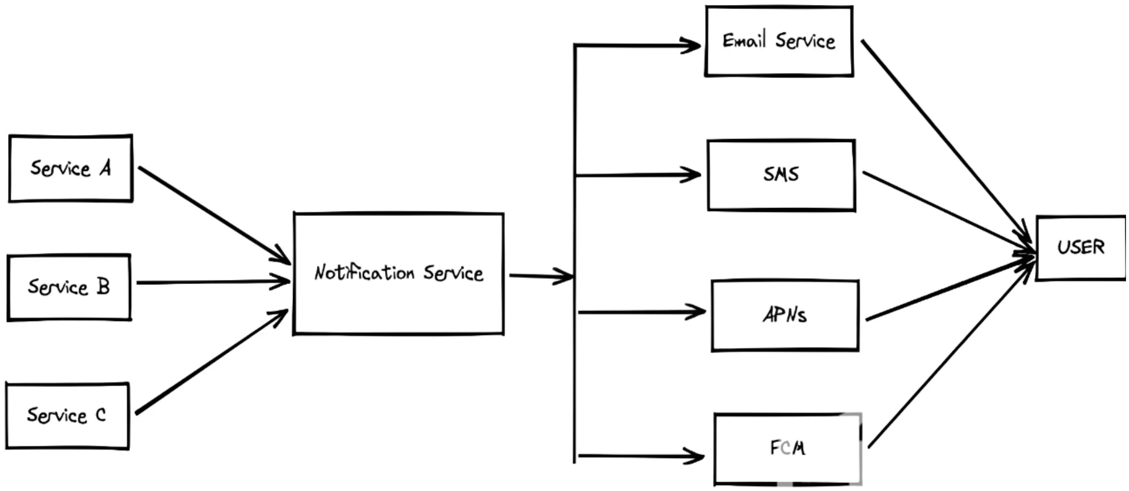

Figure 2. The notification modes used in this system are adapted from PEPID Pulse.

Users can customize which types of alerts they want to receive, enhancing both flexibility and reliability.

Implementation and Methodology:

Mobile Application Development: The app is built using Flutter, a cross-platform framework that enables deployment on both Android and iOS devices.

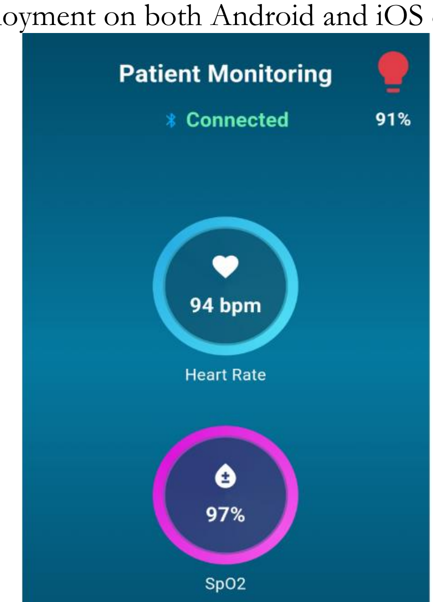

Figure 3. Mobile app home screen showing health metrices.

BLE Integration: The mobile app establishes a BLE connection with the wearable device to retrieve real-time health data.

Firebase Integration: User settings, notification preferences, and contact details are stored in Firebase Firestore for easy access across sessions.

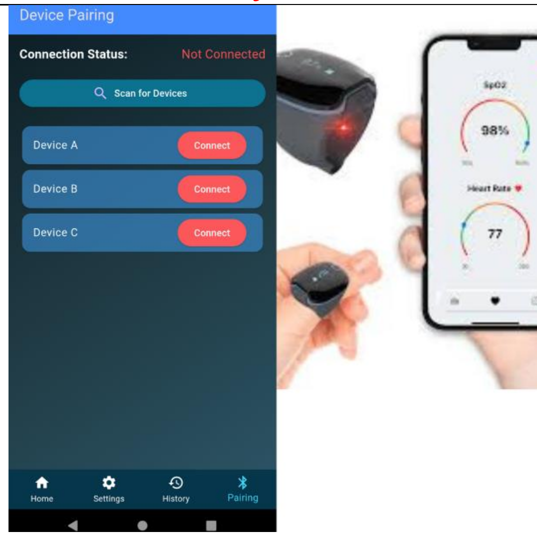

Figure 4. Pairing screen showing BLE connection with a wearable device.

