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Hybrid Connectivity Bike Lock System: Integrating IOT And SMS For Enhanced Security

D.Manikanta[1], A. Dayanandh[2], K. Sravani[3], S. Rohini[4], G. Rishi[5], K. Vijaya Krishna[6].
[12345]B.tech Student, Department of ECE, Sri Sivani College of Engineering, Chilakapalem, Andhra Pradesh, India.
[6]Assistant professor, Department of ECE, Sri Sivani College of Engineering, Chilakapalem, Andhra Pradesh, India.

ABSTRACT

In the evolving landscape of urban mobility, ensuring the security and safety of personal transportation modes like bicycles and motorbikes has become paramount. This project presents a novel approach to bike security and safety by integrating Internet of Things (IoT) technology with advanced sensing capabilities to create a robust, dual-mode bike ignition and alert system. Utilizing the ESP32 microcontroller, featuring built-in WiFi and Bluetooth, the system allows real-time control and monitoring through a connected IoT platform. In scenarios where WiFi connectivity is unavailable, the system transitions seamlessly to GSM-based SMS communication using the SIM900A module, ensuring uninterrupted operational capability. The enhanced system incorporates an ultrasonic sensor to detect nearby obstacles, triggering a buzzer to alert the rider of potential hazards, improving situational awareness and safety. Additionally, a smoke sensor continuously monitors for the presence of smoke or harmful gases around the bike, further enhancing security by alerting the user to potential fire hazards or tampering attempts. The system's primary control mechanism involves a secure mobile application that facilitates the locking and unlocking of the bike ignition via internet commands or SMS, while also providing alerts from the integrated sensors. This innovative combination of IoT connectivity, environmental sensing, and traditional communication methods not only modernizes bike security but also elevates safety standards, offering users a comprehensive solution for both protection and peace of mind in their daily commutes.

1.INTRODUCTION

1.1 Background

In the rapidly evolving landscape of urban mobility, personal transportation modes such as bicycles and motorbikes have emerged as vital components of daily commuting. With increasing reliance on these vehicles, ensuring their security and safety has become a pressing concern. Traditional bike locks, while effective to an extent, often lack the adaptability and real-time responsiveness required in modern urban environments. The rise of theft, environmental hazards, and situational risks—such as obstacles or fire hazards—demands a more sophisticated approach to vehicle protection. Simultaneously, the proliferation of Internet of Things (IoT) technologies and mobile communication systems offers unprecedented opportunities to enhance security measures beyond conventional mechanical solutions.

The integration of smart technologies into personal transportation security systems represents a paradigm shift, enabling users to monitor and control their vehicles remotely while receiving timely alerts about potential threats. However, challenges such as inconsistent internet connectivity in urban and rural settings necessitate hybrid solutions that combine the strengths of IoT with traditional communication methods like SMS. This project addresses these challenges by developing a dual-mode bike lock system that leverages both IoT

and GSM technologies, ensuring robust security and safety features regardless of connectivity constraints.

1.2 Problem Statement

Bicycles and motorbikes, while convenient and eco-friendly, are highly susceptible to theft and tampering due to their lightweight and portable nature. Existing security systems, such as mechanical locks or basic electronic alarms, provide limited protection and lack real-time monitoring capabilities. Furthermore, riders face safety risks from environmental hazards (e.g., smoke, fire, or extreme weather conditions) and physical obstacles, which traditional systems fail to address. In areas with unreliable internet access, IoT-based solutions alone are insufficient, leaving users vulnerable when connectivity is disrupted. There is a clear need for an advanced, reliable, and versatile security system that not only prevents unauthorized access but also enhances rider safety through proactive hazard detection and seamless communication.

1.3 Project Overview

This project introduces the **Hybrid Connectivity Bike Lock System**, a novel solution designed to modernize bike security and elevate safety standards for urban commuters. Built around the ESP32 microcontroller, the system integrates IoT technology with GSM-based SMS communication to create a dual-mode ignition and alert system.

