**Empowering Personalized Care:**

**A 4G-Powered Patient Monitoring System**

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Electronics and Communication Engineering

*by*

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December 2024

**DECLARATION**

We hereby declare that the capstone project group report title “Empowering Personalized Care” is an authentic record of our own work carried out at “Thapar Institute of Engineering and Technology, Patiala” as a Capstone Project in the seventh semester of B.E. (Electronics & Computer Engineering), under the guidance of **Dr. Rajesh Khanna and Dr. Jaswinder Kaur**, during January to December 2024.

25 October 2024:

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**CERTIFICATE**

This is to certify that the report titled “**Empowering Personalized Care: A 5G-Powered Patient Monitoring System” REPORT**, submitted by **Anisha Sinha, Kartikay Shori, Riya Khera, Surya Pratap Mittal & Pulkit Garg**, to the Thapar Institute of Engineering & Technology, Patiala, for the award of the degree of **Bachelor of Technology**, is a record of the project work done by them under our supervision. The contents of this report, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

**Place**: Patiala  **Dr. Rajesh Khanna** (Professor, ECED)   
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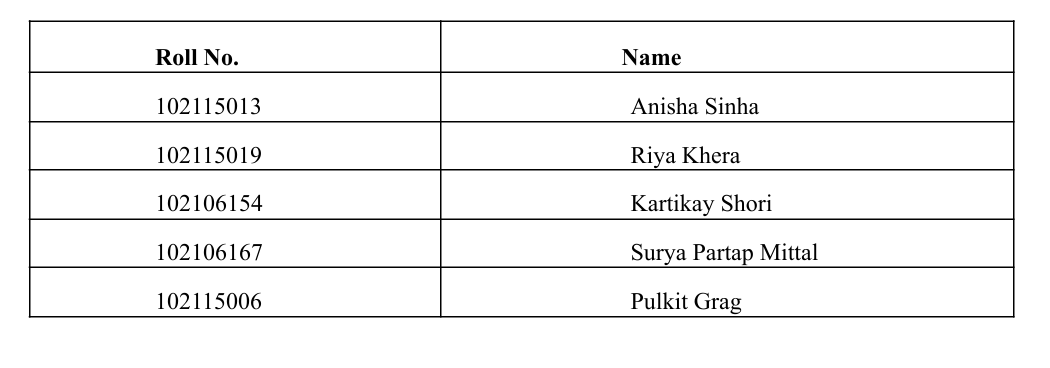
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25th October 2024:



**i**

# **ABSTRACT**

# This project focuses on developing and implementing a cutting-edge 5G-enabled Patient Medical Record System (PMRS) within a hospital setting, aimed at transforming healthcare delivery through advanced wireless technology. By leveraging the high-speed, low-latency capabilities of 5G networks, the system will enable real-time access to patient medical records, seamless communication among healthcare providers, and proactive health management. Key components include establishing a robust 5G network with small cells and edge computing resources, integrating Wi-Fi 6 (IEEE 802.11ax) for efficient and high-speed wireless communication, and utilizing IEEE 802.15.4 for continuous health monitoring through wearable devices. Additionally, the project ensures interoperability and real-time data exchange through IEEE 11073 standards for medical device communication and implements robust network security via IEEE 802.1X for authenticating devices and users. An IoT framework (IEEE 2413) will support the scalable integration of connected devices within the hospital ecosystem. A secure, personalized mobile application will be developed to allow patients to access their medical records, receive health updates, and interact with healthcare providers securely, featuring multi-factor authentication, offline access, and personalized health information. The project will adhere to strict data security standards, including end-to-end encryption and role-based access control. Executed in phases—assessment and planning, network deployment, system integration, mobile app development, security implementation, and training and rollout—the project aims to enhance patient safety, healthcare efficiency, and data security while reducing costs. This initiative will advance the application of 5G technology, integration of wearable devices, and development of predictive models, setting a new standard for innovative, patient-centric solutions in healthcare and leading to improved patient outcomes and a more efficient healthcare system.

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# **ABBREVIATIONS**

**LAN Local Area Network**

**PMRS Patient Medical Record System**

**MDPI Multidisciplinary Digital Publishing Institute**

**EHR Electronic Health Record**

**FHIR Fast Healthcare Interoperability Resources**

**MQTT Message Queuing Telemetry Transport**

**API Application Program Interface**

**MFA Multi-factor authentication**

**E2EE End-to-end encryption**

**RBAC Role-Based Access Control**

**BPM Beats per minute**

**IEEE Institute of Electrical and Electronics Engineers**

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**CHAPTER – 1 INTRODUCTION**

**1.1 Project Overview**

The project aims to implement a 5G-enabled Patient Medical Record System (PMRS) in a hospital setting to revolutionize healthcare delivery by enhancing the efficiency, accuracy, and security of patient data management. This system will leverage the advanced capabilities of a 5G Local Area Network (LAN) to provide high-speed, low-latency access to patient records, ensuring that healthcare professionals have real-time information at their fingertips. This will facilitate seamless communication among healthcare providers and between providers and patients. The key components of the project include establishing a robust 5G network infrastructure, integrating the PMRS with existing hospital IT systems using Fast Healthcare Interoperability Resources (FHIR) standards, and developing a secure, personalized mobile application for patients.

The 5G network infrastructure will be established by installing small cells and edge computing resources within the hospital to ensure comprehensive coverage and low latency. Network slicing will be used to provide dedicated bandwidth for the PMRS, ensuring reliable performance. The system integration will involve developing APIs and webhooks for real-time data synchronization between the PMRS, mobile app, and other hospital systems, ensuring compatibility with existing electronic health records (EHR) and medical devices. The mobile app will be designed with a focus on security, usability, and personalization. It will feature multi-factor authentication (MFA) to ensure secure access, offline access to allow patients to view their records even without internet connectivity, and personalized health information, reminders, and notifications based on patient data. The app will also adhere to strict data security standards, implementing end-to-end encryption (E2EE) for all data transmitted between the app and PMRS, and Role-Based Access Control (RBAC) to restrict access to sensitive information based on user roles. Continuous monitoring and regular security audits will be conducted to detect and respond to potential security threats.

The expected outcomes of the project include enhanced healthcare efficiency through real-time access to accurate patient records, improved patient engagement and satisfaction

through personalized app experiences, stronger data security and privacy protection, seamless interoperability with existing hospital systems, and a scalable and reliable system capable of supporting future growth and technological advancements.

**1.2 Motivation**

The motivation for implementing a 5G-enabled Patient Medical Record System (PMRS) in a hospital setting stems from the need to enhance the efficiency, accuracy, and security of healthcare delivery. Traditional healthcare systems often struggle with slow data access, fragmented patient records, and security vulnerabilities, which can lead to delays in patient care and increased operational costs. By leveraging 5G technology, the project aims to provide high-speed, low-latency access to patient information, ensuring that healthcare professionals have real-time data at their fingertips, which is crucial for timely and informed decision-making. The introduction of a secure and personalized mobile app for patients further addresses the growing demand for patient-centric healthcare solutions. Modern patients expect seamless and secure access to their medical records, personalized health information, and real-time updates, which can significantly improve their engagement and satisfaction with the healthcare services they receive. Additionally, the ability to access records offline ensures continuity of care even in areas with poor connectivity. The healthcare industry is increasingly targeted by cyber threats, making data security and privacy paramount. Implementing end-to-end encryption, robust access controls, and continuous monitoring will safeguard sensitive patient information against unauthorized access and breaches, fostering trust among patients and compliance with stringent data protection regulations. Interoperability is another critical motivator. By adhering to standards such as FHIR and integrating the PMRS with existing electronic health record (EHR) systems and medical devices, the project aims to eliminate data silos, reduce redundancy, and facilitate seamless communication across different healthcare systems. This integration is essential for providing comprehensive patient care, reducing administrative burdens, and improving overall operational efficiency. Thus, the implementation of this project is motivated by the potential to transform healthcare delivery, making it more responsive, efficient, and patient-centred. With the rapid advancements in technology and increasing patient expectations, there is a pressing need for healthcare systems to evolve and adopt innovative solutions that can meet these demands. The 5G-enabled PMRS project represents a significant step toward achieving these goals, ultimately leading to better patient outcomes and a more effective healthcare system.