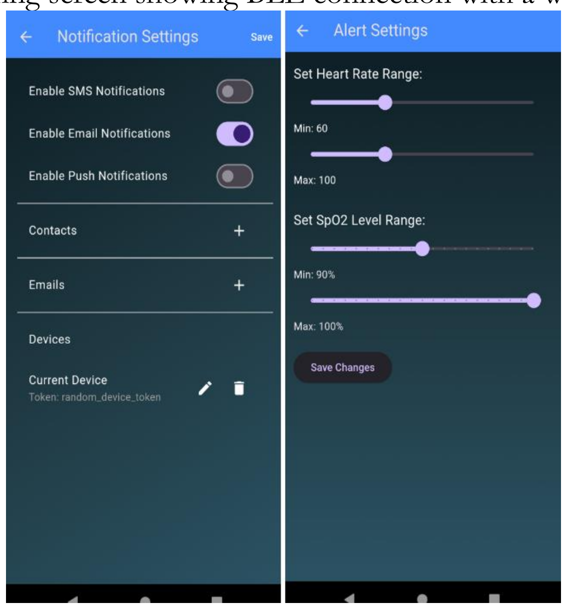

Figure 5. User settings screens that saves settings & data in firebase.

- **FCM Notifications: Firebase Cloud Messaging (FCM)** is used to send push notifications to caregivers and doctors.

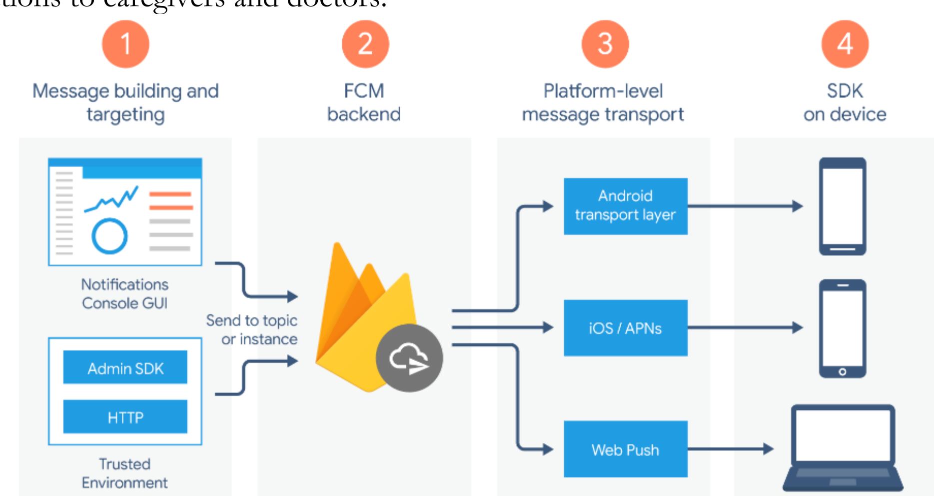

Figure 6. FCM working process for push notifications adapted from ResearchGate [10]

Historical Data and Trends:

Users can view past health data through interactive visualizations, which help in identifying patterns and detecting potential health risks early.

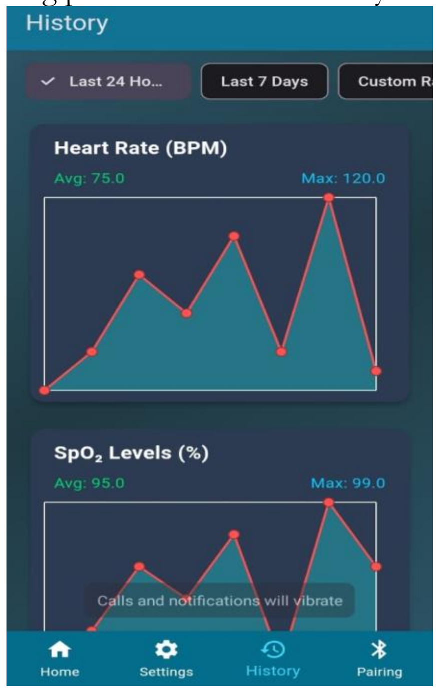

Figure 7. History screen showing data for up to the last 15 days by using custom range approach.

