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BiSafe: An IoT-Based Smart Bike Security System

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Abstract*—Two-wheeler theft has emerged as a serious concern in urban and semi-urban regions, where effective yet affordable vehicle security solutions are limited. Conventional mechanical locks and basic alarm systems provide minimal protection and fail to support real-time monitoring or recovery assistance. Although advanced vehicle security solutions exist, they are often expensive, subscription-based, and targeted toward premium vehicles. This paper presents BiSafe, a low-cost, industry-oriented Internet of Things (IoT)- based smart bike security system designed to provide real-time theft detection, prevention, and recovery support. The proposed system integrates an ESP32 microcontroller, an EC200U LTE communication module, an MPU6050 motion sensor, an ESP32 CAM, a Global Positioning System (GPS) tracking system, and a relay-based engine immobilisation mechanism. A cross-platform application developed using Flutter enables users to configure geofencing parameters, monitor live vehicle location, receive instant alerts, and remotely disable the engine when unauthorised movement is detected. Cloud-based backend services are used for secure authentication, alert management, and real-time data storage. Experimental evaluation demonstrates that the proposed system delivers reliable performance and security features comparable to those of commercial solutions, while maintaining affordability and scalability.

***Keywords* - IoT security; smart bike protection; low cost vehicle security; geofencing; ESP32; engine immobilization; real time GPS tracking**

I. INTRODUCTION

Vehicle theft, particularly two-wheeler theft, remains a major challenge across many regions worldwide. Traditional security mechanisms such as steering locks, chains, and basic alarm systems offer limited protection and do not provide any real-time monitoring or recovery support once a theft occurs. As a result, stolen vehicles are often difficult to track and recover. Recent advancements in Internet of Things technology and mobile computing have enabled the development of intelligent vehicle security solutions using compact hardware and cloud platforms. However, most commercially available systems are costly and primarily designed for high-end vehicles, making them inaccessible to common users. The BiSafe system is designed to address this gap by offering advanced security features such as geofencing, motion detection, engine immobilisation, and visual monitoring at a low implementation cost. The system aims to provide reliable, user-controlled, and scalable bike security suitable for real-world deployment.

II. LITERATURE SURVEY

Current vehicle security relies heavily on mechanical locks, which are easily bypassed. Recent studies show that while GPS tracking is common, the lack of remote engine control makes vehicle recovery difficult. Research by Ashton (2009) highlights the importance of the Internet of Things in everyday asset protection. The BiSafe system addresses these gaps by integrating ESP32-CAM for visual evidence, which is often missing in existing low-cost solutions.

III. PROBLEM STATEMENT

The rising number of two-wheeler theft incidents highlights the limitations of existing vehicle security solutions. Many currently available systems suffer from one or more of the following drawbacks:

- Absence of real-time theft detection
- Lack of user-configurable geofencing
- No remote engine immobilisation capability
- Unavailability of visual evidence during theft
- High device cost and recurring subscription charges
- Limited integration with modern mobile applications

There is a clear requirement for a low-cost, intelligent, and user-controlled security system that not only detects theft but

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also actively prevents unauthorised usage and assists in vehicle recovery.

IV. EXISTING SYSTEM

Existing bike security solutions primarily depend on basic Global Positioning System tracking and short message service-based alerts. Some systems provide geofencing functionality, but with fixed or limited radius configurations. High-end solutions may include engine immobilisation and mobile applications; however, such systems are expensive and unsuitable for widespread adoption among common users.

In addition, most existing solutions do not support motion-based pre-theft alerts or camera-based monitoring, which reduces their effectiveness during real theft scenarios.

V. PROPOSED SYSTEM

The proposed BiSafe system is an integrated Internet of Things-based security solution that combines multiple layers of protection while maintaining low cost and high reliability. The system allows users to define custom geofencing boundaries, monitor live vehicle location, receive instant alerts, and remotely disable the engine during unauthorised movement.

A. Key Features

- User configurable geofencing radius
- Real-time GPS-based location tracking
- Motion-based pre-theft alerts
- Automatic phone call and message alerts
- Remote engine immobilisation
- Image capture during theft events
- Cross-platform mobile and web application
- Cloud-based backend automation

The system is designed to be scalable and suitable for mass adoption in real-world environments.

VI. SYSTEM ARCHITECTURE

The BiSafe system consists of three major components:

A. Hardware Unit

The bike-mounted hardware unit includes the ESP32 microcontroller, EC200U LTE communication module, MPU6050 motion sensor, ESP32 CAM, relay module for engine control, and a rechargeable lithium-ion battery.

B. Software Layer

The firmware is developed using the Arduino framework to handle sensor data processing, communication, and control logic. A Flutter-based application provides a unified interface for Android, iOS, and web platforms.

C. Backend Infrastructure

Cloud backend services are used for authentication, real-time data storage, alert handling, and device-to-user mapping. The backend enables secure and reliable communication between the hardware unit and the user application.

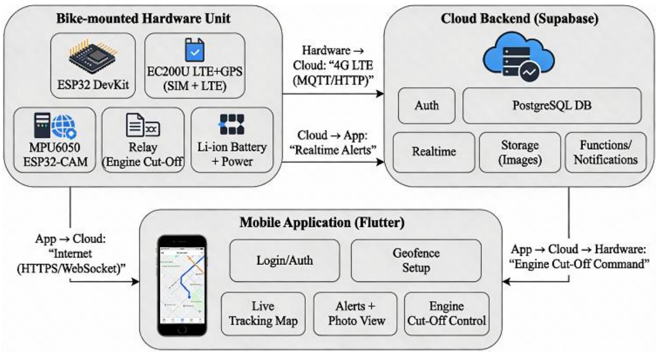

Fig. 1. System Architecture

VII. HARDWARE DESCRIPTION

The ESP32 microcontroller serves as the central processing unit, managing sensor inputs, communication modules, and system logic. The EC200U LTE module provides cellular connectivity for GPS tracking, message transmission, and call alerts. The MPU6050 sensor detects abnormal motion and vibration, enabling pre-theft detection. The ESP32 CAM captures images during theft events to provide visual evidence. A relay module is used to remotely disable the engine ignition, while rechargeable lithium-ion batteries supply portable power to the system.