**1.3 Assumptions and Constraints**

Assumptions on which our project is based:

1. 5G Infrastructure Availability: The hospital has access to 5G infrastructure, either through a telecom provider or in-house deployment capabilities.
2. Technical Expertise: The hospital IT staff possess the necessary technical expertise to manage and maintain the 5G network and associated technologies.
3. Budget Allocation: Adequate budget is available for the deployment of 5G infrastructure, development of the mobile app, integration with existing systems, and ongoing maintenance.
4. Regulatory Compliance: The implementation adheres to relevant healthcare regulations and data protection laws.
5. Patient Engagement: Patients are willing to use the mobile app and have access to smartphones.
6. Existing Systems Compatibility: Current EHR systems and other healthcare IT systems support integration with the new PMRS through FHIR or other interoperable standards.

Constraints to consider include:

1. Network Coverage: Ensuring comprehensive 5G coverage within the hospital premises, including challenging areas such as basements and shielded rooms.
2. Data Security and Privacy: Strict adherence to data security and privacy regulations, requiring robust encryption, access controls, and continuous monitoring.
3. Interoperability: Achieving seamless interoperability with various existing systems and devices, some of which may be legacy systems with limited compatibility.
4. Cost: High costs associated with deploying 5G infrastructure, developing a secure and robust mobile app, and ensuring real-time synchronization and integration.
5. Latency and Reliability: Ensuring low latency and high reliability of the 5G network, especially for critical healthcare applications that require real-time data access and communication.
6. Scalability: The system must be scalable to accommodate future growth in the number of patients, devices, and data volume.
7. User Training: Training hospital staff and patients to effectively use the new system and mobile app, which may require significant time and resources.
8. Data Migration: Migrating existing patient records to the new PMRS without data loss or corruption.
9. Support and Maintenance: Establishing a robust support and maintenance framework to address technical issues promptly and ensure system uptime.

**1.4 Novelty of Work**

The novelty of the 5G-enabled Patient Medical Record System (PMRS) lies in its integration of advanced 5G technology with healthcare data management to create a highly efficient and secure system.

Key innovations include:

1. 5G Integration: Utilizing high-speed, low-latency 5G connectivity with network slicing ensures reliable performance and real-time access to patient records.
2. Real-Time Synchronization and Interoperability: Employing FHIR standards and APIs for seamless data exchange and real-time updates, enhancing interoperability with existing EHR systems.
3. Secure and Personalized Mobile App: Featuring multi-factor authentication, offline access, and personalized health information, improving patient engagement and security.
4. Advanced Security Measures: Implementing end-to-end encryption and role-based access control to protect patient data and ensure privacy.
5. Comprehensive Coverage and Scalability: Deploying small cells and edge computing for thorough 5G coverage and designing the system to be scalable and future-proof, supporting emerging healthcare technologies. These elements collectively advance healthcare delivery by ensuring faster, more secure, and patient-centric management of medical records.

**CHAPTER – 2 LITERATURE SURVEY**

**2.1 Literature Survey**

***2.1.1 5G Technology in Digital Transformation of healthcare: A Systematic Review***

5G technology is revolutionizing the digital transformation of healthcare by offering significantly enhanced data transmission, which is crucial for real-time health monitoring and telemedicine. The improved data speed and reliability provided by 5G allow for the seamless transmission of large amounts of data, reducing latency and improving the quality of telehealth services. This enables the development and deployment of comprehensive health monitoring systems and supports advanced applications such as remote surgical procedures, including the use of robotic systems that require high precision and real-time feedback. The low latency and high reliability of 5G networks make these advanced medical applications possible. Furthermore, the enhanced connectivity provided by 5G facilitates various medical advancements, supporting the aggregation and analysis of big data in medical research, enabling faster diagnosis through real-time imaging, and improving patient care through telemedicine consultations. These capabilities collectively enhance medical research, diagnosis, and treatment, leading to improved patient outcomes and a more efficient healthcare system. [1]

***2.1.2 Low-Cost, Non-Invasive Continuous Vital Signs Monitoring Device for Pregnant Women in Low-Resource Settings***

Dese, Ayana, and Simegn (2022) developed an affordable, non-invasive monitoring device called Lvital, specifically designed to track vital signs in pregnant women in low-resource areas. The device monitors blood pressure, pulse rate, and body temperature, utilizing cuffless technology that eliminates discomfort and allows continuous monitoring. Its low production cost and solar-powered design make it particularly suitable for rural settings with limited access to healthcare. The Lvital device uses an Arduino microcontroller paired with sensors to measure these vital signs, and it includes a GSM module to alert caregivers if abnormal readings are detected. This feature enhances early diagnosis and prompt medical response, addressing the lack of affordable and accessible healthcare technologies in underserved regions​. The authors compare Lvital with existing smart bands and commercial monitoring devices, noting that while consumer-grade devices often lack clinical accuracy, Lvital provides reliable and continuous monitoring at a significantly lower cost. Additionally, the device’s integration of solar charging and its compact, portable design improve its applicability in regions with scarce medical resources. The study underscores the device’s potential to reduce maternal and neonatal mortality by enabling timely medical interventions, showcasing an innovative approach to healthcare delivery in economically constrained environments. [2]

***2.1.3 5G Technology for Healthcare: Features, Serviceable Pillars, and Applications***

The core features of 5G technology, such as high-speed data transmission, low latency, and reliable connectivity, are pivotal for advancing healthcare applications according to the article. These attributes enable rapid and dependable communication, essential for delivering advanced healthcare services. 5G supports key pillars of healthcare services including remote patient monitoring, telemedicine, and robotic surgery, which are critical for modern healthcare delivery. Remote patient monitoring allows continuous monitoring of patient health metrics outside traditional healthcare settings, while telemedicine facilitates virtual consultations, enabling healthcare providers to reach patients regardless of geographical barriers. Additionally, 5G's capability to support robotic surgery enhances precision and enables real-time feedback, improving surgical outcomes. Overall, by facilitating real-time monitoring and advanced technological solutions, 5G enhances healthcare delivery by providing timely and accurate medical interventions, which are crucial in both emergency and chronic care scenarios. This technological advancement holds promise for improving patient outcomes and transforming the efficiency of healthcare services. [3]

***2.1.4 5G Technology in Healthcare and Wearable Devices: A Review***

5G technology is facilitating significant advancements in healthcare by enabling the integration of wearable devices for continuous health monitoring. This capability is particularly beneficial in managing chronic diseases, as wearable devices can collect and transmit health data in real-time. This real-time data allows for proactive health management and timely medical interventions, improving overall patient outcomes. The versatility of 5G extends beyond wearable devices to various healthcare applications such as remote monitoring, robotic surgery, and infectious disease management. These applications demonstrate 5G's potential to transform healthcare delivery by enhancing efficiency and expanding access to specialized medical services. Moreover, 5G technology offers cost-saving benefits by providing healthcare providers with real-time access to data, enabling better clinical decision-making, reducing the need for in-person visits, and optimizing the utilization of healthcare resources. Overall, 5G is poised to revolutionize healthcare by improving patient care, streamlining processes, and advancing medical capabilities across diverse healthcare settings. [4]

