SMART WHEELCHAIR

TERM PROJECT REPORT

21ES614 - INTERNET OF THINGS

Submitted by

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Chapter 1

Introduction

The rapid advancement of the Internet of Things (IoT) and embedded systems has opened new opportunities in the healthcare domain, especially in assisting individuals with mobility challenges. Traditional wheelchairs, although effective in basic mobility, lack intelligent features such as access control, health monitoring, obstacle detection, and real-time feedback. With the increasing elderly population and physically disabled individuals who require not only mobility but also continuous health supervision, there is a growing need for an intelligent, secure, and health-aware wheelchair system.

This project introduces a Smart Wheelchair System, an IoT-based solution designed to improve the quality of life and ensure safety for patients or individuals who rely on wheelchairs for mobility. The system is composed of multiple interconnected nodes, each responsible for specific tasks and functions. It includes a pulse sensor to monitor the user's heart rate, an RFID-based access control to ensure that only authorized users can operate the wheelchair, an ultrasonic sensor with a servo to detect obstacles in various directions, and an MPU6050 accelerometer for fall detection by monitoring tilt angles.

Communication between these components is achieved using the MQTT protocol, which ensures efficient and reliable data transmission across the network. The EDGE NODE acts as the central decision-making unit, processing incoming data from sensors and publishing control commands to actuator nodes. Additionally, all critical information such as RFID data, pulse rate, fall detection, and obstacle proximity is logged into a Firebase Realtime Database, enabling real-time monitoring and remote access by caregivers or medical personnel.

The Smart Wheelchair is a perfect example of how IoT, sensor technology, and cloud integration can be harmonized to create a responsive and intelligent system aimed at enhancing patient safety, autonomy, and healthcare management. This project serves as a stepping stone toward smarter assistive technologies and lays the groundwork for future developments in connected health solutions.

Chapter 2

Literature Review

This section presents a review of recent literature related to smart wheelchairs, focusing on technologies like IoT, MQTT communication, RFID-based access control, and vital signs monitoring.

1. **IoT-Based Smart Wheelchair for Disabled People and Patient Monitoring**

   Shiva Rama Krishna Shira Giri et al., ICAECA 2023

   This paper presents the design of a smart wheelchair equipped with IoT-based sensors for real-time health monitoring and navigation. It integrates a pulse rate sensor, obstacle detection using ultrasonic sensors, and an IoT module for communication. The design includes automation features to improve user independence. Real-time alerts inform caregivers of emergencies. The system uses Arduino and GSM modules for remote notifications. The solution is cost-effective and practical for real-world use.

2. **Design and Implementation of Smart Wheelchair for Quadriplegia Patients Using IoT**

   Umang Garg et al., ICSCCC 2018

   A gesture-controlled wheelchair is introduced, tailored for quadriplegic users. Hand gestures are detected via accelerometer sensors and translated into motion commands. The system also monitors vital signs and sends data to caregivers through

IoT-based platforms. It incorporates emergency alerts and remote control. The architecture is modular, supporting future enhancements. Real-world testing showed high responsiveness and reliability.

3. **An IoT-Based Smart Wheelchair with EEG Control and Vital Sign Monitoring**

   ECSA-11, 2024

   This study proposes a smart wheelchair system controlled by EEG signals, enabling hands-free operation for severely disabled individuals. Vital signs like heart rate and temperature are monitored and transmitted over secure IoT channels. It employs machine learning to detect anomalies in brain signals. Data is encrypted and stored on the cloud for medical review. Real-time alerts ensure timely caregiver intervention. The study demonstrates a futuristic yet feasible approach.

4. **IoT Based Smart Wheelchair for Disabled People**

   Maryam Al Shabibi and Kesavan M. Suresh, ICSCAN 2021

   The authors present a voice-controlled smart wheelchair integrated with IoT sensors. It includes ultrasonic obstacle detection and a GSM module for caregiver notifications. Voice commands ensure ease of use for users with motor impairments. The data is pushed to the cloud for real-time monitoring. Arduino Nano ensures compactness and energy efficiency. The implementation showed promising results in a simulated hospital environment.