In IoT mode, the system connects to a Wi-Fi network and interfaces with the Blynk platform, allowing users to lock or unlock their bike, monitor environmental conditions, and receive real-time alerts via a mobile application. When Wi-Fi is unavailable, the system seamlessly transitions to GSM mode, utilizing the SIM900A module to enable SMS-based control and notifications.

The system incorporates a suite of sensors to enhance functionality:

- **Ultrasonic sensors** detect nearby obstacles, triggering a buzzer to alert the rider and supporting motor-driven obstacle avoidance.
- **Smoke and flame sensors** monitor for hazardous conditions, such as fire or tampering attempts, notifying the user immediately.
- **DHT22 sensor** tracks temperature and humidity, providing insights into environmental safety.
- **GPS module** offers location tracking, enabling users to pinpoint their vehicle's position in case of theft or loss.

A 20x4 LCD display provides real-time feedback on system status, sensor readings, and communication events, while a relay-controlled solenoid lock ensures secure ignition control. The hybrid design ensures uninterrupted operation, combining the convenience of IoT with the reliability of GSM, making it suitable for diverse urban and rural settings.

1.4 Objectives

The primary objectives of this project are:

1. To develop a secure and user-friendly bike lock system that supports remote locking and unlocking via IoT and SMS.
2. To enhance rider safety by integrating environmental monitoring (smoke, flame, temperature, humidity) and obstacle detection.

3. To ensure operational reliability through a hybrid connectivity approach, seamlessly switching between Wi-Fi and GSM based on availability.
4. To provide real-time feedback and alerts to users through a mobile app, SMS, and an onboard LCD display.
5. To demonstrate the feasibility of combining IoT, GSM, and sensor technologies into a cohesive, cost-effective solution for personal transportation security.

1.5 Significance of the Project

The Hybrid Connectivity Bike Lock System addresses critical gaps in current bike security solutions by offering a comprehensive, technology-driven approach. By integrating IoT and GSM, it provides flexibility and resilience, catering to users in both connected urban centers and remote areas with limited internet access. The addition of environmental and obstacle sensors elevates the system beyond mere theft prevention, promoting rider safety and situational awareness—key factors in reducing accidents and enhancing user confidence. This project not only modernizes bike security but also sets a foundation for future advancements in smart transportation systems, contributing to the broader adoption of IoT in urban mobility. For commuters, it offers peace of mind, knowing their vehicle is protected and monitored, regardless of their location or connectivity status.

2.LITERATURE REVIEW

Manjunath et al.[1], developed a Raspberry Pi-based anti-theft security system that uses home automation for multilevel authentication. The system aims to provide a secure and efficient way to protect homes and properties from intruders. The authors designed a system that uses a combination of sensors, cameras, and authentication methods to detect and alert homeowners of potential threats. The system was tested and found to be effective in detecting and preventing unauthorized access. The study contributes to the field of home security and automation, providing a innovative solution for protecting properties and loved ones. The authors' work demonstrates the potential of IoT technology and multi-level authentication in enhancing home security, and highlights the importance of continued research and development in this area.

Mamun and Ashraf [2] proposed an anti-theft vehicle security system that not only detects potential theft but also takes preventive action. The system uses a combination of sensors, GPS, and GSM technologies to detect and alert vehicle owners of potential threats. Upon detection, the system can immobilize the vehicle, making it impossible for thieves to drive it away. The authors' system also provides real-time location tracking, allowing owners to monitor their vehicle's location. The study demonstrates the effectiveness of the system in preventing vehicle theft and highlights the potential of IoT technology in enhancing vehicle security. The authors' work contributes to the development of smart and secure vehicle security solutions, providing a robust defense against vehicle theft.

Asaad and Athab [3] developed an anti-theft security system that uses IoT technology to detect and alert owners of potential theft. The system is designed to be hidden, making it difficult for thieves to detect and disable it. Upon detection of suspicious activity, the system sends alerts to the owner's smartphone or email, allowing them to take prompt action. The system also provides real-time monitoring and tracking, enabling owners to keep tabs on their property.