***2.1.5 5G and AI in Real-Time Diagnostics***

In their research, Ma, Zhang, and Wang (2020) emphasize how 5G technology’s high-speed data transfer and low latency enable real-time diagnostic processes when combined with artificial intelligence (AI). This study explains that traditional healthcare networks often suffer from delays in data transmission, limiting the effectiveness of real-time diagnostics. The authors argue that with 5G, large-scale medical data can be processed instantly, allowing for faster and more accurate diagnostic results. They propose that the integration of AI with 5G technology can analyze data continuously and adjust treatment plans based on patient response in real time. This application has been shown to be particularly impactful in critical care, where quick diagnostics can be lifesaving. Their work contributes significantly to understanding how AI-enhanced 5G diagnostics can reduce decision-making delays, improve patient outcomes, and streamline workflows for healthcare providers​. [5]

***2.1.6 Applications of 5G in Wearable Health Monitoring***

According to Liu and Bai (2019), 5G technology holds substantial potential for wearable health-monitoring devices by facilitating real-time data transmission essential for chronic disease management. Their research highlights that wearable devices, when integrated with a 5G network, can transmit critical health data such as heart rate, oxygen levels, and blood pressure to healthcare providers instantly. This capability allows for timely medical interventions and continuous health monitoring, which is especially valuable for patients with chronic illnesses who require constant supervision. Additionally, the authors discuss the benefits of 5G's scalability and reliability, which are essential for supporting the high data volume generated by multiple wearable devices. This integration minimizes the need for frequent in-person visits, optimizing both healthcare resources and patient convenience​. [6]

***2.1.7 Enhancing Telemedicine with 5G Technology***

Kshetri (2018) explores the transformative impact of 5G on telemedicine by focusing on the stability and speed of 5G connections in providing healthcare services. The study underscores how 5G connectivity can help bridge the gap between rural and urban healthcare facilities by facilitating high-quality telemedicine consultations. Kshetri suggests that, through 5G-enabled telemedicine, patients in underserved or geographically remote areas gain better access to healthcare services, leading to improved health outcomes and reduced health disparities. With lower latency and greater bandwidth, 5G provides an uninterrupted video and data-sharing experience, making it easier for healthcare providers to diagnose and treat patients remotely. This accessibility transforms telemedicine into a viable solution for more widespread healthcare delivery​. [7]

***2.1.8 Security Protocols for 5G in Healthcare Applications***

Chen and Zhao (2014) provide a detailed analysis of the security protocols necessary for implementing 5G in healthcare. The paper addresses specific security challenges associated with 5G technology, such as the high volume of interconnected devices and the sensitive nature of patient data. The authors identify several robust encryption techniques, such as AES-256, which can secure both data storage and transmission, ensuring compliance with data protection regulations. They also highlight the importance of multi-factor authentication and role-based access controls (RBAC) for maintaining data privacy within a healthcare ecosystem. By adopting these protocols, healthcare organizations can better protect patient information and maintain system integrity, even in environments where data is continuously exchanged across devices and platforms. This research contributes to the ongoing discussion on enhancing data security and privacy in 5G-enabled healthcare systems​. [8]

**2.2 Research Gaps**

* ***Integration Challenges:*** There are significant challenges in integrating 5G technology with existing healthcare systems and workflows. Understanding how to seamlessly incorporate 5G into current practices without disrupting operations is a crucial area that requires further research.
* ***Standardization and Regulation:*** There is a lack of standardized protocols and regulations for the use of 5G in healthcare. This gap leads to uncertainties regarding data security, privacy, and interoperability. Developing comprehensive guidelines and standards is essential to ensure the safe and effective use of 5G technology in healthcare.
* ***Accessibility and Equity:*** The literature often does not fully address issues related to accessibility and equity. Ensuring that 5G-enabled healthcare solutions are accessible to underserved populations and do not exacerbate existing healthcare disparities is critical. Research should focus on how to make these technologies available and affordable for all segments of the population.
* ***Reliability of 5G in Emergency Settings:*** There is limited research on the reliability of 5G networks in critical healthcare settings, especially during emergencies where network stability is crucial. Further studies are needed to explore how 5G’s capabilities hold up under high-stress conditions and if additional measures are needed for redundancy.
* ***Impact of Latency Variability on Data Transmission:*** While 5G promises low latency, fluctuations in latency could impact Data Transmission rates. Research into consistent low-latency performance across different healthcare environments can help mitigate risks in real-time applications.
* ***Data Privacy Concerns with Interconnected Devices:*** Interconnected devices in a 5G healthcare setup increase data security concerns. Research needs to address the vulnerabilities associated with device intercommunication and identify ways to enhance end-to-end encryption and authentication.

**2.3 Problem definition and scope**

* **Identify Gaps in Current Patient Monitoring Technologies:** Evaluate existing patient monitoring systems to pinpoint inefficiencies and areas for improvement. Develop solutions that leverage 5G technology to enhance these systems.
* **Meet the Increasing Demand for Continuous, Real-Time Health Monitoring:** Design and implement 5G-enabled monitoring solutions that provide continuous, real-time health data. These solutions should be capable of supporting proactive and preventative healthcare practices.
* **Ensure Applicability Across Diverse Healthcare Settings:** Develop 5G healthcare solutions that are adaptable to various settings, including hospitals, clinics, and home care. This ensures a broad impact and usability across different healthcare environments.
* **Integrate Seamlessly with Existing Healthcare Infrastructure for Enhanced Interoperability:** Focus on creating 5G solutions that can be easily integrated with current healthcare infrastructures. This includes ensuring compatibility with existing electronic health records (EHR) systems and other healthcare technologies.
* **Enhance Patient Safety and Data Security Through Advanced Measures and Personalized Care:** Implement advanced security measures to protect patient data and ensure privacy. Additionally, develop personalized care solutions that leverage the high-speed and low-latency capabilities of 5G to provide tailored healthcare interventions.

**CHAPTER – 3 PROBLEM FORMULATION AND OBJECTIVES**

**3.1 Problem Formulation**

The current healthcare infrastructure faces numerous challenges in managing patient medical records efficiently and securely. Traditional systems often struggle with real-time data synchronization, interoperability between different hospital systems, and ensuring the security of sensitive medical information. This results in delays in decision-making, inefficiencies in patient care, and vulnerabilities in data protection. Moreover, the increasing complexity of healthcare services and the growing demand for telemedicine and remote patient monitoring call for an enhanced system that can provide real-time data access, secure communication, and seamless integration with existing healthcare infrastructure.

With the advent of 5G technology, there is an opportunity to address these challenges through a 5G-enabled Patient Medical Record System (PMRS). This system aims to leverage high-speed, low-latency communication to provide seamless data sharing, robust security, and enhanced interoperability across hospital networks, enabling better healthcare delivery. However, developing such a system requires overcoming integration challenges, ensuring data security, and meeting regulatory standards for privacy and interoperability.

**3.2 Objectives**

1. ***Develop a 5G-Enabled Patient Medical Record System (PMRS):***

Design and implement a system that leverages the high-speed, low-latency capabilities of 5G technology to enhance the efficiency and accuracy of patient record management in real-time.