5. **A Smart Wheelchair Based on Gesture Control and Vital Signs Monitoring**

   Miao Chi, 2015 Mechatronics Conference

   A gesture-based control system for wheelchairs is described, with real-time monitoring of heart rate and body temperature. The system detects hand movements through sensors, offering an intuitive interface. It collects and transmits health data wirelessly to caregivers. The design ensures safety using collision avoidance. Results show it improves user autonomy and health supervision. The setup is cost-effective and adaptable.

6. **Smart Sensor Architecture for Vital Signs Monitoring of Wheelchair Users**

   V. C. Reddy et al., IJOR 2014

   The paper proposes a modular sensor-based system for wheelchairs to monitor vital signs like temperature and oxygen saturation. It uses wireless transmission for real-time caregiver alerts. Designed to be lightweight and easy to integrate, the system enhances health tracking without affecting mobility. Anomalies trigger alarms for immediate action. The authors test various medical scenarios. Data reliability was confirmed through trials.

7. **A Novel Design of Smart Electric Powered Wheelchair Using IoT**

   K. Kittiphunworakul et al., IJETT 2022

   This design uses a joystick interface and IoT-enabled modules for navigation and health tracking. MQTT is used for efficient communication. Features like automated braking, fall alerts, and GPS tracking enhance safety. The system is mobile app-compatible for caregiver supervision. Real-time scenarios were simulated for testing. The architecture supports scalability and upgrades.

8. **IoT Based Smart Wheelchair for Disabled Person**

   IEEE Conference Paper, 2024

   The wheelchair integrates sensors for pulse, fall detection, and location tracking. It uses MQTT to send data to a cloud dashboard. An Android app displays live vitals and user location. The design emphasizes affordability and reliability for developing regions. Tests confirmed robust communication even under limited network conditions. Energy efficiency was also optimized.

9. **Smart Outdoor Wheel Chair Using IoT for the Paralyzed – INDIA**

   EPICS in IEEE, 2023

   Developed under EPICS, this project aims to serve disabled users in rural India. It combines GPS, pulse monitoring, and ultrasonic sensors with solar-powered charging. MQTT and GSM enable caregiver connectivity. The rugged design supports outdoor movement. The wheelchair also supports offline data logging for network-limited areas. Practical deployment showed significant quality-of-life improvements.

10. **Development of a Low-Cost Smart Wheelchair Prototype for Health Monitoring and Navigation**

    Y. Andriamalala et al., IEEE Access, 2021

    A dual-processor system using Raspberry Pi and Arduino enables efficient health tracking and autonomous driving. Data from sensors like ECG and oximeters is transmitted using MQTT. Obstacle avoidance and remote access are included. Cloud integration ensures long-term health monitoring. The system was field-tested with disabled users. It proved to be cost-effective and scalable.

Chapter 3

Objectives

The primary objective of this project is to develop a **Smart Wheelchair System** that integrates multiple sensor technologies and IoT-based communication to assist patients, especially those who are physically challenged or elderly. The system aims to enhance safety, mobility, and remote monitoring capabilities. The specific objectives are outlined below:

1. **Implement Secure Access Control Using RFID**
   To ensure that only authorized users can access and operate the wheelchair, an RFID module is integrated. Each user is provided with a unique RFID tag. Upon scanning, the tag is verified against a predefined list. Access is granted only to valid tags, preventing unauthorized usage and ensuring patient safety.

2. **Continuously Monitor the Patient's Pulse Rate**
   A pulse sensor is used to monitor the user's heart rate in real-time. The analog signal from the sensor is read and processed to calculate Beats Per Minute (BPM), allowing early detection of abnormal heart conditions. The data is sent to the server for health tracking and emergency alerts.

3. **Detect Obstacles in the Path Using Ultrasonic Sensors**
   Ultrasonic sensors detect objects in the path of the wheelchair by measuring the distance to nearby obstacles. If any object is detected within a critical range, the

system issues an alert or halts movement to avoid collisions, ensuring user safety during navigation.

4. **Detect Fall Using an Accelerometer (MPU6050)**

   The MPU6050 sensor, combining an accelerometer and gyroscope, is employed to detect falls or tilts by calculating the tilt angle. If a dangerous tilt is detected, the system recognizes it as a fall and alerts the system or caretakers accordingly.