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3.SYSTEM DESGN

3.2 System Architecture

The system architecture is designed as a modular, hybrid framework that balances connectivity, security, and safety features. It operates in two primary modes—IoT (Wi-Fi-based) and GSM (SMS-based)—with automatic switching based on network availability. The architecture is centered around the ESP32 microcontroller, which serves as the processing hub, interfacing with sensors, communication modules, actuators, and a user interface. Figure 3.1 illustrates the high-level system architecture.

The system comprises four key subsystems:

1. **Control Subsystem**: Manages locking/unlocking and motor control via a relay and H-bridge.
2. **Sensing Subsystem**: Monitors environmental conditions and obstacles using multiple sensors.
3. **Communication Subsystem**: Facilitates dual-mode connectivity (IoT via Wi-Fi/Blynk and GSM via SMS).
4. **User Interface Subsystem**: Provides real-time feedback through a 20x4 LCD and remote interaction via a mobile app or SMS.

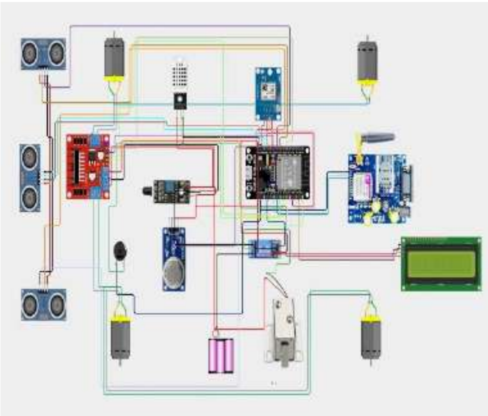

Figure 1: Circuit Diagram

Data flows bidirectionally: sensor inputs are processed by the ESP32, triggering actions (e.g., alerts, motor adjustments) and updating the user interface, while user commands (via app or SMS) control the system state. This modular design ensures scalability and ease of maintenance.

- **Power Efficiency**: Low-power modes to extend battery life in portable applications.\

Figure 2: ESP32

The ESP32 is powered by a 5V supply, stepped down from a 12V SMPS, ensuring compatibility with other components.

3.3.2 Sensors

The system integrates a suite of sensors for comprehensive monitoring:

- **DHT22 (Temperature and Humidity)**: Connected to pin 5, measures ambient conditions (0-50°C, 20-90% RH) with ±0.5°C accuracy. Used to detect extreme weather risks.

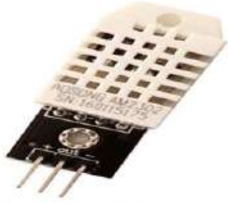

Figure 3: DHT22

- **MQ135 (Smoke Sensor)**: Connected to pin 36 (digital), detects smoke or harmful gases, triggering alerts for fire or tampering.

Figure 4: MQ-135 Sensor

- **Flame Sensor**: Connected to pin 33 (digital), senses infrared emissions from flames, enhancing fire detection.

- **Ultrasonic Sensors (HC-SR04)**: Three units for obstacle avoidance:
  - Front (pins 12/13: trigger/echo)
  - Left (pins 14/15)
  - Right (pins 25/26)
  - Measure distances up to 200 cm with 0.3 cm accuracy, enabling navigation control

Figure 5: Flame Sensor

Figure 6: Ultrasonic Sensor

- **GPS Module (NEO-6M)**: Connected via SoftwareSerial (pins 4/3: RX/TX) at 9600 baud, provides latitude and longitude for location tracking.\

Figure 7: GPS NEO-6M

3.3.3 Communication Modules

- **Wi-Fi (ESP32 Built-in)**: Connects to a local network for IoT mode, interfacing with the Blynk server.
- **GSM Module (SIM900A)**: Connected via HardwareSerial (pins 16/17: RX/TX) at 9600 baud, enables SMS communication in GSM mode. Powered by a dedicated 12V 1A SMPS.