1. ***Ensure Seamless Interoperability:***

Integrate the PMRS with existing hospital management systems, including Electronic Health Records (EHR) and Electronic Medical Records (EMR), to ensure smooth data flow and interoperability between different systems.

1. ***Enhance Data Security and Privacy:***

Implement robust security measures such as end-to-end encryption, biometric authentication, and multi-factor authentication to protect patient data. Ensure compliance with healthcare regulations, such as HIPAA (Health Insurance Portability and Accountability Act), for data security and privacy.

1. ***Enable Real-Time Health Monitoring and Data Synchronization:***

Utilize wearable sensors and biometric devices to collect and transmit real-time health data to the cloud. Ensure real-time synchronization of patient records across devices and healthcare providers to support continuous patient monitoring and proactive healthcare interventions.

1. ***Develop a User-Friendly Mobile and Web Interface:***

Create secure, intuitive mobile and web applications for patients and healthcare providers to access and manage patient records. Incorporate real-time alerts and visualizations to improve patient engagement and healthcare outcomes.

1. ***Facilitate Scalable and Efficient Hospital Operations:***

Utilize cloud computing and IoT standards to ensure the system is scalable, supporting a large number of connected devices while maintaining efficiency in data processing and storage.

1. ***Address Standardization and Compliance Challenges:***

Follow IEEE and healthcare industry standards for communication, device integration, and network security to ensure the PMRS is compliant with international regulations and can be adopted across various healthcare settings.

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#### CHAPTER-4 PROJECT DESIGN AND DESCRIPTION

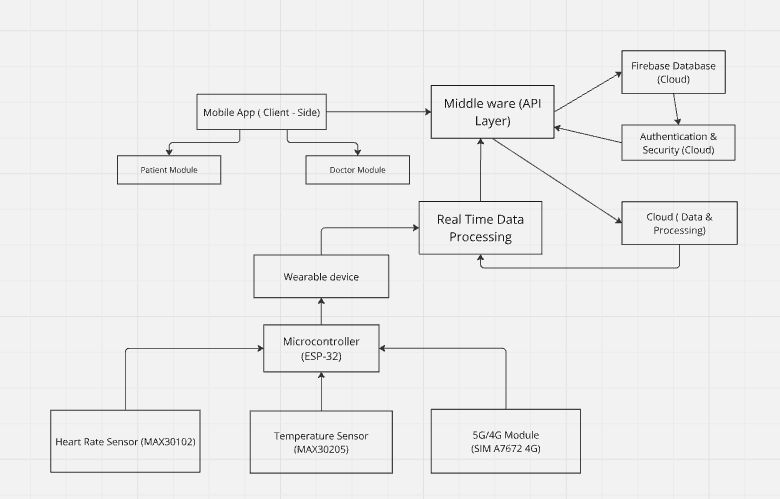
#### 4.1 Description

The project aims to implement a 5G-enabled Patient Medical Record System (PMRS) in hospital settings to enhance the efficiency and effectiveness of patient care. The first step involves establishing a high-speed and low-latency 5G network to ensure seamless communication across the hospital. A secure and personalized mobile app will be developed for patients, featuring robust authentication methods such as biometrics and multi-factor authentication, as well as offline access capabilities. To safeguard data security and privacy, end-to-end encryption will be implemented alongside strict access controls and compliance with regulations. The overall goal is to create a reliable, user-friendly, and secure PMRS that enhances patient engagement and improves healthcare delivery.

**4.2 System Architecture**

The system architecture for this project involves multiple interconnected modules, each performing specific functions within the 5G-enabled Personal Mobile Rescue System (PMRS). The architecture can be divided into hardware, software, and communication layers.

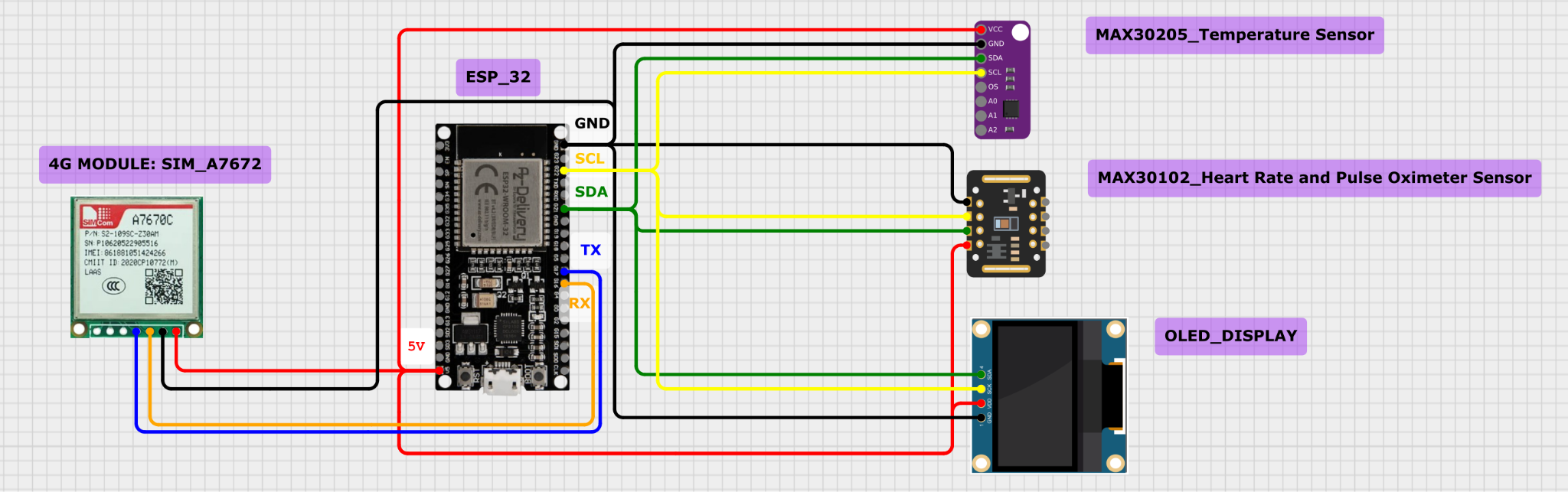
* ***Hardware Layer:*** This consists of wearable sensors for vital sign monitoring, such as heart rate, temperature, and SpO2 sensors. The sensors are integrated with a microcontroller, which processes the data before transmitting it to the cloud.
* ***Software Layer:*** The software layer includes the real-time operating system (RTOS) running on the microcontroller, responsible for managing data acquisition and control. Additionally, a mobile application is developed to interface with users and medical professionals, providing an intuitive GUI for data visualization.
* ***Communication Layer:*** Data from the wearable device is transmitted via 5G small cells to cloud servers. The low latency of the 5G network ensures real-time updates, which are essential for critical healthcare applications.



***Fig: Block Diagram***

**4.3 Hardware Design and Components**

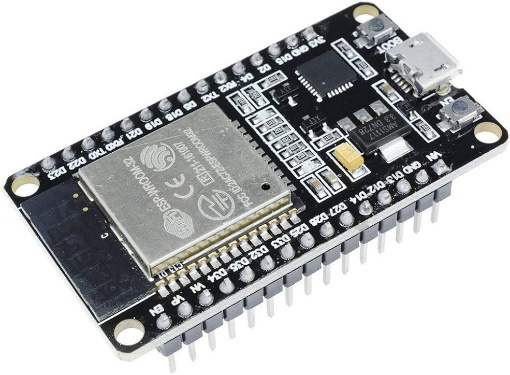
The hardware for this project includes both sensing and communication components. Each component is carefully selected based on power efficiency, accuracy, and compatibility with the system requirements.