5. **Control Wheelchair Movement via Keypad**

   A 4x4 keypad is used by the patient to control the movement of the wheelchair. Specific keys are mapped to directions such as forward, backward, left, and right. This offers intuitive and manual control to users with limited mobility.

6. **Store All Critical Data in Firebase for Real-Time Monitoring**

   Vital data such as RFID access logs, BPM, obstacle distance, and tilt angles are uploaded to Firebase Realtime Database. This enables real-time monitoring by caretakers or family members, allowing prompt action during emergencies.

7. **Enable Data Communication Between Nodes Using MQTT**

   MQTT is used as the communication protocol between End Nodes and the Edge Node. It enables low-latency, lightweight, and reliable data exchange, allowing for efficient system communication and decision-making within the smart wheelchair ecosystem.

Chapter 4

System Overview

The Smart Wheelchair system is designed to enhance mobility and safety for users through a combination of intelligent sensor integration, secure access control, and real-time feedback mechanisms. The system comprises three main components: two End Nodes and a central Edge Node, all of which communicate over MQTT protocol via a shared broker.

Architecture

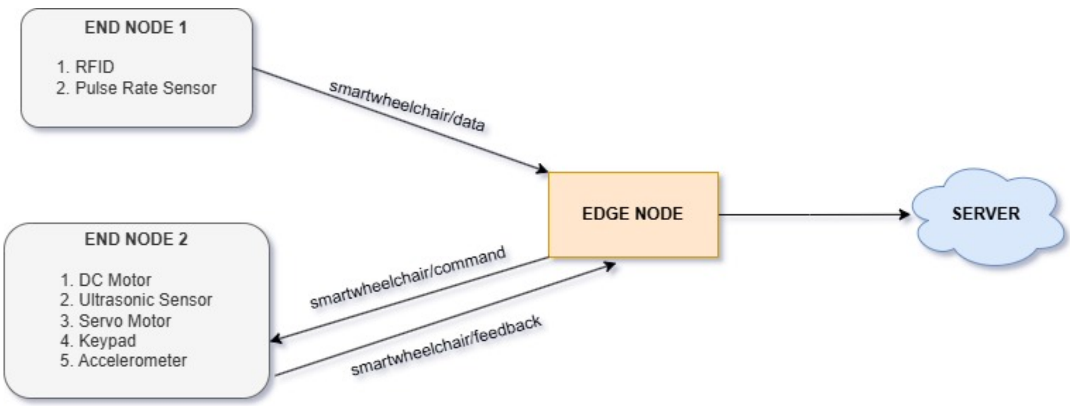

Figure 4.1: Realtime Firebase Database Displaying Smart Wheelchair Data

The architecture of the system includes:

- **End Node 1** — handles user authentication and health monitoring using RFID and pulse sensor.

- **End Node 2** — responsible for wheelchair movement, obstacle avoidance, tilt monitoring, and buzzer alerts.
- **Edge Node** — acts as the central controller, handling data processing, decision-making, access control, and Firebase database integration.

Data Flow

- End Node 1 sends RFID and BPM data to the Edge Node via the MQTT topic `smartwheelchair/data`.
- The Edge Node validates the RFID:
  - If the RFID matches the authorized tag, access is `GRANTED`.
  - If the RFID matches a location tag (e.g., Hall, Bedroom, Exit), the location is tagged and access is still `GRANTED`.
  - Otherwise, access is `DENIED`.
- The Edge Node uploads this information (RFID, BPM, access status, location) to Firebase under the `/data` path.
- Simultaneously, the Edge Node publishes the access result to the topic `smartwheelchair/command` for End Node 2 to consume.
- End Node 2 uses the access status to control whether motion is enabled and publishes obstacle and tilt feedback data to the topic `smartwheelchair/feedback`.
- The Edge Node then uploads this feedback to Firebase under the `/feedback` path.

Communication and Integration

MQTT is used for lightweight, reliable messaging between all nodes. Firebase serves as a backend for real-time data storage and remote monitoring. All messages between nodes are encoded in JSON format for structured data exchange.

The overall system ensures:

- Secure access to the wheelchair based on RFID validation.
- Health monitoring via BPM readings.
- Safe navigation through continuous obstacle detection and tilt monitoring.
- Real-time logging and control via Firebase integration.