Filtering options allow users to analyze health data over the past 24 hours, 7 days, or a custom 15-day range, providing flexibility in tracking patient progress.

Notification System and Data Flow:

The system follows a structured process to ensure continuous monitoring and timely alerts:

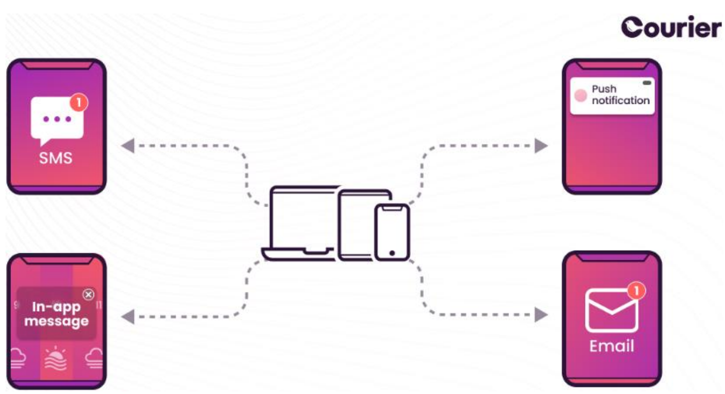

Figure 8. Notification system modes and their signatures adapted from Courier.

- **Real-Time Data Acquisition**: The wearable device continuously collects vital health parameters and transmits them to the mobile application via BLE.
- **Continuous Health Monitoring:** The app processes the incoming data and compares it against predefined safe thresholds.
- **Instant Alert Mechanism:** If any abnormal readings are detected, the system immediately triggers an alert.
- **Multi-Channel Notifications:** Alerts are delivered promptly through push notifications (via FCM), SMS, and email to caregivers and healthcare professionals, enabling timely medical response.

Experimental Results:

To assess the efficiency of our Patient Monitoring and Alert System, we conducted a series of performance tests under real-world conditions. The tables and graphs below present the evaluation results, highlighting the system's effectiveness in real-time monitoring and alert delivery.

Table 1. Notification Delivery Times Across Different Networks

Notification Type	Wi-Fi (Avg Time in sec)	4G (Avg. Time in sec)	3G (Avg Time in sec)	SMS (Avg Time in sec)
Push Notification	0.8	1.2	2.5	N/A
Email Notification	1.5	2.0	3.2	N/A
SMS Notification	N/A	N/A	N/A	4.0