* ***Wearable Sensors:*** The core components include a PPG sensor for heart rate, an NTC thermistor for temperature monitoring, and a pulse oximeter sensor for SpO2 readings. These sensors are connected to the nRF52832 microcontroller, which is chosen for its low power consumption and BLE/5G communication capabilities.
* ***Microcontroller:***The nRF52832 also has onboard temperature sensing and edge processing capabilities. It collects and processes data from the sensors in real time, minimizing communication load.
* ***Power Management:*** A rechargeable lithium-ion battery powers the wearable unit, ensuring the system can operate continuously for extended periods. A power management IC regulates battery usage, optimizing the device for low-power consumption. The compact design of the wearable device ensures that it remains lightweight and user-friendly, essential for continuous use in healthcare monitoring.

***Fig: Circuit Diagram***

***HARDWARE COMPONENTS USED :***

1. **ESP32** : The ESP32 is a versatile, low-cost microcontroller with built-in Wi-Fi and Bluetooth, widely used in IoT projects and embedded systems. Developed by Espressif Systems, it features a dual-core processor, 520 KB SRAM, and supports various peripherals through 34 GPIO pins, making it highly adaptable for connecting sensors and external devices.



***Fig 4.3.2 : ESP32 [1]***

1. **Heart Rate and Pulse Sensor** : The MAX30102 heart rate and pulse sensor uses red and infrared LEDs to emit light into the skin and measures reflected light changes with a photodetector. Variations in absorption, caused by blood flow changes with each heartbeat, enable it to calculate heart rate and estimate blood oxygen (SpO2) levels. This compact sensor is ideal for low-power, continuous monitoring in wearable devices.



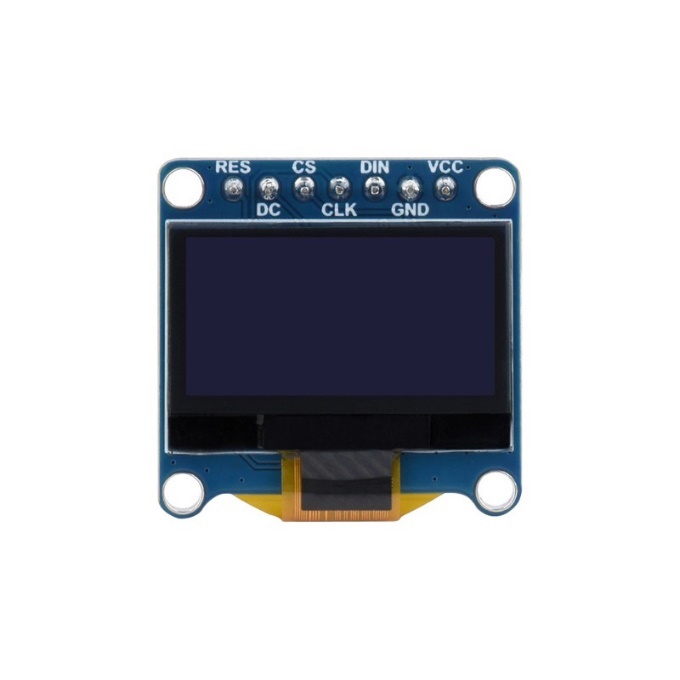
***Fig 4.3.3 : Max30102 Heart Pulse Sensor [2]***

1. **Temperature Sensor:**.The MAX30205 is a highly accurate digital temperature sensor, ideal for body temperature measurement in health and wearable devices. It operates within 0°C to 50°C with ±0.1°C accuracy, using I2C for data communication. It features an over temperature alert function and low power consumption, making it perfect for portable and battery-powered applications.

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***Fig 4.3.4 : Max30205 temperature sensor [3]***

1. **OLED display module:** It uses the I2C interface, indicated by the GND, VDD, SCK, and SDA pins, and is commonly used with microcontrollers like ESP32 or Arduino to display real-time data or messages. Its compact size and low power consumption.



***Fig 4.3.5 : OLED Display [4]***

1. **4G Module :** The A70760C is a 4G LTE module that supports high-speed data transmission with download speeds up to 150 Mbps. It offers multi-band LTE for global use, GNSS for location tracking, and interfaces like UART and USB for easy integration with microcontrollers. Its low power consumption makes it ideal for IoT applications such as asset tracking, smart meters, and remote monitoring.



***Fig 4.3.6 : 4G Module [5]***

#### 4.4 SOFTWARE ARCHITECTURE

The 5G-Powered Patient Monitoring System’s software architecture is crafted to ensure smooth interactions between patients, healthcare providers, and backend systems. Key priorities include high performance, data security, scalability, and ease of use. Built in Java for Android with an XML front end, the system uses Firebase for real-time data management and secure data exchange. It also integrates wearable devices and predictive analytics to enhance proactive healthcare.

### ***CORE COMPONENTS:***

1. **Client-Side (Mobile Application)**
   * **Patient Module**: This Android module enables patients to register, log in, book and cancel appointments, view history, and monitor their health data. Real-time data is displayed through a user-friendly interface.
   * **Doctor Module**: Provides healthcare providers with access to patient information, appointment scheduling, and real-time monitoring data, supporting timely medical interventions.
2. **Backend (Firebase Database)**
   * **Database**: Firebase serves as a real-time, scalable database for patient records, appointment history, and health data, ensuring up-to-date information for both patients and providers.
   * **Authentication and Security**: Firebase Authentication manages secure login and access control, with encryption to protect patient privacy and ensure regulatory compliance.
3. **Middleware (API Layer)**
   * **Data Handling**: This layer connects the mobile app, Firebase, and wearable devices, managing real-time data updates and secure transmission.
4. **Wearable Device Integration**: Wearable devices transmit real-time data on vital signs like heart rate and blood pressure, continuously syncing with the backend to support ongoing patient monitoring.

**4.5 UG COURSES REFERRED**

1. IoT Systems
2. Data Science
3. Computer Networks
4. Cloud Computing
5. Analog and Digital Communication
6. Electronics

#### 4.6 STANDARDS USED

#### 1. IEEE 802.11ax (Wi-Fi 6) : Provides efficient, high-speed wireless communication essential for handling large volumes of patient data, supporting real-time video consultations, and ensuring reliable connectivity throughout the hospital network. [14]

#### 2. IEEE 802.15.4 : Enables low-rate wireless personal area networks (LR-WPANs) suitable for IoT devices within hospitals, offering low power consumption, reliable short-range communication, and ensuring continuous data transmission for devices like wearable health monitors. [15]

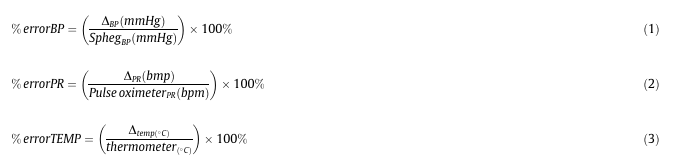
#### 3. IEEE 11073 : Defines standards for medical device communication, ensuring interoperability among various medical devices integrated into the Patient Medical Record System (PMRS), supporting real-time data exchange critical for medical interventions and accurate record-keeping. [16]

#### 4. IEEE 802.1X : Provides port-based network access control with authentication mechanisms, ensuring only authorized devices and users can access the network, thus protecting sensitive patient data through dynamic key management and integration with security protocols like RADIUS. [17]

#### 5. IEEE 2413 : Establishes an architectural framework for IoT, supporting scalability and interoperability of numerous IoT devices in hospital environments, while also providing guidelines for implementing security and privacy measures to protect patient data. These standards collectively contribute to the efficiency, security, interoperability, and scalability necessary for modern healthcare infrastructures, ensuring enhanced patient care and operational effectiveness within hospitals. [18]

**4.7 IMPLEMENTATION RESULT**

To validate the accuracy of the developed patient monitoring device, 20 volunteers participated in testing their blood pressure, pulse rate, and body temperature using the prototype device. Each measurement was then compared against a reference device: a sphygmomanometer for blood pressure, a pulse oximeter for pulse rate, and a thermometer for body temperature.