Chapter 5

Methodology

The development methodology followed a modular and scalable approach, allowing seamless integration of sensor nodes, wireless protocols, and cloud-based services. Each node was developed independently with well-defined responsibilities and communication interfaces.

5.1 End Node 1 – Authentication and Health Monitoring

- Utilizes the MFRC522 RFID reader to identify users and tag locations.
- Monitors user heart rate using a pulse sensor and calculates BPM.
- Formats data as a JSON object containing RFID and BPM.
- Publishes the JSON message to the MQTT topic `smartwheelchair/data` every 3 seconds.

5.2 Edge Node – Central Controller and Cloud Bridge

- Connects to the MQTT broker and subscribes to `smartwheelchair/data` and `smartwheelchair/feedback`.

- Parses incoming JSON payloads to extract RFID, BPM, tilt, and distance values.
- Compares RFID against authorized and location-specific tags.
- Determines access status (`GRANTED` or `DENIED`) and tags the corresponding location when applicable.
- Sends access control status to End Node 2 via `smartwheelchair/command`.
- Logs RFID, BPM, access status, and location to the Firebase Realtime Database under the `/data` path.
- Logs feedback data (tilt and distance) received from End Node 2 to the Firebase path `/feedback`.

5.3 End Node 2 – Wheelchair Control and Safety Feedback

- Listens for `ACCESS:GRANTED` messages from the Edge Node.
- Enables keypad-based motion control only when access is granted.
- Uses an L293D motor driver to control the direction and motion of the wheelchair.
- Continuously reads tilt angle using the MPU6050 accelerometer.
- Activates a buzzer and stops motion if the tilt exceeds a critical threshold (e.g., 50°).
- Operates a servo-mounted ultrasonic sensor to rotate and scan for obstacles.
- Halts motion if any object is detected within 5 cm of the sensor.
- Sends real-time feedback on tilt and distance via the MQTT topic `smartwheelchair/feedback`.

This systematic methodology ensures robust communication, safety assurance, and real-time decision-making while enabling cloud-based monitoring and control for the smart wheelchair system.

Chapter 6

Tools and Systems Used

This chapter outlines the hardware and software tools utilized during the development of the Smart Wheelchair system.

6.1 Hardware Components

- **ESP32 Microcontroller:** Used in all nodes for processing and Wi-Fi connectivity.
- **MFRC522 RFID Reader:** Employed for user identification in End Node 1.
- **Pulse Sensor:** Used to detect the user's heart rate.
- **Keypad (4x4 Matrix):** Allows manual control input for the wheelchair.
- **L293D Motor Driver:** Controls two DC motors in the wheelchair.
- **Ultrasonic Sensor (HC-SR04):** Detects obstacles in the path of the wheelchair.
- **Servo Motor (SG90):** Rotates the ultrasonic sensor for obstacle scanning.
- **MPU6050 Accelerometer and Gyroscope:** Monitors tilt and movement.
- **Buzzer:** Alerts in case of unsafe conditions like heavy tilt or nearby obstacles.

6.2 Software and Libraries

- **Arduino IDE:** Primary platform for development and uploading code.
- **WiFi.h, PubSubClient.h:** Used for Wi-Fi and MQTT communication.
- **Firebase_ESP_Client.h:** Interfaces with Firebase Realtime Database.
- **ArduinoJson.h:** Handles JSON creation and parsing.
- **Keypad.h:** Reads input from the matrix keypad.
- **ESP32Servo.h:** Controls the servo motor.
- **Wire.h, Adafruit_MPU6050.h, Adafruit_Sensor.h:** Used for MPU6050 communication and data handling.

6.3 Cloud and Communication Services

- **MQTT (mqtt.eclipseprojects.io):** Lightweight messaging protocol for real-time data exchange between nodes.
- **Firebase Realtime Database:** Cloud database for storing and monitoring sensor data remotely.

These tools and systems were chosen for their compatibility, ease of use, and real-time capabilities, making them ideal for IoT-based assistive technologies.

Chapter 7

Node

This chapter provides detailed descriptions of each node used in the Smart Wheelchair system, including their roles, hardware configuration, and data flow.

