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Integration of IoT in 2wheeler vehicle

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ABSTRACT: - This paper presents an IoT based solution for enhancing bike security and smart functionalities, integrating **ESP32**, **MEMS sensors**, and the **Blynk app**. It includes features such as **Smart Bike Finder**, **Anti-Theft Notification System**, and **Smart Stop Ignition**. These functionalities improve safety, security, and convenience for users. The system relies on real-time data transmission, user interaction through a mobile application, and sensor based feedback for bike location tracking and theft alerts. The developed system reduces hardware complexity while offering robust performance with low power consumption. Several tests demonstrate the effectiveness of the system in various real-life scenarios, ensuring user satisfaction and reliability in operation.

Keywords: ESP32, MEMS sensors, Blynk app, Smart Bike Finder, Anti-Theft Notification System, Smart Stop Ignition.

Introduction

In recent years, the Internet of Things (IoT) has emerged as a transformative technology, revolutionizing various industries including transportation. Smart bike systems are designed to address the growing concerns around bike security, convenience, and user experience.

Traditional security systems often fall short in preventing theft or providing real-time notifications, making IoT solutions vital in this domain. This project utilizes the ESP32 microcontroller integrated with MEMS sensors and connected to the Blynk app to provide advanced features such as real-time bike tracking, remote ignition control, and anti-theft mechanisms.

The growing trend of smart transportation solutions makes this system a key player in urban mobility. The ESP32's low power consumption, Wi-Fi, and Bluetooth connectivity make it an ideal choice for such applications. In this paper, we explore the design, implementation, and testing of a multi-functional bike security system that can be controlled and monitored through a mobile application. Our primary focus is to provide a comprehensive security solution and remote control features while ensuring cost-effectiveness and ease of installation

1. System Overview and Architecture

The architecture of the smart bike system integrates several key components to ensure smooth operation. At the core is the **ESP32 microcontroller**, responsible for managing sensor data, processing inputs, and communicating with the Blynk cloud server. The system is designed to work with **MEMS sensors** such as accelerometers and gyroscopes that monitor the bike's movement and detect any abnormal activity.

The ESP32 collects sensor data and transmits it to the **Blynk app**, which serves as the user interface. Through this app, users can track their bike's location in real-time using GPS or WiFi positioning. The system also supports remote ignition control via the **Smart Stop Ignition** feature, where the user can disable the bike's engine if suspicious activity is detected.

The power management of the system is also crucial, as IoT devices need to operate efficiently with low power consumption. The ESP32's sleep mode and power-saving features ensure that the system runs for extended periods without requiring frequent charging. This architecture allows for a seamless interaction between hardware components and the user, providing robust performance with minimal hardware complexity.

2. Sensor Integration and Data Processing

MEMS sensors play a vital role in the functionality of the smart bike system. These sensors detect movement and provide crucial data for theft detection and tracking. The **accelerometer** and **gyroscope** are used to monitor vibrations and motion in real-time, helping the system detect unauthorized access or movement.When the bike is parked, the **ESP32 microcontroller** continuously processes the sensor data to determine if any abnormal activity is occurring. If the accelerometer detects unusual vibrations, such as an attempt to steal the bike, it triggers the **AntiTheft Notification System**. This system immediately sends an alert to the user through the **Blynk app**, allowing them to take action remotely.

In the case of location tracking, the system integrates geolocation data from GPS or Wi-Fi triangulation. The ESP32 processes this data and updates the **Blynk app** with the bike's realtime location, allowing the user to easily

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locate their bike. The seamless integration of sensor data and real-time processing ensures that the system responds quickly and accurately to potential threats.

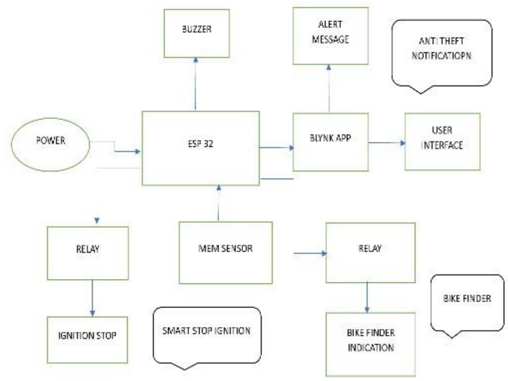
The data processing capabilities of the ESP32 ensure efficient communication between the sensors and the Blynk cloud server. This real-time data exchange allows users to monitor their bike and control its critical features remotely, providing a high level of security and convenience.