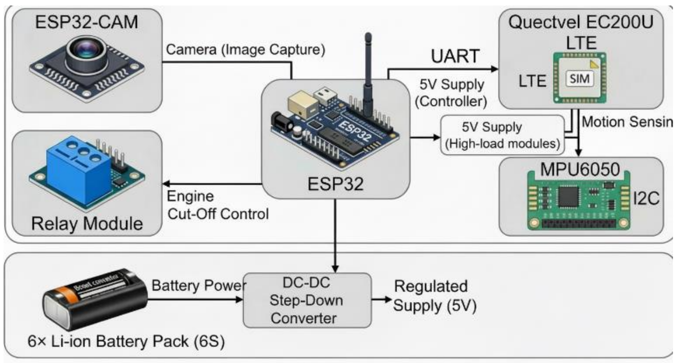

Fig. 2. Hardware Description

VIII. SOFTWARE DESCRIPTION

The embedded firmware continuously monitors GPS and motion sensor data, performs geofence validation, triggers alerts, and controls engine immobilisation. The mobile application allows users to configure system parameters, view live location, and receive notifications. The backend infrastructure manages user authentication, alert logging, real-time data updates, and secure data access.

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IX. WORKING METHODOLOGY

After installation and device registration, the user configures a circular geofence by selecting a centre location and defining a radius. The BiSafe hardware unit continuously monitors the vehicle location and motion data. Based on the geofence status and detected movement, the system executes appropriate security actions.

A. Distance Calculation

The system computes the distance between the current vehicle location and the geofence centre using a spherical distance calculation method to ensure accurate boundary detection.

B. Security Workflow

When the vehicle remains within the geofence, the system monitors motion and sends pre-theft alerts upon abnormal vibration. If the vehicle moves outside the geofence, the system initiates alert actions, including phone calls, messages with live location, image capture, and backend logging. During recovery mode, the user can track the vehicle in real time and remotely immobilise the engine through the application.

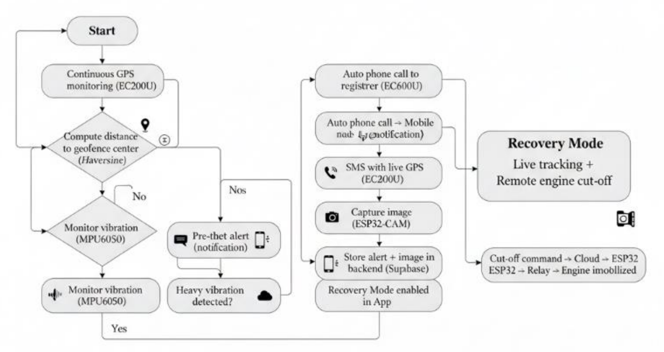

Fig. 3. Theft Detection Workflow

X. EXPERIMENTAL RESULTS

The BiSafe hardware unit was tested for geofencing accuracy using the Haversine formula. * In a test radius of 100 meters, the system successfully triggered phone calls and SMS alerts within 5 seconds of the vehicle crossing the boundary. * The ESP32-CAM captured and uploaded clear images to the Supabase cloud backend during simulated theft events. * Remote engine immobilisation via the Flutter application was tested multiple times and showed zero failure rate.

TABLE I. Performance Analysis of BiSafe System

Parameter	*Testing Scenario*	*Measured Value (Avg)*
GPS Accuracy	Open Sky Environment	2.5 meters
Alert Latency	4G LTE Network	1.8 – 3.2 seconds
Image Upload Time	640x480 Resolution	5.5 seconds
Battery Life	3000mAh Li-ion Pack	40 – 48 hours

XI. BACKEND IMPLEMENTATION

The backend infrastructure manages user authentication, device linking, real-time GPS updates, alert history storage, and automated processes. This architecture improves system reliability while reducing dependency on manual verification mechanisms.

XII. RESULT AND DISCUSSION

The system was tested under real-world conditions with varying geofence sizes and motion scenarios. Experimental results demonstrate accurate geofence detection, timely alert delivery, stable GPS tracking, and reliable engine immobilisation. Despite its low-cost design, the BiSafe system performs comparably to commercial security solutions.

XIII. CONCLUSION

The BiSafe system demonstrates that an advanced and reliable bike security solution can be implemented using cost-effective Internet of Things hardware and cloud technologies. By integrating real-time monitoring, theft prevention, and recovery mechanisms, the system offers a practical and scalable solution for two-wheeler security. Its affordability and modular design make it suitable for individual users, startups, and industry-level deployment.

XIV. FUTURE ENHANCEMENTS

Future improvements may include artificial intelligence-based image analysis for theft identification, voice command integration, enhanced power management techniques, and integration with law enforcement systems.

XV. INTELLECTUAL PROPERTY AND COMMERCIAL SCOPE

BiSafe represents a unique solution crafted to address real-world challenges in bike security. Its proprietary architecture facilitates potential for industry-level applications ranging from two-wheeler theft prevention to fleet management solutions. For commercial deployment, appropriate licenses will be required to safeguard the intellectual property developed by the authors, ensuring ethical technology usage while fostering partnerships with startups and government agencies.

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