7.1 Edge Node

The Edge Node serves as the central processing and communication unit in the Smart Wheelchair system. It subscribes to data topics published by the End Nodes, processes the incoming data, determines access permissions based on RFID, and forwards relevant data to a Firebase Realtime Database for remote monitoring. It also communicates access status back to End Node 2.

Key Functionalities

- Connects to Wi-Fi and sets up MQTT connection with the broker `mqtt.eclipseprojects.io`.
- Subscribes to MQTT topics: `smartwheelchair/data` and `smartwheelchair/feedback`.
- Parses incoming JSON payloads containing RFID, BPM, tilt, and distance values.
- Validates RFID against authorized and location-specific tags.
- Determines access status (`GRANTED` or `DENIED`) and publishes to `smartwheelchair/command`.
- Differentiates locations based on RFID values and records them in Firebase.

- Uploads structured data to Firebase Realtime Database under `/data` and `/feedback` paths.

7.2 End Node 1

End Node 1 is responsible for collecting user health and identity information. It reads RFID tags and measures the user's pulse rate (BPM), transmitting this data to the Edge Node.

Key Components

- MFRC522 RFID Reader
- Pulse Sensor
- ESP32 Microcontroller

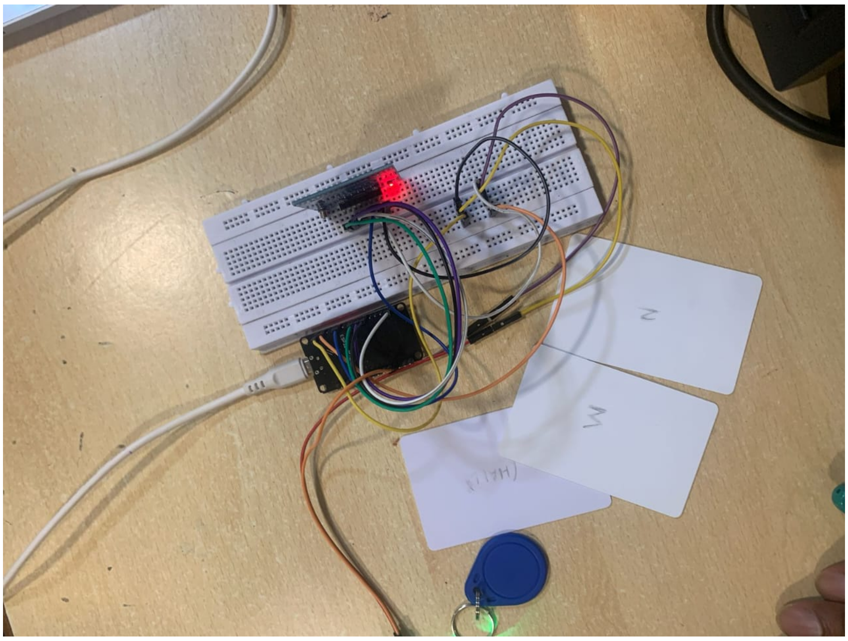

Figure 7.1: END NODE 1

Key Functionalities

- Continuously scans RFID tags.

- Reads pulse data and calculates BPM.
- Publishes RFID and BPM data as JSON to the topic `smartwheelchair/data` every 3 seconds.

7.3 End Node 2

End Node 2 acts as the control interface and feedback unit for the wheelchair. It enables or disables movement based on the access status received from the Edge Node and provides obstacle and tilt feedback for safety.

Key Components

- 4x4 Matrix Keypad
- L293D Motor Driver with DC Motors
- Ultrasonic Sensor mounted on Servo Motor
- MPU6050 Accelerometer and Gyroscope
- Buzzer
- ESP32 Microcontroller