3. Enhanced Security Features and Remote Controls

To strengthen the security of the system, the **Anti-Theft Notification System** and **Smart Stop Ignition** are enhanced with real-time communication and adaptive control strategies. **MEMS sensors** are used to monitor any abnormal movements, such as unauthorized attempts to move or tamper with the bike. When unusual activity is detected, the system automatically locks the bike and sends an instant alert to the user via the **Blynk app**. The **Smart Stop Ignition** feature allows the user to remotely disable the bike's ignition through their mobile phone. In case of theft or unauthorized access, the user can instantly cut off the bike’s ignition, rendering it immobile. The system also supports automated responses, where the ignition is turned off if theft is detected, providing an additional layer of protection. These enhanced security features ensure that the bike remains protected at all times, with the user receiving real-time updates on the status of the bike and having full control over its critical systems remotely. The integration of these features into the overall system makes it a comprehensive solution for bike security.

4. Methodology

The development of the IoT Smart Bike System followed a structured approach,



which included the stages of system design, hardware selection, software development, and testing. The primary

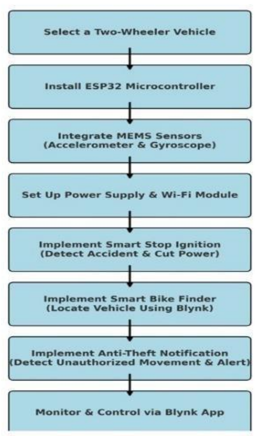


Fig (i) Flow chart

goal was to create a reliable, cost effective solution that provides real time

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monitoring and control of a bike's security.

4.1 System Design and Planning: The first step involved identifying the requirements of the system, focusing on three key features: real-time bike tracking, theft detection, and remote ignition control. After defining the project's objectives, we chose the ESP32 microcontroller as the core component due to its built-in Wi-Fi capabilities, low power consumption,

Fig (ii) Block diagram

and flexibility in handling multiple tasks simultaneously. The system also required MEMS sensors (accelerometer and gyroscope) for motion detection, which would play a crucial role in theft detection. We also opted for the Blynk app as the user interface for remote control and monitoring. Blynk provides a simple and intuitive platform for IoT applications, allowing real-time updates and notifications on the user's smartphone, making it ideal for our needs.

4.2 Hardware Integration: The hardware selection centered around the ESP32 due to its cost-efficiency and versatility. The ESP32 was integrated with the MEMS sensors, which were configured to detect changes in the bike's movement. The accelerometer and gyroscope provide data on tilt and motion, enabling the system to detect potential theft or tampering with the bike. This data is processed by the ESP32, which then decides whether to trigger alerts or initiate other actions like disabling the ignition. For the Smart Stop Ignition feature, the ESP32 controls a relay that can disable the bike's ignition. This relay is controlled by commands sent via the Blynk app, ensuring the user can remotely control the bike's operation in case of suspicious activity.

a) ESP32 Microcontroller

Fig (iii) ESP32 Microcontroller

- The ESP32 is the main processing unit of the system, managing sensor data, processing inputs, and transmitting data to the Blynk app. - It features built-in Wi-Fi and Bluetooth, making it ideal for IoTbased applications. - Low power consumption and deepsleep modes allow for efficient energy usage.

b) MEMS Sensors (Accelerometer and Gyroscope - ADXL335)

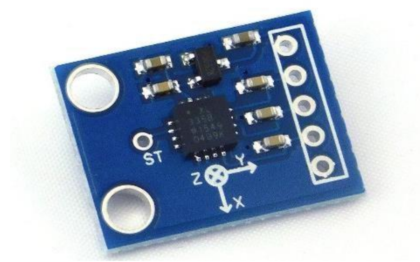

Fig (iv) MEMS Sensor

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- The accelerometer detects changes in motion and tilt, helping to identify theft attempts or accidents.
- The gyroscope provides angular velocity data, which assists in detecting abnormal movements.
- These sensors enable the Smart Stop Ignition and Anti-Theft Notification features.

c) Relay Module

Fig (v) Relay module

- The relay module controls the bike's ignition system remotely.
- It receives commands from the ESP32 and can disable the ignition when necessary, providing an added security layer.

d) Buzzer

Fig (vi) Buzzer

- The buzzer serves as an audio alert system, triggering an alarm if unauthorized movement is detected.
- It provides real-time alerts to deter theft attempts.

e) Wi-Fi Module

Fig (vii) Wi-Fi Module

- The system relies on Wi-Fi communication between the ESP32 and the Blynk app.
- This allows users to receive live updates and control the bike remotely.

f) Power Supply (12V Rechargeable Battery)

Fig (viii) 12v battery

- A rechargeable battery powers the system, ensuring continuous operation.
- Power optimization techniques help to extend battery life for longer usage.