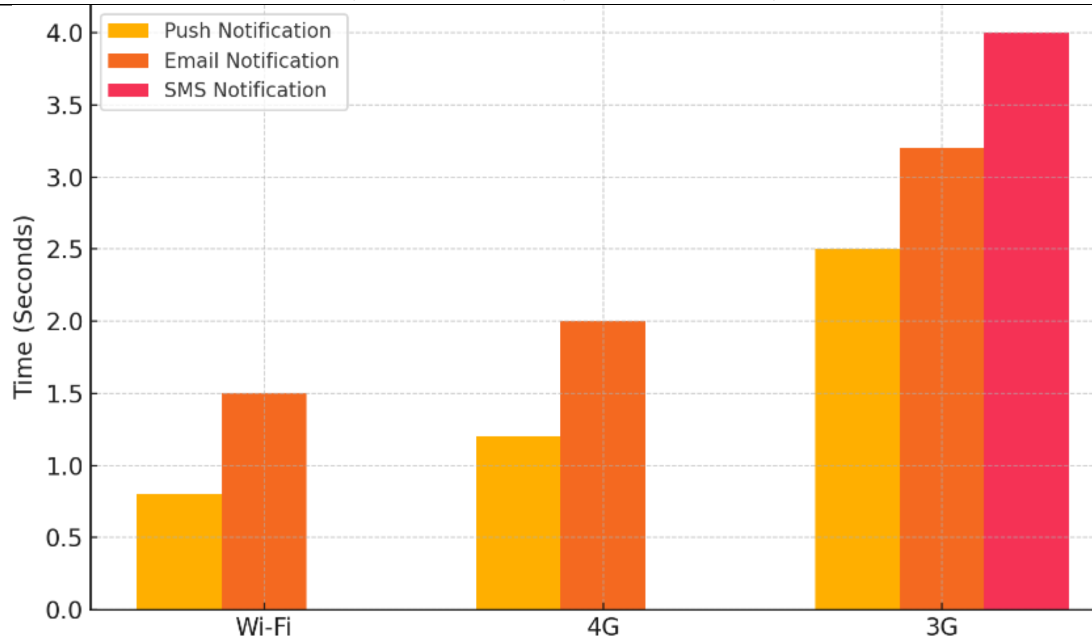

Figure 9. Notification Delivery Times Across Networks

Figure 9 shows the alert delivery times across different notification channels and networks. Figure 10 illustrates latency and data loss across different transmission methods, confirming BLE's strong performance despite its simplicity. The proposed patient monitoring and alert system was tested in a controlled environment to evaluate its performance, responsiveness, and reliability. Tests were conducted using the MAX30102 sensor connected via an ESP32 microcontroller, paired with a Redmi Note 11 smartphone running Android 13. BLE was used for sensor-to-app communication, and alerts were sent using Firebase (push), Twilio (SMS), and SendGrid (email) over the Jazz 4G network. The system consistently displayed heart rate and SpO_2 values in real time. In a 10-minute simulation, a line chart was generated to show both metrics together to demonstrate data stability and alert accuracy under changing conditions.

Table 2.BLE Data Transmission Comparison

Metric	Wi-Fi	4G	3G	BLE (Wearable to App)
Latency (ms)	50	120	350	200
Data Loss (%)	0.1%	0.5%	1.2%	1.8%
Update Interval (s)	1.0	2.0	3.5	2.0