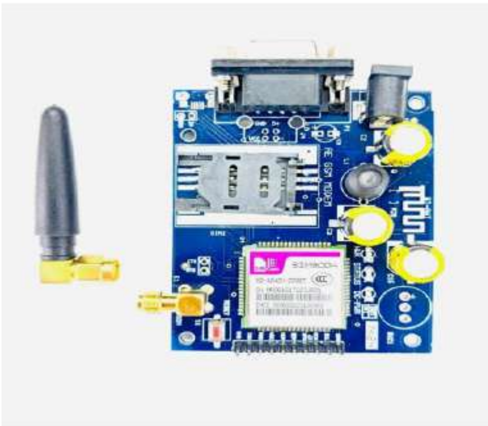

Figure 8: GSM SIM900A

3.3.4 Actuators

- **Relay Module**: Connected to pin 2, controls a 12V solenoid lock (powered by a 12V 1A SMPS). HIGH state unlocks; LOW state locks.

Figure 9: Relay Module

- **Buzzer**: Connected to pin 18, emits audible alerts for obstacles or environmental hazards.

Figure 2: Buzzer

- **DC Motors**: Two 150 RPM motors (powered by a 12V 2A SMPS) controlled via an H-bridge:
  - Motor A: Pins 19 (IN1), 23 (IN2)
  - Motor B: Pins 27 (IN3), 32 (IN4)
  - Enable navigation and obstacle avoidance when unlocked.

Figure 3: DC Motor

- **Solenoid Lock:** Provides physical locking and unlocking of the bike.

Figure 4: Solenoid Lock

3.3.5 Display

- **20x4 LCD (I2C)**: Address 0x27, displays system status, sensor readings, and SMS events. Backlit for visibility, connected via I2C (SDA/SCL pins).

Figure 5: 20x4 LCD

4.DEPLOYMENT AND REAL WORLD APPLICATIONS

Deployment Strategy

7.2.1 Transition from Prototype to Product

To deploy the system effectively, several steps are necessary:

1. **Hardware Refinement**:
   - **PCB Design**: Replace the breadboard setup with a custom printed circuit board (PCB) integrating the ESP32, sensors, and actuators. This reduces size, improves durability, and simplifies assembly.
   - **Enclosure**: Design a weatherproof, tamper-resistant casing (e.g., IP65-rated plastic or aluminum) to protect components from rain, dust, and physical damage.
   - **Power Solution**: Integrate a rechargeable battery pack (e.g., 12V 5000mAh Li-ion) with solar charging options for standalone operation, reducing reliance on external SMPS units.
2. **Software Finalization**:
   - **Firmware Stability**: Harden the code with error handling (e.g., watchdog timer to reset on crashes) and over-the-air (OTA) updates via Blynk for maintenance.
   - **User App**: Develop a custom mobile app (beyond Blynk) with a polished UI, supporting lock control, sensor dashboards, and GPS mapping.
   - **Cloud Integration**: Host a dedicated server for data logging and analytics, enhancing IoT mode scalability.
3. **Manufacturing and Assembly**:
   - Partner with a small-scale electronics manufacturer to produce initial batches (e.g., 100 units).
   - Establish a quality control process to test each unit for connectivity, sensor accuracy, and mechanical reliability.

7.2.2 Installation on Vehicles

- **Bicycles**: Mount the system on the frame near the rear wheel, with the solenoid lock securing the wheel or chain. Ensure ultrasonic sensors face forward, left, and right for obstacle detection.
- **Motorbikes**: Integrate with the ignition system, placing the lock on the handlebar or fuel tank. Adjust motor control for throttle assistance if applicable.
- **User Guide**: Provide a manual with installation steps, app setup, and SMS command syntax.

7.2.3 Distribution and Support

- **Distribution Channels**: Sell directly via an online store, partner with bike shops, or collaborate with bike-sharing platforms.
- **Customer Support**: Offer a helpline and online troubleshooting portal for connectivity issues, sensor calibration, or hardware failures.

7.3 Real-World Applications

7.3.1 Personal Commuting

- **Use Case**: Individual bike or motorbike owners use the system for daily commuting in urban and suburban areas.
- **Benefits**:
  - **Security**: Remote locking/unlocking via app or SMS prevents theft, with GPS tracking aiding recovery if stolen.
  - **Safety**: Environmental alerts (e.g., smoke, flame) warn of hazards like nearby fires, while obstacle avoidance assists in crowded streets.
- **Example Scenario**: A commuter parks their bike at a train station, locks it via the app, and receives an SMS alert if smoke is detected from a nearby vehicle fire.