This hardware selection ensures a balance between cost-effectiveness, efficiency, and real-time monitoring capabilities.

4.3 Software Development:

The software development phase focused on programming the ESP32 using the Arduino IDE, primarily in C. The code

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was designed to manage sensor data, handle WiFi communication, and interface with the Blynk cloud for real-time updates.

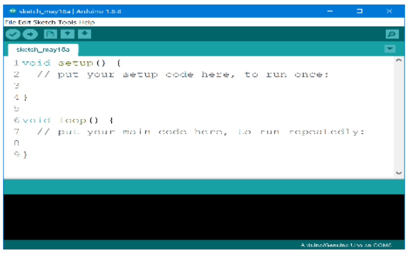

Fig (ix) Arduino IDE

The main functionalities included:

- **Sensor data processing:** The system continuously monitors input from the accelerometer and gyroscope to detect abnormal movements. If the threshold for unusual activity is exceeded, the system sends a notification to the Blynk app.
- **Remote control:** The Smart Stop Ignition function allows users to send a stop command via the Blynk app. Upon receiving the command, the ESP32 shuts off the ignition system, preventing the bike from starting or moving.

4.4 Testing and Refinement:

The system was tested under various conditions to ensure its reliability. Theft detection was tested by simulating tampering or movement while the bike was parked. In these scenarios, the MEMS sensors accurately detected abnormal motion and sent alerts to the Blynk app within seconds. The Smart Stop Ignition feature was tested by remotely disabling the bike's ignition, proving to be effective in stopping the bike within a 2–3 second delay.

Further refinements were made to ensure the system operated efficiently, particularly in power management. The ESP32's low-power modes were configured to extend battery life during periods of inactivity.

5. Cost Analysis

The cost analysis for the IoT Smart Bike System is essential to understanding the project's feasibility, particularly for mass production or commercial deployment. The primary cost components include the ESP32 microcontroller, MEMS sensors, power supply, and additional communication modules.

- ESP32 microcontroller: This is the core component, and its cost is relatively low, ranging from $5 to $10, depending on the supplier. Its built-in Wi-Fi capabilities reduce the need for additional communication modules, making it a cost-effective choice.
- MEMS sensors: The accelerometer and gyroscope are critical for detecting motion. These sensors cost approximately $2 to $5 each, contributing to the overall affordability of the system.
- Power supply: The system operates on a rechargeable battery, which costs around $10 to $20. Power management strategies are in place to ensure that the system operates

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efficiently, reducing the need for frequent recharging.

In terms of software, the Arduino IDE is free to use, and the Blynk app offers a cost-effective solution for cloud services and user interfaces, with minimal subscription fees for advanced features. The total cost for a single unit of the IoT Smart Bike System is estimated to be between $40 to $60, making it an affordable solution for individual users. For mass production, economies of scale could further reduce costs, making the system a commercially viable product.

6. Results and Discussion

Fig (i) Integration of IoT in 2 wheeler vehicle

Several tests were conducted to evaluate the performance of the IoT Smart Bike System, focusing on the Smart Bike Finder, Anti-Theft Notification System, and Smart Stop Ignition features. The system was tested in various environments to assess its reliability, responsiveness, and efficiency.

The Smart Bike Finder was tested using Wi-Fi triangulation for location tracking. Results showed that in urban areas with strong Wi-Fi signals, the system could locate the bike with an accuracy of 10–15 meters. However, in areas with weaker Wi-Fi signals, the accuracy decreased slightly. Despite this, the system proved effective in providing real-time location updates through the Blynk app, ensuring that users could reliably track their bikes in most conditions.