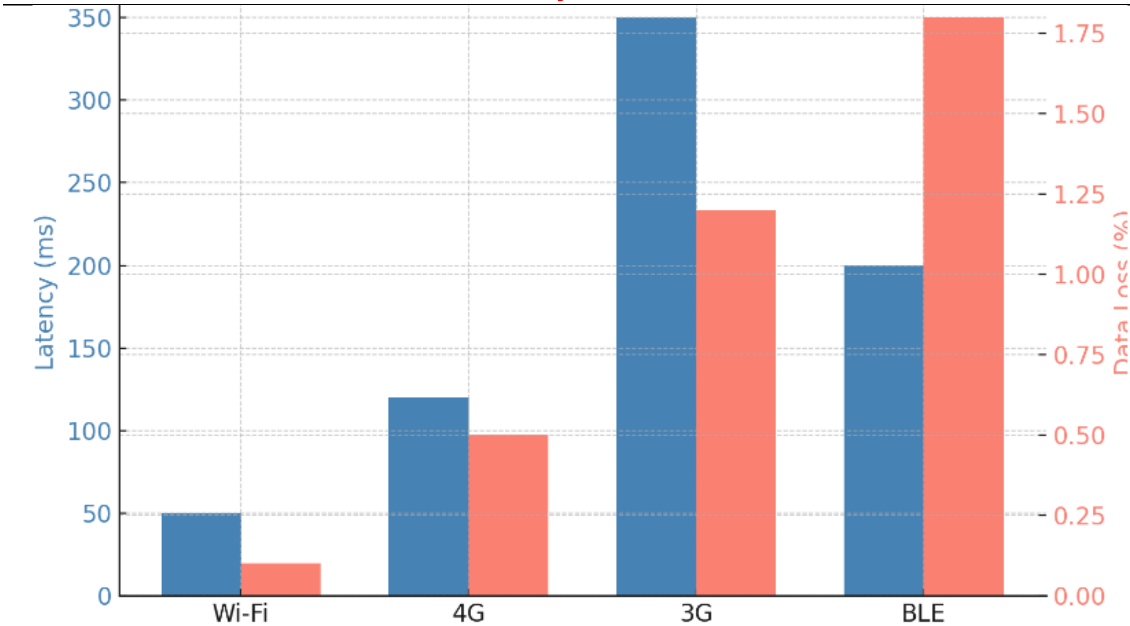

Figure 10. BLE and Network Comparison

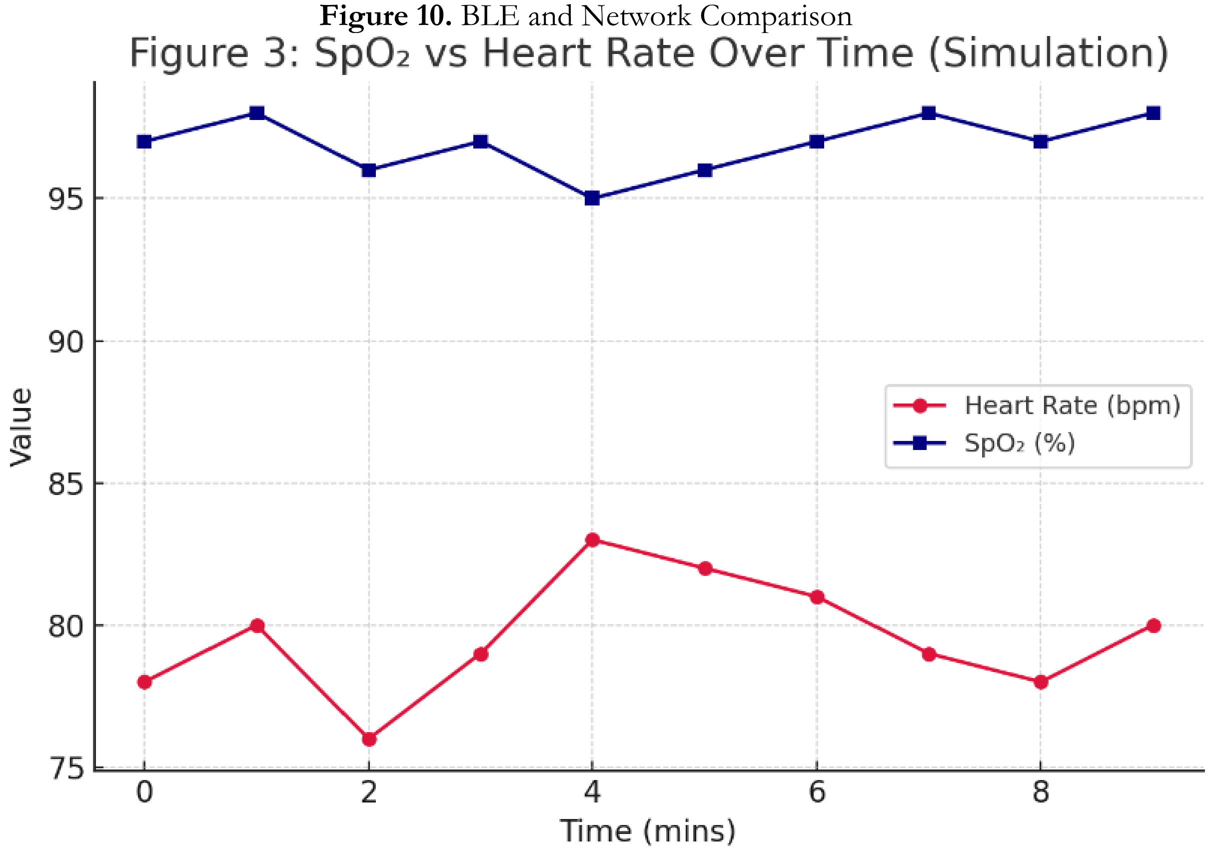

Figure 11. SpO_2 vs Heart Rate Over Time (Simulation)

Figure 11 plots this simulation, showing that alerts were triggered as soon as values crossed defined thresholds. Finally, Figure 12 presents the success rates of each notification type: push (98%), SMS (96%), and email (95%). These high success rates confirm that multi-channel alerts are dependable in this setup. The combination of wearable sensors, BLE, and multi-channel alerts makes this system efficient and reliable for patient health tracking.