The results of the one-time measurements for the 20 volunteers are presented in Table 1.

……. (1)

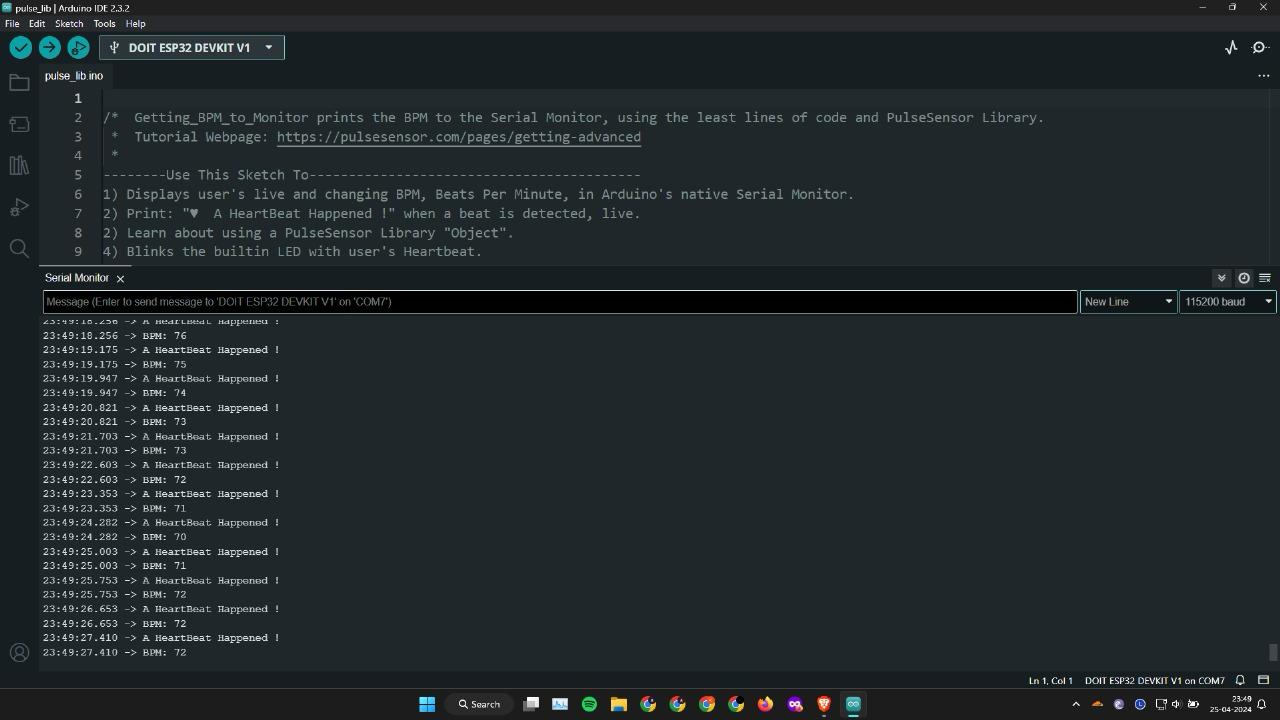
……..(2)

Using Equations 1 and 2, the percentage error for each of the two parameters was calculated by comparing the prototype device’s readings to those of the reference devices, thereby determining the accuracy of the developed device.

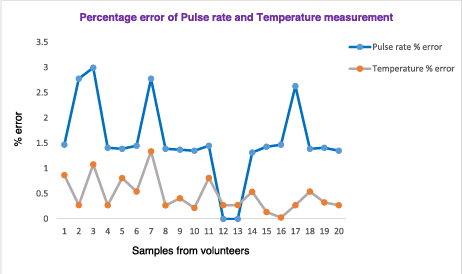
Furthermore, the Figure below presents the calculated percentage errors for pulse rate and temperature measurement, illustrating the comparative accuracy of the prototype device against the gold-standard device, pulse oximeter, and thermometer respectively. This analysis provides insights into the prototype's reliability and alignment with established medical measurement standards.

When the pulse rate beat and temperature reading were 60 beats per minute, and 36.5 C respectively, first the alarm was automatically triggered to make an alert. Then later on after a minute, the GSM modem triggered and sent an alert to the doctor’s dashboard app.

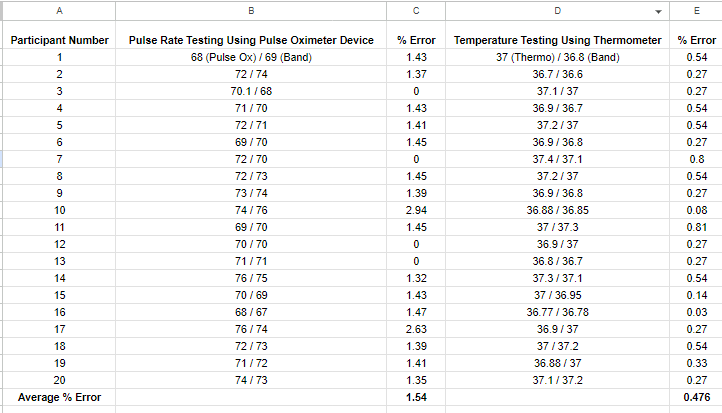
As per Table 1,the prototype device demonstrates a high level of accuracy for both pulse rate and temperature measurements, with an average error of 1.54% for pulse rate and 0.476% for temperature, indicating strong performance across different test cases. The low variation in error rates suggests consistent reliability in readings, making the device dependable for multiple users.

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***Fig: Heart rate and pulse sensor simulation result***

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***Fig: %error of Pulse rate and temperature measurement***

 ***Table* *1*: *Comparison of our device performance level with gold standard methods.***

**CHAPTER- 5 OUTCOMES AND PROSPECTIVE LEARNING**

**5.1 OUTCOME**

The outcomes of the 5G-Powered Patient Monitoring System project highlight significant improvements in patient care, healthcare delivery efficiency, and data security. The following are the key outcomes achieved:

1. Enhanced Real-Time Patient Monitoring: The integration of wearable devices and 5G connectivity allows continuous, real-time monitoring of vital signs, enabling healthcare providers to detect and respond quickly to critical health conditions. This significantly reduces the risk of severe medical events and improves patient outcomes.
2. Improved Patient Safety: Real-time alerts and predictive analytics empower healthcare providers to intervene proactively, enhancing patient safety through timely responses to potential health issues before they escalate.
3. Streamlined Healthcare Delivery: The seamless data exchange facilitated by the system reduces administrative workload, allowing healthcare providers to focus more on patient care. This efficiency in communication and data synchronization results in better resource management within healthcare facilities.
4. Personalized Healthcare Experiences: The system enables customized health insights and recommendations for each patient, helping providers develop personalized treatment plans. This personalization enhances patient satisfaction and contributes to better health outcomes.
5. Cost Reduction: Early detection and preventive interventions minimize the need for expensive emergency treatments and hospitalizations, reducing overall healthcare costs and improving system sustainability.
6. Data Security and Compliance: The system incorporates robust end-to-end encryption and secure access controls, ensuring patient data is well-protected and complies with healthcare regulations. This focus on data security enhances patient trust and aligns with industry standards.
7. Scalability and Versatility: Designed with scalability in mind, the system can be implemented in various healthcare settings—hospitals, clinics, or even at-home care—demonstrating adaptability and broad applicability across the healthcare sector.