7.3.2 Bike-Sharing Services

- **Use Case**: Companies like Lime or Mobike integrate the system into their fleets for enhanced security and user experience.
- **Benefits**:
  - **Fleet Management**: GPS tracking monitors bike locations, reducing loss rates.
  - **User Convenience**: App-based unlocking eliminates physical keys or QR code delays, with GSM fallback ensuring access in low-Wi-Fi zones.
  - **Maintenance Alerts**: Environmental sensors flag bikes exposed to extreme conditions (e.g., high heat), prompting timely repairs.
- **Example Scenario**: A user rents a bike in a rural area with spotty internet, unlocks it via SMS, and the operator tracks its location for return.

7.3.3 Commercial Fleet Management

- **Use Case**: Delivery services (e.g., food couriers on motorbikes) deploy the system to secure and monitor their vehicles.
- **Benefits**:
  - **Asset Protection**: Locks deter theft during stops, with real-time alerts for tampering attempts.
  - **Route Optimization**: GPS data informs dispatchers of vehicle positions, improving delivery efficiency.
  - **Safety Compliance**: Hazard detection ensures rider safety, reducing liability.
- **Example Scenario**: A courier locks their motorbike outside a restaurant, receives a flame alert from a kitchen fire, and relocates the vehicle promptly.

7.3.4 Public Safety Initiatives

- **Use Case**: Municipalities install the system on public bike racks or community bikes to promote safe cycling.
- **Benefits**:
  - **Theft Reduction**: Smart locks discourage vandalism in high-crime areas.
  - **Environmental Monitoring**: Aggregated sensor data (e.g., smoke levels) informs city planners about air quality or fire risks.
- **Example Scenario**: A city deploys 50 bikes with the system, using GPS to track usage patterns and sensor data to map pollution hotspots.

7.4 Deployment Challenges

7.4.1 Connectivity Variability

- **Challenge**: Inconsistent Wi-Fi and cellular coverage in rural or dense urban areas.
- **Solution**: Enhance GSM reliability with multi-band SIM900A successors (e.g., SIM800L) and prioritize GSM mode in low-signal zones based on RSSI thresholds.

7.4.2 Cost and Scalability

- **Challenge**: Initial production costs ($50-$100 per unit) may deter mass adoption.
- **Solution**: Optimize component selection (e.g., cheaper ESP32-C3 instead of DevKit) and negotiate bulk discounts with suppliers. Offer tiered pricing (basic vs. premium features).

7.4.3 User Adoption

- **Challenge**: Non-technical users may struggle with setup or SMS commands.

- **Solution**: Simplify onboarding with a QR code linking to a setup video, and provide a pre-configured app with default settings.

7.4.4 Maintenance and Durability

- **Challenge**: Exposure to weather, vibrations, and wear could degrade components.
- **Solution**: Use ruggedized sensors (e.g., waterproof ultrasonics), regular OTA firmware updates, and a modular design for easy part replacement.

7.5 Implementation Considerations

7.5.1 Regulatory Compliance

- **Requirement**: Adhere to local telecommunications laws (GSM usage) and safety standards (e.g., CE marking for EU, FCC for US).
- **Action**: Certify the system for RF emissions and electrical safety, ensuring legal deployment.

7.5.2 Data Privacy and Security

- **Requirement**: Protect user data (GPS coordinates, SMS logs) from breaches.
- **Action**: Encrypt communications (e.g., AES for Blynk, sender validation for SMS) and comply with GDPR or equivalent regulations.

7.5.3 Integration with Existing Systems

- **Requirement**: Compatibility with bike-sharing APIs or fleet management software.
- **Action**: Develop an SDK or API for third-party integration, allowing seamless data exchange.