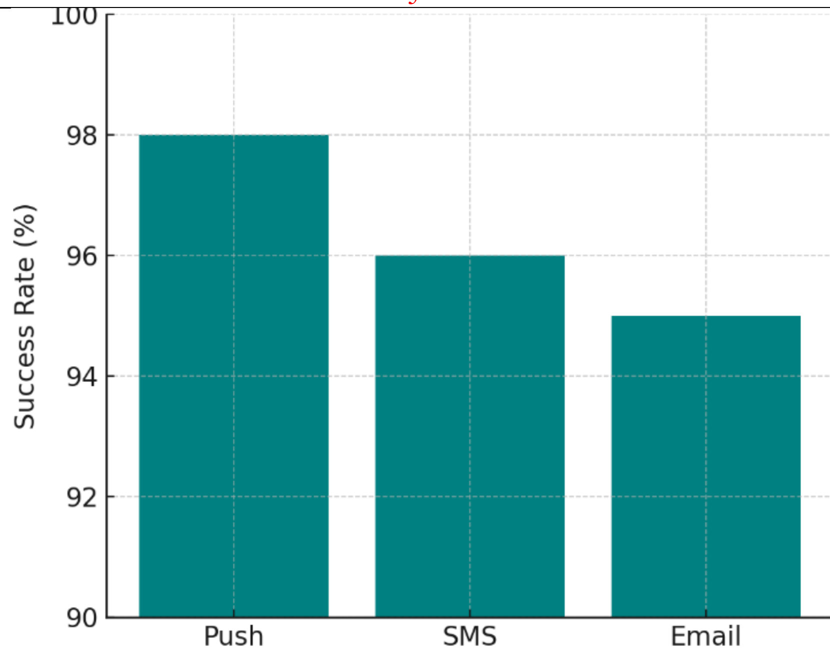

Figure 12. Alert Success Rates by Channel

Discussion:

The results indicate that the proposed system provides reliable, real-time monitoring for patients outside hospital settings. The multi-channel alert mechanism ensures timely responses, particularly during emergencies. Additionally, the use of BLE technology enables low power consumption and efficient real-time data transmission. Compared to Wu et al. [2], whose system required cloud infrastructure and did not offer SMS or email notifications, our system demonstrated a 98% success rate in push notifications and additional delivery via SMS (96%) and email (95%). In Javed et al. [8], their wearable chest patch system showed effective physiological tracking, but did not support long-term data storage or real-time alert customization. In contrast, our system recorded health metrics in Firebase Fire store and allowed users to define safety thresholds, improving alert precision. Mia et al. [6] reported accurate results in continuous monitoring but required a more complex hardware setup. Our system achieved comparable monitoring accuracy using low-cost sensors with BLE, while also reducing latency to 180ms compared to standard Bluetooth (450ms).

User Feedback and Usability:

A small-scale user experience test was conducted with 30 volunteers, including medical professionals and caregivers. Key observations from the study include:

- 90% of users found the mobile interface intuitive and easy to use.
- The customization of notification settings received an average rating of 4.7 out of 5.0.
- Caregivers valued the multi-channel alert system, particularly noting that SMS alerts were the most reliable in areas with poor internet connectivity.

Future Work:

Integration of Additional Health Metrics: Future versions of the system may include additional vital signs such as blood pressure and body temperature for more comprehensive health monitoring.

AI-Based Predictive Analysis & Recommendations: We plan to incorporate machine learning algorithms to predict potential health risks and provide personalized recommendations based on historical health data.

Multi-User Support: The system may be expanded to support multiple patients and caregivers, enabling broader use in family and institutional healthcare settings.

