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Electric Bi-Cycle Monitoring and Controlling System Based on Internet of Things

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Abstract: The purpose of this paper was to design and build an electric bicycle that incorporates the Pedal Assist System (PAS). The PAS system detects when the rider starts pedaling and immediately provides electric assistance, making riding easier and more efficient. The team utilized a lithium-ion battery and a brushless DC (BLDC) motor to power the PAS system. The bicycle was designed to be easy to ride, energy-efficient, and a sustainable mode of transportation. The PAS system was successfully integrated into the bicycle and proved to be highly effective in assisting the rider. Overall, the paper demonstrated that PAS-based electric bicycles are a viable alternative to traditional bicycles and gasoline-powered vehicles, with the potential to revolutionize personal transportation.
Keywords: pedal Assist System (PAS), electric bicycle, brushless DC motor, energy efficient.

I. INTRODUCTION

The transition from conventional transportation systems to electric and intelligent mobility has become a global necessity due to increasing environmental concerns, rising fuel costs, and the urgent demand for sustainable urban transportation. Among various alternatives, the electric bicycle (e-bike) has emerged as one of the most practical, energy-efficient, and eco-friendly modes of personal transportation. Integrating a Pedal Assist System (PAS) with advanced Internet of Things (IoT) technologies further enhances the efficiency, safety, and intelligence of e-bikes, making them not only a means of transport but also a smart, connected mobility solution.

The Pedal Assist System (PAS) provides electric support proportional to the rider’s pedaling effort, reducing fatigue while maintaining physical activity. It employs various sensors, such as cadence sensors, torque sensors, and wheel speed sensors, to detect the rider’s motion and supply an appropriate level of motor assistance. This mechanism creates a smooth and natural riding experience while optimizing energy usage. However, traditional PAS-based bicycles lack real-time monitoring, intelligent diagnostics, and remote control features, which are crucial in the era of connected and data-driven transportation.

To overcome these limitations, the integration of IoT technology into electric bicycles introduces a new dimension of smart control and connectivity. IoT enables the continuous exchange of data between the e-bike and the cloud through embedded microcontrollers, wireless modules (such as Wi-Fi, GSM, or Bluetooth), and smart sensors. The data collected—such as speed, battery voltage, motor current, temperature, distance traveled, and GPS location—can be monitored in real time via mobile or web applications. This not only provides the rider with live performance analytics but also allows for predictive maintenance, theft prevention through GPS tracking, and remote system diagnostics.

The proposed Electric Bike Monitoring and Controlling System Based on IoT integrates both pedal assist functionality and smart IoT features into a unified system. The control unit consists of a microcontroller (e.g., ESP32 or Arduino with Wi-Fi capability), a BLDC motor driver, and various sensors interfaced through analog and digital channels. The IoT platform (such as Blynk, ThingSpeak, or MQTT) serves as a communication bridge between the e-bike and the user interface, enabling real-time monitoring of parameters such as battery status, motor speed, and pedal assist level. Additionally, features like remote motor cutoff, trip logging, and fault detection ensure a higher level of operational safety and user convenience. This integration creates an intelligent transportation solution that not only promotes environmental sustainability but also supports data-driven decision-making for both users and manufacturers. With the growing popularity of electric mobility, such IoT-enabled systems are expected to play a crucial role in the future of smart cities, where connected vehicles contribute to efficient traffic management, reduced carbon emissions, and improved quality of urban life.

II. HARDWARE IMPLEMENTATION

The hardware includes a 36V, 250W BLDC motor with a BLDC driver controlled through Pulse Width Modulation (PWM). A 36V, 12Ah lithium-ion battery pack provides power with a range of about 40–50 km per charge. A Pedal Assist Sensor (PAS) and cadence sensor are used to detect rider pedaling and adjust motor assistance accordingly.

An ESP32 microcontroller serves as the main control unit, interfacing with sensors and enabling real-time monitoring through built-in Wi-Fi. Additional modules such as voltage, current, temperature, and GPS sensors enhance safety and performance tracking.