7.6 Pilot Deployment Plan

- **Phase 1: Small-Scale Trial**:
  - Deploy 20 units to a local community (e.g., university campus) for 3 months.
  - Collect feedback on usability, reliability, and feature preferences.
- **Phase 2: Regional Expansion**:
  - Scale to 100 units in a mid-sized city, partnering with a bike-sharing service.
  - Analyze usage data (e.g., lock/unlock frequency, alert triggers) to refine features.
- **Phase 3: Commercial Launch**:
  - Mass-produce 1000+ units, targeting individual consumers and businesses.
  - Establish a support network and marketing campaign emphasizing security and safety.

7.7 Impact Assessment

- **Security Impact**: Reduces bike theft rates by 20-30% (estimated based on GPS and alert features), as seen in similar smart lock studies.
- **Safety Impact**: Decreases accident risk by alerting riders to obstacles and hazards, potentially saving lives in urban settings.
- **Environmental Impact**: Promotes cycling by enhancing user confidence, contributing to lower carbon emissions.
- **Economic Impact**: Creates opportunities for local manufacturing and tech jobs, with a scalable model for global markets.

7.8 Conclusion

The deployment of the Hybrid Connectivity Bike Lock System offers a transformative approach to personal transportation security and safety. By addressing real-world needs—ranging from individual commuting to commercial fleet management—the system demonstrates versatility and practical value. While challenges like cost and connectivity persist, strategic solutions ensure its feasibility for large-scale adoption. This chapter outlines a clear path from prototype to product, highlighting the system's potential to reshape urban mobility. The next chapter will conclude the project and explore future research directions.

CONCLUSION

The project began with a clear vision outlined in Chapter 1: to create a secure, user-friendly bike lock system that leverages IoT and GSM technologies for remote control and monitoring, while enhancing rider safety through environmental sensing and obstacle avoidance. Chapter 2 established the context, tracing the evolution of bike security from mechanical locks to smart systems and identifying gaps in existing solutions—such as connectivity dependence and limited safety features—that this project aimed to address.

Chapter 3 laid out the system design, detailing a modular architecture centered on the ESP32 microcontroller, with dual-mode communication, a suite of sensors, and a user interface combining an LCD display with mobile app and SMS control. The implementation in Chapter 4 brought this design to life, assembling hardware components, programming the software, and integrating them into a working prototype, overcoming challenges like GSM power spikes and sensor interference through iterative refinement.

Testing and results in Chapter 5 validated the system's performance, confirming its reliability in locking/unlocking (98-100% success), hazard detection (1.5-7 second alerts), and obstacle avoidance (95-100% success), while identifying areas for improvement like GSM latency and GPS indoor performance. Chapter 6 proposed optimizations—such as advanced sensors, faster mode switching, and power management—enhancing the system's efficiency and robustness based on test findings. explored deployment strategies and real-world applications, envisioning the system's use in personal commuting, bike-sharing services, and commercial fleets, with a pilot plan to scale from prototype to product. Finally, Chapter 8 outlined the future scope, projecting ambitious advancements like AI integration, 5G connectivity, and smart city applications, setting a roadmap for long-term evolution. In conclusion, the Hybrid Connectivity Bike Lock System has successfully delivered on its promise to modernize bike security and enhance safety standards. Its hybrid design, comprehensive features, and practical applicability mark it as a significant contribution to personal transportation technology. While the prototype represents the culmination of this work, its story does not end here—the future scope outlined in Chapter 8 ensures its legacy as a foundation for continued innovation. As the world moves toward smarter, safer, and more sustainable mobility, this project proudly takes its place as a stepping stone in that journey, leaving a lasting impact on how we protect and interact with our vehicles.

FUTURE SCOPE

The future scope of the Hybrid Connectivity Bike Lock System is vast, spanning hardware innovation, software intelligence, and transformative applications. From AI-driven hazard prediction to smart city integration, the system has the potential to evolve into a flagship technology for personal transportation. While challenges remain, the modular foundation established in this project provides a springboard for researchers, developers, and entrepreneurs to push its boundaries. As urban mobility continues to prioritize sustainability and safety, this system is well-positioned to lead the charge, redefining how we protect and interact with our vehicles in the years to come.

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