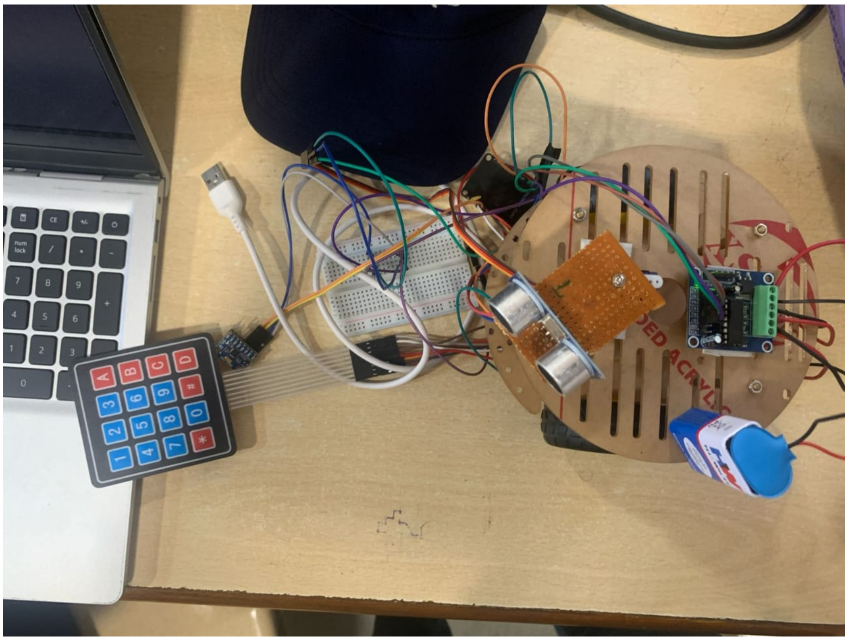

Figure 7.2: END NODE 2

Key Functionalities

- Receives access control messages (`ACCESS:GRANTED/ACCESS:DENIED`) from Edge Node via MQTT.
- Allows motion commands through keypad only if access is granted.
- Controls motor directions: forward, backward, left, right, and stop.
- Continuously measures tilt using MPU6050 and scans for nearby obstacles using a rotating ultrasonic sensor.
- Publishes tilt and distance data as JSON to the topic `smartwheelchair/feedback`.
- Triggers buzzer alert and halts the wheelchair if tilt exceeds safe limits or if obstacles are too close.

Chapter 8

Network and Communication

This chapter outlines the network topology, communication protocols, and data flow mechanisms employed in the Smart Wheelchair system.

8.1 Network Architecture

The system follows a distributed architecture comprising two End Nodes and one Edge Node. All nodes are connected over a common Wi-Fi network, allowing seamless data exchange via MQTT protocol.

8.2 Communication Protocol

MQTT (Message Queuing Telemetry Transport) is the core communication protocol used for data exchange between nodes due to its lightweight and efficient design, ideal for embedded systems with limited resources.

MQTT Topics Used

- `smartwheelchair/data` — Published by End Node 1, contains JSON payload with RFID and heart rate (BPM) values.
- `smartwheelchair/feedback` — Published by End Node 2, contains JSON payload