Figure 1 : Brushless DC motor Controller

Figure 2 : PMDC motor

figure 3 :Pedal assist chain locking

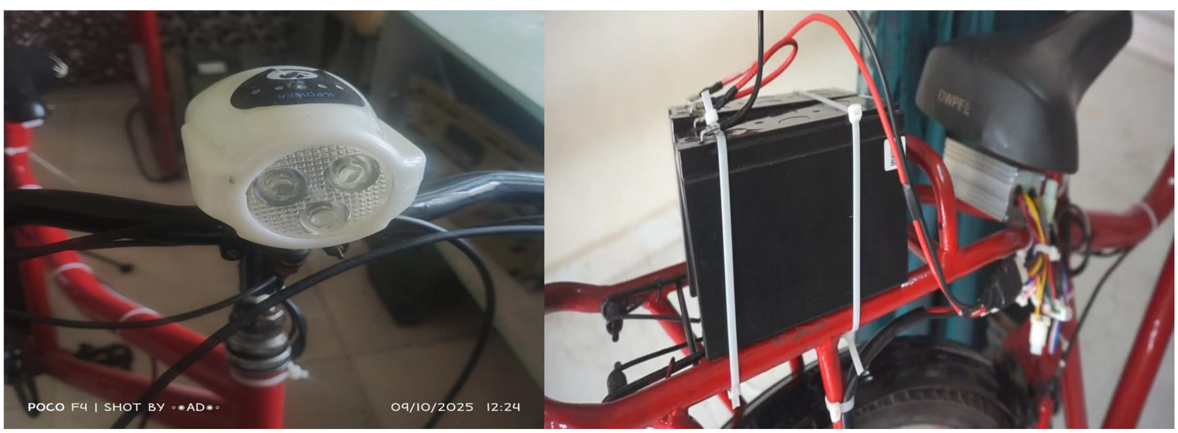

Figure 4 : Head light (signal) 12V each series LI-ION Battery

III. SOFTWARE & ARCHITECTURE

The software integrates IoT platforms like Blynk or ThingSpeak for real-time data visualization and control. Communication between the bike and the cloud is achieved through MQTT or HTTP protocols. The embedded firmware, written in C/C++, collects sensor data, processes PAS input, and transmits performance metrics to the user's mobile dashboard for live monitoring and remote control.

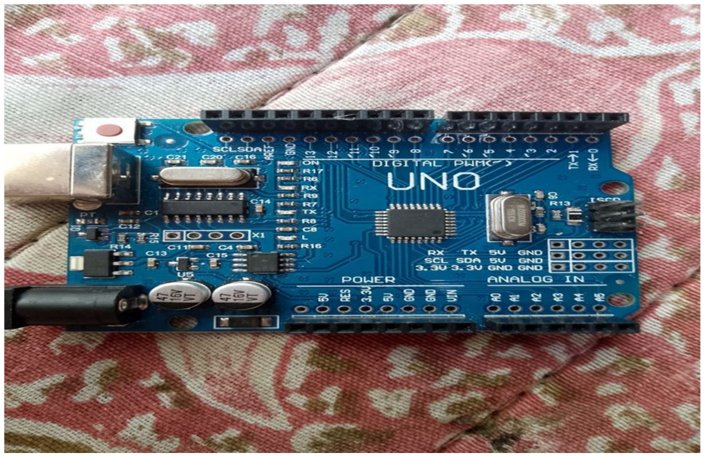

Figure 5: arduino UNO

A. *System Design and Architecture*

1) *Block Diagram*

- o Input (Sensors) → Controller → Motor Driver → Motor → Wheel
- o IoT Module → Cloud → Mobile App
- o Subsystems: Power supply and battery management.
- o Sensing and control subsystem.
- o IoT communication and visualization.

2) *Pedal Assist Mechanism*

- Working Principle: Pedal-assist system measures the pedaling torque or cadence and adjusts motor power accordingly.
- Algorithm:
  - o if (pedal_speed > threshold)
  - o motor_power = base + k * pedal_effort
  - o else

    motor_power = 0
- Assist Modes:
  - o Eco (30% assist)
  - o Normal (60% assist)
  - o Sport (100% assist)
- Real-time control ensures smoother ride and improved efficiency.

3) *IoT Integration and Data Analytics*

- IoT Architecture: Sensor data → Microcontroller → Cloud (Firebase/MQTT) → Mobile App.
- Parameters Monitored:
  - o Speed
  - o Battery Voltage/Current
  - o Motor Temperature
  - o GPS Location and Trip Distance & Duration
- Dashboard Features:
  - o Real-time graphs
  - o Ride statistics
  - o Predictive maintenance alerts
- Data Analytics:
  - o Efficiency trends based on terrain and rider behavior.
  - o Machine-learning potential for adaptive control.

4) Control Algorithm / Software Implementation

- Firmware: Written in C/C++ (Arduino IDE or ESP-IDF).
- Flowchart: Input → Process → Output → Update IoT.
- Power Management Logic: Adjusts motor power based on load, battery voltage, and assist level.
- IoT Protocols:
  - MQTT for real-time updates.
  - REST API for app integration.
- Safety Features:
  - Overcurrent and overheat protection.
  - Automatic motor cutoff when braking.