The Anti-Theft Notification System was tested by simulating different theft scenarios, such as tampering with the bike or attempting to move it without authorization. The MEMS sensors (accelerometer and gyroscope) accurately detected abnormal movements and triggered alerts in under 5 seconds. The system demonstrated excellent sensitivity to theft attempts, providing timely notifications through the Blynk app. This ensured that users were informed almost immediately when suspicious activity occurred. The Smart Stop Ignition feature was tested by allowing users to remotely disable the bike’s ignition via the Blynk app. The system responded within 2–3 seconds of receiving the stop command, successfully preventing unauthorized use of the bike. This feature was effective in both stationary and moving conditions, giving the user full control over the bike’s ignition remotely. Power consumption was another crucial factor tested. The ESP32's power saving modes helped reduce battery usage during idle times. The system remained operational for extended periods without needing frequent recharges, making it practical for real world applications where bikes may remain parked for long durations. One challenge observed during testing was the system's reliance on Wi-Fi for communication and tracking. In areas with limited Wi-Fi coverage, the system’s performance was affected, particularly in sending notifications or providing accurate

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location data. However, this can be mitigated by ensuring the bike is in an area with stable Wi-Fi or enhancing the network with extenders.

Overall, the testing demonstrated that the IoT Smart Bike System is a reliable and responsive solution for bike security. The Wi-Fi-based location tracking was effective in most urban settings, while the Anti-Theft Notification System and Smart Stop Ignition provided robust protection against theft. The system's low power consumption and fast response times make it a practical solution for enhancing bike security in urban environments.

6.1Feature-Specific Working and Mobile Notifications

a). Smart Stop Ignition System

Fig (i) Smart stop ignition system

- This feature detects an excessive tilt of the bike using the MEMS sensor accelerometer and gyroscope sensors
- If the bike tilts beyond a predefined threshold (indicating an accident), the ESP32 microcontroller immediately triggers the ignition cut-off relay.
- This prevents further damage to the vehicle and injury to the rider.
- The system sends an instant notification to the user's mobile phone via the Blynk app , alerting them about the accident.
- Users can also check the status of their vehicle remotely through the app.

b). Smart Bike Finder

Fig (ii) Smart bike finder

- This feature helps users locate their bike in a crowded parking area.
- When activated via the Blynk app, the ESP32 microcontroller triggers the buzzer and signal indicators on the bike.
- The buzzer produces a loud beeping sound, and the indicator lights start blinking, making the bike easy to spot.
- The user can turn the finder on or off using the mobile app.
- A confirmation message is displayed in the app when the feature is activated or deactivated.

c). Anti-Theft Notification System

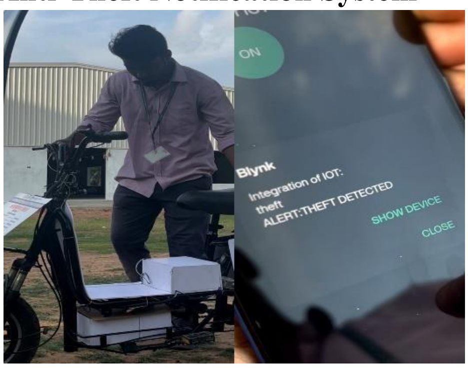

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Fig (iii) Anti-theft notification

- The system continuously monitors the bike's movement using MEMS sensors.
- If any unauthorized movement or vibration is detected, the ESP32 microcontroller instantly sends an alert notification to the user's mobile via Blynk.
- If the movement persists, the system can automatically trigger the Smart Stop Ignition System, cutting off the engine to prevent theft.
- A real-time log of security alerts is maintained in the app for user reference.
- The system provides instant notifications, ensuring the user can take immediate action if needed.

7. Conclusion

The IoT Smart Bike System represents a significant advancement in enhancing the security and convenience of bike ownership through the integration of IoT technologies. By leveraging the ESP32 microcontroller, MEMS sensors, and the Blynk app, the system successfully addresses key challenges faced by bike owners, such as theft prevention, remote monitoring, and control. The inclusion of features like the Smart Bike Finder, Anti-Theft Notification System, and Smart Stop Ignition provides a holistic solution that ensures peace of mind for users. By using ESP32, a powerful yet affordable microcontroller, the system benefits from built-in Wi-Fi capabilities, enabling seamless communication with the Blynk app. The integration of MEMS sensors allows for real-time monitoring of the bike's movement, detecting potential theft or unauthorized access in a timely manner.

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