These outcomes underscore the project’s contribution to transforming healthcare delivery through innovative 5G-powered technology, setting a foundation for more efficient, secure, and patient-centric healthcare solutions.

**5.2 PROSPECTIVE LEARNING**

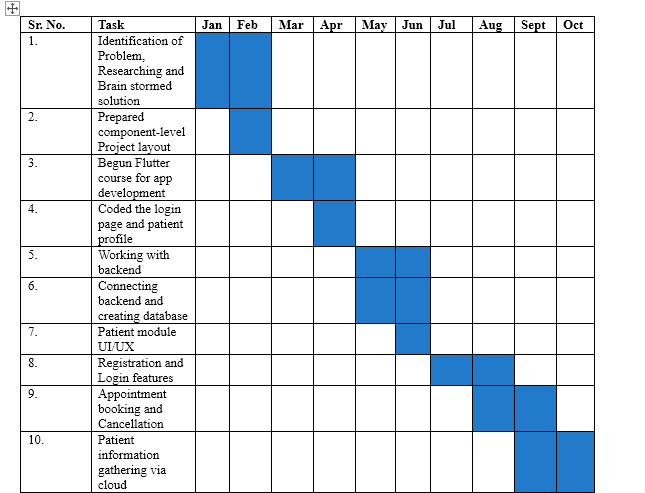
The development and implementation of the 5G-Powered Patient Monitoring System provide valuable learning opportunities that contribute to technical expertise and practical healthcare innovation. The following key areas of learning are anticipated:

1. **Advanced Application of 4G Technology**: A deeper understanding of 5G’s capabilities, particularly its high-speed, low-latency data transmission, and its impact on real-time healthcare monitoring. This experience highlights the potential of 5G to revolutionize connectivity in healthcare and other data-intensive sectors. [19]
2. **Integration of Wearable Health Monitoring Devices**: Exposure to the technical challenges and solutions related to integrating wearable devices with a centralized patient monitoring system, including data synchronization, device connectivity, and real-time data transmission. This learning is crucial for applications involving IoT in healthcare.
3. **Predictive Analytics and Data Insights**: Hands-on experience with developing and deploying predictive algorithms that analyse health data to provide proactive healthcare insights. Understanding how predictive models can enable early intervention for patients will enhance future applications in preventive healthcare.[20]
4. **Data Security in Healthcare Systems**: Gaining expertise in implementing robust data security measures, such as encryption and access control, in line with healthcare regulations (e.g., HIPAA, GDPR). This experience provides valuable knowledge for managing sensitive data and ensuring privacy in future healthcare or data-driven projects.
5. **User-Centric Mobile Application Development**: Learning the importance of creating intuitive and accessible mobile applications that meet the specific needs of patients and healthcare providers. This involves designing for usability and ensuring smooth, secure access to health data, which contributes to user satisfaction and engagement. [21]
6. **Cloud and Real-Time Data Management**: Experience with cloud services like Firebase for real-time data storage and management, which is invaluable for understanding how cloud-based infrastructure can enhance data accessibility, scalability, and efficiency in healthcare applications. [22]
7. **Interdisciplinary Knowledge in Healthcare Technology**: Developing a broader understanding of the intersection between healthcare and technology, especially around patient care workflows, regulatory compliance, and the challenges in adopting digital health solutions within traditional healthcare systems. [23]

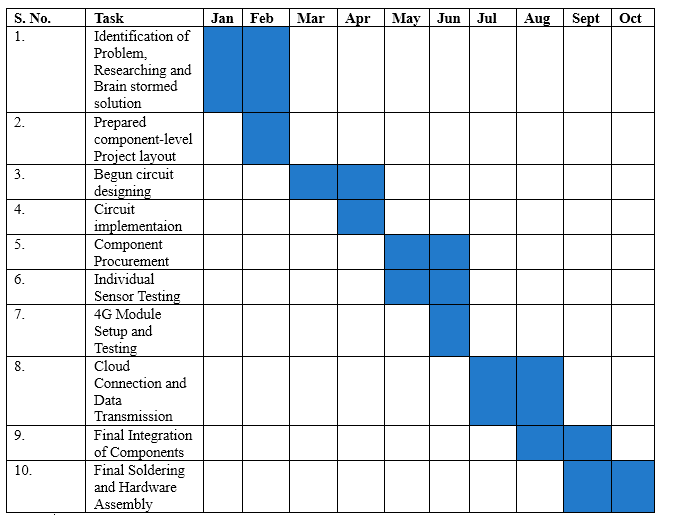
These learnings collectively enrich technical, analytical, and practical skills, equipping the team with the knowledge necessary to tackle future challenges in digital healthcare and related field.

**6.2 Individual Plan**

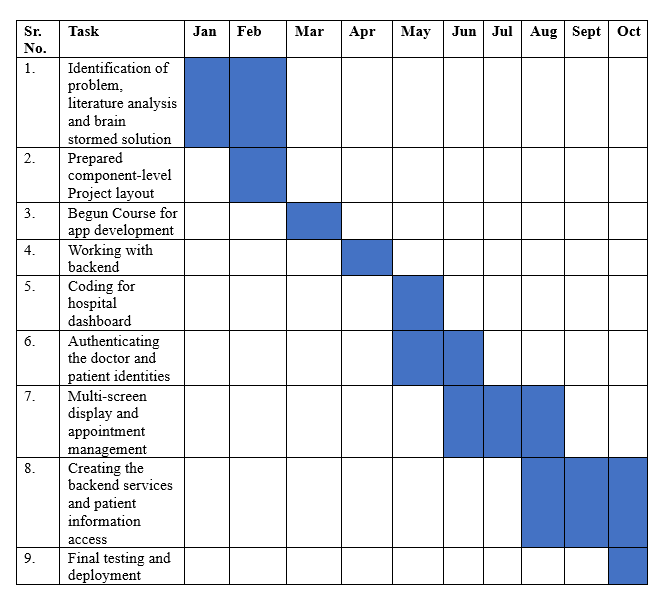
1. **Anisha Sinha**

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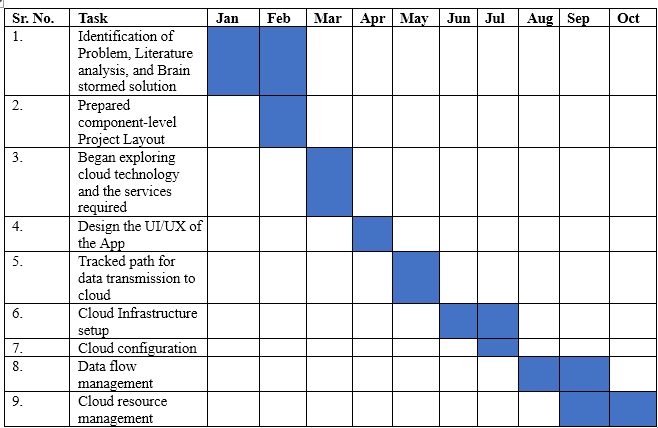
1. **Kartikay Shori**