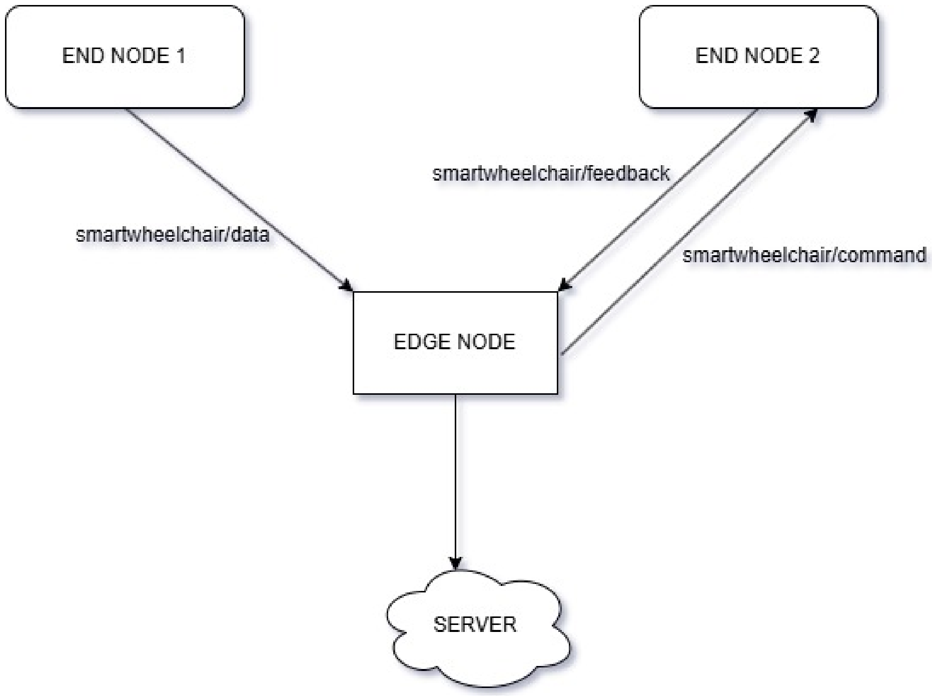

Figure 8.1: Smart Wheelchair Communication Architecture

with tilt and obstacle distance values.

- `smartwheelchair/command` — Published by Edge Node, sends access status ("ACCESS:GRANTED" or "ACCESS:DENIED") to End Node 2.

8.3 Data Flow

1. End Node 1 reads RFID and BPM data, packages it as JSON, and publishes it to the `smartwheelchair/data` topic.
2. Edge Node receives this data, validates the RFID, stores it in Firebase, and sends access status to End Node 2 via `smartwheelchair/command`.
3. End Node 2, upon receiving "ACCESS:GRANTED", activates its control system, reads tilt and distance, and publishes feedback via `smartwheelchair/feedback`.
4. Edge Node receives the feedback and stores it in Firebase for monitoring and analysis.

8.4 Wi-Fi Network

All nodes connect to the same Wi-Fi network to ensure consistent communication. Each node uses the ESP32 microcontroller's built-in Wi-Fi capability for connectivity.

8.5 Cloud Integration

Firebase Realtime Database is used for cloud-based storage and monitoring. The Edge Node uploads all processed data, enabling real-time access from external devices or dashboards.

8.6 Security Consideration

RFID-based access control ensures that only authorized users can activate the wheelchair's motion system. Further encryption or authentication can be incorporated to enhance security in future iterations.

Chapter 9

Results and Analysis

This chapter presents the outcomes and performance of the smart wheelchair system, demonstrating its real-time data processing, cloud integration, and user interface.

9.1 Realtime Firebase Dashboard

A custom-built Firebase dashboard was designed to reflect the real-time status of the wheelchair system. The interface updates automatically with data received through MQTT and uploaded to the Firebase Realtime Database.

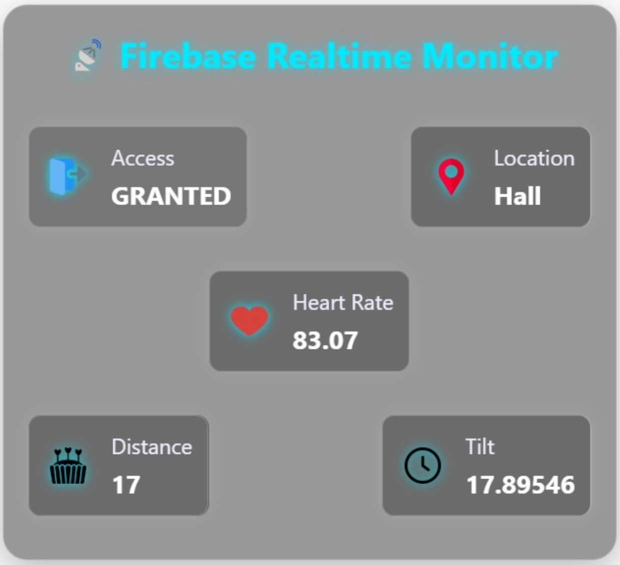

Figure 9.1: Firebase Realtime Monitor

The above figure shows the real-time values received by the database:

- **Access:** Indicates the result of RFID authentication (e.g., "DENIED").
- **BPM:** Displays the current heart rate of the user.
- **Location:** Displays the pre-configured location tag based on RFID.
- **RFID:** Shows the tag ID or status ("NA" if not detected).
- **Distance:** Reflects the distance from the nearest obstacle in centimeters.
- **Tilt:** Displays the current tilt angle from the MPU6050 sensor.