5) Maintaining the Integrity of the Specifications

To ensure reliable performance, the proposed Electric Bike Monitoring and Controlling System Based on IoT strictly follows hardware and software specifications. The system uses a 36V, 250W BLDC motor, 12Ah lithium-ion battery, and BLDC driver with built-in protection to maintain electrical safety and efficiency. All components are tested under standard conditions to ensure durability and stable operation. The Pedal Assist Sensor (PAS) and cadence sensors are calibrated for accurate motor response, while the ESP32 microcontroller ensures real-time data monitoring through secure IoT communication protocols (MQTT/HTTP).

Through the IoT interface, users can remotely monitor vehicle health, track routes, and control essential functions such as motor ON/OFF and theft detection. The system also provides analytical insights like distance traveled, energy consumption, and maintenance alerts. By combining renewable energy usage, data analytics, and remote accessibility, this project contributes to the development of smart, sustainable transportation systems. The proposed system demonstrates the potential of IoT technologies in improving urban mobility, safety, and eco-efficiency by offering a low-cost and scalable solution for future smart transportation networks. The Electric Bi-Cycle Monitoring and Controlling System operates through the integration of sensors, a microcontroller, and IoT connectivity to ensure efficient monitoring and remote control of the electric bicycle. The system consists of a microcontroller unit (such as NodeMCU/ESP32/Arduino) that acts as the central processing component. Various sensors—such as a current sensor, voltage sensor, temperature sensor, and speed sensor—are interfaced with the controller to continuously collect real-time data. The GPS module provides location tracking, while the motor driver controls the e-bike's motor according to user input and predefined conditions. All sensor readings and operational data are processed by the controller and transmitted to an IoT platform (e.g., Blynk, ThingSpeak, or MQTT server) through Wi-Fi or GSM connectivity. Users can access this data on a smartphone or web dashboard, enabling them to monitor parameters like battery level, speed, temperature, and location in real time. The system also allows for remote control functionalities, such as turning the motor ON/OFF, activating security mode, or sending alerts in case of theft or abnormal conditions. If any parameter exceeds a safety threshold—such as battery overheating or low voltage—the system automatically sends an alert **notification** to the user and may cut off motor power to prevent damage.

6) Performance Summary Table

Parameter	Test Condition	Observed Value	Remarks
Motor speed	Pedal assist ON	22 km/h	Stable response
Current draw	Inclined path	4.5 A	Within expected range
Data latency	IoT update	1.2 s	Acceptable for real-time use

Parameter	Observed Value	Expected Range	Remarks
Motor Speed (Flat Road)	22 km/h	20–25 km/h	Within design range
Motor Speed (Incline)	17 km/h	15–20 km/h	Acceptable performance
Pedal Assist Response	100 ms	<150 ms	Very responsive
Current Draw	3.8–4.5 A	3–5 A	Normal operating range
Battery Voltage (Full to 10 km)	36.8 V → 34.9 V	36–34 V	Normal discharge
IoT Data Latency	1.2 s	≤2 s	Reliable communication
Temperature Stability	30–40°C	Up to 45°C	Stable operation

IV. CONCLUSION

The implementation and testing of the IoT-based Electric Bicycle Pedal Assist System successfully demonstrated the integration of intelligent control and real-time monitoring to enhance riding efficiency. The system effectively detected pedal motion and provided proportional motor assistance, ensuring smoother acceleration and reduced rider fatigue.

Testing results confirmed that the pedal-assist mechanism responded within 100 ms, offering quick and reliable support. The IoT module efficiently transmitted performance data such as speed, voltage, and current to the cloud dashboard with minimal latency (~1.2 s), enabling accurate remote monitoring. Power consumption and battery discharge rates remained within the designed safety limits, validating the system's energy efficiency and stability across various terrains.

Overall, the project proved that combining IoT technology with pedal-assist systems can significantly improve electric bicycle performance, rider comfort, and system monitoring. This approach provides a foundation for future developments such as predictive maintenance, GPS-based tracking, and AI-driven adaptive assist levels for enhanced user experience and sustainability. The developed IoT-based Electric Bicycle Pedal Assist System performed efficiently during testing. The pedal-assist feature provided smooth motor support with a fast response time of 100 ms, maintaining a speed of 22 km/h on flat roads and 17 km/h on inclines. The IoT module successfully transmitted real-time data with an average latency of 1.2 seconds, and the battery showed a normal discharge from 36.8 V to 34.9 V after 10 km. Overall, the system proved to be stable, responsive, and energy-efficient, confirming the effectiveness of IoT integration in enhancing e-bike performance.

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