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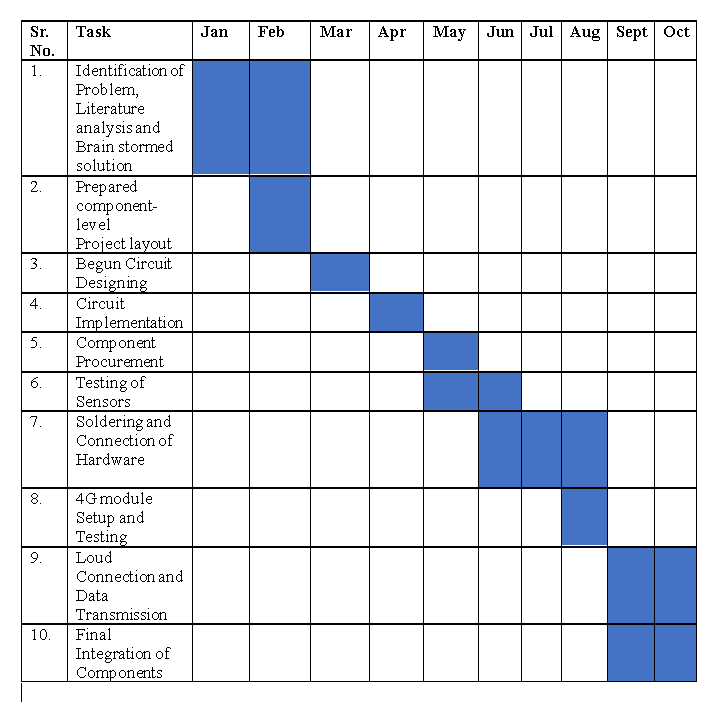
1. **Pulkit Garg**



1. **Surya Partap Mittal**



1. **Riya Khera**

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**CHAPTER-7 CONCLUSION AND FUTURE WORK**

**7.1 CONCLUSION:**

The project "Empowering Personalized Care: A 5G-Powered Patient Monitoring System" successfully demonstrates the potential of integrating 5G technology into healthcare to enhance patient monitoring, provide real-time insights, and improve overall medical care. The system, developed in Java with a Firebase backend and an XML-based Android front-end, offers seamless functionality across the patient and doctor modules. Through key features such as patient registration, login, appointment booking and cancellation, appointment history, and real-time patient information gathering, the platform enables effective, personalized care.

By leveraging 5G's high-speed and low-latency capabilities, the system ensures that critical health data is instantly available, supporting proactive decision-making by healthcare providers. The integration of wearable devices further strengthens the platform’s ability to monitor vital signs and generate real-time alerts. Robust security measures, backed by Firebase, ensure the protection of sensitive health data, complying with healthcare industry standards and regulations.

The outcomes achieved through this project include enhanced patient-doctor interactions, improved healthcare delivery efficiency, and a more personalized healthcare experience. Patients are empowered to manage their health records, appointments, and medical history, while doctors gain a comprehensive view of their patients' health status for better-informed decision-making.

### **7.2 FUTURE WORKS**

While this project lays a strong foundation for revolutionizing patient care through 5G technology, several future enhancements can further empower personalized care:

1. **AI-Driven Predictive Analytics**: Future iterations could incorporate AI algorithms to predict patient health trends based on historical data, allowing healthcare providers to intervene early and offer preventative care. [24]
2. **Advanced Wearable Integration**: Expanding the system to support more advanced wearable devices for a broader range of vital signs, such as glucose monitoring, oxygen levels, and stress indicators, would deepen real-time monitoring capabilities. [25]
3. **Telemedicine Integration**: Including telemedicine functionalities, such as video consultations and remote diagnostics, would provide a comprehensive digital healthcare experience for patients, particularly for those in remote areas. [26]
4. **Multi-Language Support**: Incorporating support for multiple languages within the mobile app would enhance accessibility for non-English speakers, improving patient engagement across diverse demographics. [27]
5. **Machine Learning for Appointment Scheduling**: Implementing machine learning algorithms to optimize doctor appointment schedules based on patient preferences, urgency, and historical data would further streamline the healthcare process. [28]
6. **Blockchain for Data Security**: Exploring blockchain technology for more robust patient data security and transparency could increase trust and ensure better compliance with healthcare data regulations. [29]
7. **Cross-Platform Compatibility**: Developing an iOS version of the mobile application to extend the system’s reach across a broader range of users could increase adoption rates and improve patient accessibility. [30]

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**APPENDICES**

**APPENDIX I**

**Detailed Calculations for Network Deployment**

This appendix provides a comprehensive breakdown of the detailed calculations used for deploying the 5G network infrastructure in the project. The calculations include the necessary bandwidth, latency requirements, and cell coverage to ensure optimal performance for the Patient Medical Record System (PMRS).

1. **Bandwidth Calculation**The bandwidth required for real-time data transmission of patient records was calculated using the following equation:  
   Bandwidth=Total data size/Transmission = (500MB / 0.5seconds) = 800Mbps  
   This ensures low-latency access to medical records in real-time.
2. **Latency Estimation**To maintain seamless real-time communication between the wearable devices and the PMRS, the estimated latency should not exceed 5 ms. This was determined based on previous research on 5G network performance in healthcare applications.
3. **Cell Coverage Calculation**For effective hospital-wide coverage, small cells were installed based on the following calculation: Coverage area per cell = Hospital area / Number of cells=10000 / 50=200 m2

**APPENDIX II**

**Wearable Device Data Analysis**

This section provides raw experimental observations collected from wearable devices. Data includes continuous monitoring of vital signs such as blood pressure, heart rate, and body temperature.

1. **Blood Pressure Monitoring**Data from the wearable device during testing revealed the following results:
   * **Patient A:**
     + **Resting BP:** 120/80 mmHg
     + **Post-activity BP:** 140/85 mmHg
2. **Heart Rate Monitoring**
   * **Patient A:**
     + **Resting HR:** 72 bpm
     + **Post-activity HR:** 110 bpm
3. **Temperature Readings**Temperature monitoring was consistent, with the wearable device measuring an average body temperature of 37°C.

**APPENDIX III**

**Algorithm for Predictive Analytics**

The following is the algorithm implemented for predictive analytics in the PMRS to anticipate patient health issues:

*Algorithm Predictive Analytics*

*Input: Real-time health data (HeartRate, BloodPressure, Temperature)*

*Output: Health alerts for proactive intervention*

*Step 1: Collect continuous data from wearable sensors.*

*Step 2: Apply moving average filter to smooth noisy data.*

*Step 3: Use historical data to identify patterns indicating potential health issues.*

*Step 4: If abnormal patterns are detected, generate health alerts.*

*End Algorithm*

**APPENDIX IV**

**Data Security and Privacy Measures**

This appendix outlines the data security and privacy measures adopted in the 5G-enabled PMRS to ensure compliance with healthcare regulations.

1. **Encryption Techniques**All patient data is encrypted using AES-256 during both storage and transmission. This ensures confidentiality and protection against unauthorized access.
2. **Role-Based Access Control (RBAC)**RBAC was implemented to ensure that only authorized personnel could access sensitive patient data. Permissions are assigned based on roles such as doctors, nurses, and IT staff.
3. **Regular Security Audits**Security audits are conducted quarterly to identify potential vulnerabilities in the system. Any identified issues are promptly addressed to maintain compliance with healthcare security standards.