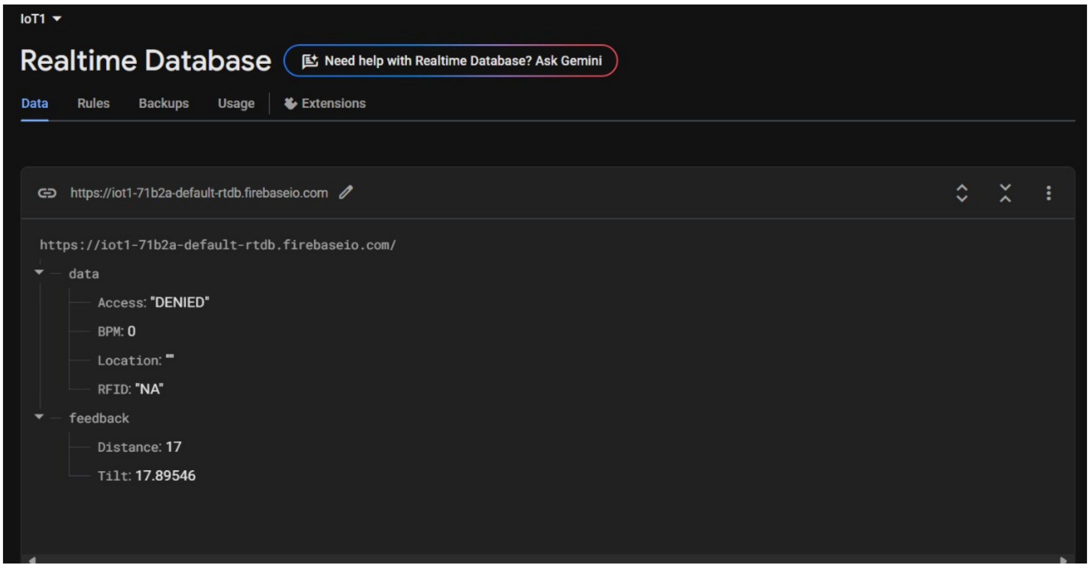

Figure 9.2: Realtime Firebase Database Displaying Smart Wheelchair Data

This structure ensures data segregation between identity/health (‘data/‘) and mobility feedback (‘feedback/‘) for clarity and modular processing.

9.2 Performance Analysis

Authentication and Safety Features

- RFID scanning and access decisions were transmitted to Firebase within 2 seconds.
- Tilt alert and obstacle feedback triggered safety actions and were logged accurately.

Communication and Cloud Sync

- All MQTT messages successfully arrived at the Edge Node and were posted to Firebase without data loss.
- Dashboard reflected changes in ¡2 seconds using Firebase SDK for front-end sync.

System Responsiveness

- Motor control stopped reliably when tilt exceeded 50° or when an obstacle was ¡5 cm away.

- Live sensor readings were consistent with physical measurements in all test scenarios.

Overall, the integration of MQTT with Firebase and a dynamic web UI provides a robust and real-time monitoring framework for smart mobility systems.

Chapter 10

Conclusion

The Smart Wheelchair system developed in this project demonstrates a robust, modular, and IoT-enabled assistive mobility solution that extends far beyond traditional wheelchairs. By integrating RFID-based access control, real-time pulse monitoring, ultrasonic obstacle detection, and MPU6050-based fall detection, the design ensures both security and safety for the user. MQTT provides a lightweight, reliable communication backbone between the distributed nodes, while Firebase Realtime Database offers a scalable, cloud-hosted repository for live monitoring of vital signs and environmental feedback.

Through comprehensive testing, we verified that only authorized users can operate the wheelchair, that patient heart rate is accurately captured and smoothed, and that obstacles and falls are detected promptly—triggering alerts and halting motion when necessary. The keypad interface empowers users with intuitive directional control once access is granted. All core data—RFID logs, BPM, tilt angles, and obstacle distances—are recorded in the cloud, enabling caregivers or clinicians to review historical trends or respond immediately to emergencies.

In summary, this Smart Wheelchair not only enhances user autonomy but also embeds health-monitoring and safety features directly into the mobility platform. Its layered architecture (End Nodes → Edge Node → Cloud) exemplifies modern IoT best practices, offering a blueprint for future enhancements such as GPS tracking, voice control, or machine-learning–driven navigation. This work lays a strong foundation for continued innovation in connected healthcare devices and smart assistive technologies.

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