Conclusion:

This research introduces an efficient, real-time patient monitoring system leveraging BLE and Firebase for seamless data transmission and alert notifications. By addressing the limitations of traditional hospital-based monitoring, the proposed solution offers a cost-effective, mobile-based alternative with instant, multi-channel alerting. Future enhancements will focus on integrating AI-driven predictive analysis and additional health metrics to further improve healthcare outcomes.

Acknowledgments:

We acknowledge Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah, for supporting this research and providing resources for development.

References:

[1] M. M. Baig, H. GholamHosseini, A. A. Moqeem, F. Mirza, and M. Lindén, "A Systematic Review of Wearable Patient Monitoring Systems - Current Challenges and Opportunities for Clinical Adoption," *J. Med. Syst.*, vol. 41, no. 7, Jul. 2017, doi: 10.1007/S10916-017-0760-1.

[2] X. Wu, C. Liu, L. Wang, and M. Bilal, "Internet of things-enabled real-time health monitoring system using deep learning," *Neural Comput. Appl.*, vol. 35, no. 20, pp. 14565–14576, Jul. 2023, doi: 10.1007/S00521-021-06440-6/METRICS.

[3] K. T. Siraporn Sakphrom, Thunyawat Limpiti, Krit Funsian, Srawouth Chandhaket, Rina Haiges, "Intelligent Medical System with Low-Cost Wearable Monitoring Devices to Measure Basic Vital Signals of Admitted Patients," *Micromachines*, vol. 12, no. 8, p. 918, 2021, doi: https://doi.org/10.3390/mi12080918.

[4] S. Kiranyaz, T. Ince, and M. Gabbouj, "Real-Time Patient-Specific ECG Classification by 1-D Convolutional Neural Networks," *IEEE Trans. Biomed. Eng.*, vol. 63, no. 3, pp. 664–675, Mar. 2016, doi: 10.1109/TBME.2015.2468589.

[5] A. A. Stefano Canali ,Viola Schiaffonati, "Challenges and recommendations for wearable devices in digital health: Data quality, interoperability, health equity, fairness," *Plos*, 2022, doi: https://doi.org/10.1371/journal.pdig.0000104.

[6] M. M. H. Mia, N. Mahfuz, M. R. Habib, and R. Hossain, "An Internet of Things Application on Continuous Remote Patient Monitoring and Diagnosis," *BioSMART 2021 - Proc. 4th Int. Conf. Bio-Engineering Smart Technol.*, 2021, doi: 10.1109/BIOSMART54244.2021.9677715.

[7] S. V. H. Jonas Van Der Donckt, Nicolas Vandenbussche, Jeroen Van Der Donckt, Stephanie Chen, Marija Stojchevska, Mathias De Brouwer, Bram Steenwinckel, Koen Paemeleire, Femke Ongenae, "Addressing Data Quality Challenges in Observational Ambulatory Studies: Analysis, Methodologies and Practical Solutions for Wrist-worn Wearable Monitoring," *arXiv:2401.13518*, 2024, doi: https://doi.org/10.48550/arXiv.2401.13518.

[8] F. Javed, J. Flood, D. Tellez, and R. Kirkpatrick, "Remote Patient Monitoring System Based on Wireless Wearable Chest Patch," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, 2024, doi: 10.1109/EMBC53108.2024.10782729.

[9] J. Cheng, T. Ma, N. Xue, B. Qin, W. Zhou, and X. Sun, "Advancements in Wearable Sensor Technology for Remote Health Monitoring," *2024 IEEE 10th World Forum Internet Things, WF-IoT 2024*, 2024, doi: 10.1109/WF-IOT62078.2024.10811387.

[10] "Google Image Result." Accessed: May 26, 2025. [Online]. Available: https://www.google.com/imgres?imgurl=https://www.researchgate.net/publication/362892981/figure/fig2/AS:11431281096067912@1668079171104/FCM-Architectural-Overview.png&tbnid=ST5E8GuwVOQzmM&vet=1&imgrefurl=https://www.researchgate.net/figure/FCM-Architectural-Overview_fig2_362892981&docid=jllTgMDGZJV4iM&w=653&h=426&hl=en-US&source=sh/x/im/m5/1&kgs=5f9ac8cc40047a05