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IoT-Enabled Smart Home Security System Using ESP32 Nano with Real-Time Intrusion Alerts via Telegram Bot and Automated Locking Mechanism

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Abstract- Home security has grown to be a boosting issue in the current society and as such, there has been a necessity of affordable and effective security equipment to protect residential areas. In this paper, a smart home security system connected to the IoT is introduced and includes a laser module, ESP32 Nano, LDR sensor, buzzer, Telegram bot, and an electronic lock to identify intrusion and add more security. The system works based on an on-going scanning of a laser beam with the aid of an LDR sensor. Following the breakage of the laser path by an intruder, the LDR determines the disturbance and commands the ESP32 Nano to switch on the buzzer alarm, send an immediate notification through Telegram, and unlock the door automatically in order to inhibit illegal access. The application of IoT communication to the Telegram bot will guarantee that a homeowner can be alerted to any possible security breaches in real-time and respond adequately. The application of ESP32 Nano, which is a low-power microcontroller that has inbuilt Wi-Fi features, will make data processing efficient and also enable an easy remote communication with minimal power consumption. The design of the proposed system is aimed at being economically friendly to purchase and easy to install without requiring difficult wire connections or expensive hardware materials. It has a better automation, ability to have remote monitoring and ease of response as compared to traditional security systems. There is also the option of the very automatic locking that provides more layers of safety in reference to the intrusion security. The results indicate the system to be practical, reliable and scalable therefore making it a solution to consider in contemporary smart home setup. Additional visualization could be incorporated in the future such as camera support, AI support in motion mechanism, and cloud support in data storage to add more security and monitoring features.

Keywords: Home Security, IoT based System, ESP 32 Nano, Intrusion detection, Telegram Bot, Automated locking.

I. INTRODUCTION

Securing homes has become a very critical issue since cases of intrusions and unwarranted access have increased. Most of the traditional security systems prove costly in terms of installation and upkeep positions and therefore effective use of these systems cannot be attained by a good number of house hold occupants. The present paper offers a less expensive and feasible solution a laser-based intrusion detection system, crafted around an ESP32 Nano microcontroller that provides a reasonable cost and reliable protection in comparison to the costly conventional systems.

The suggested system will include a laser module, a sensor of the LDR (Light Dependent Resistor), an audible alarm, a smart locking mechanism, and a Telegram bot that will provide instant remote alerts. An interrupting laser beam detects the change in the LDR, which transmits a signal a signal to the ESP32 Nano. The microcontroller will then raise the alarm, send real time message to the owner using Telegram, as well as automatically lock the door so that he cannot enter. The combination of basic hardware and communication through the IoT enables the design to have continuous monitoring and quick action in case of an emergency. This study presents the architecture of such a system, the principles of its operation, its implementation, and testing, and also dismisses potential improvements to be done to enhance its strength and increase applicability in residential and commercial use.

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II. LITERATURE REVIEW

In the fight against residential energy consumption, Barhate et al. [1] (2025) came up with an intelligent home energy management system with a low-cost aiming at budget conscious home consumers. Their platform takes advantage of the Internet of Things (IoT) to manage the appliances at home and uses predictive algorithms, the Random Forest algorithm in this case to predict the power demand. The essence of the new system introduced by them is that it is still able to regulate the use of electricity depending on the set budget, to optimize the possibility of managing resources, and to avoid a manifestation of a suddenly high bill. The authors offer a viable solution to smarter and cost-effective energy regulation in the homes of the present days by combining machine learning to predict what to do and observe with IoT to control it in real time.

The intrusion-detection system suggested by Khope et al. [2] (2024), is based on an ESP32-CAM and comprises a laser-based system. An LDR is constantly assessing a beam of light and any deviation, right away, generates an alarm and forwards the mobile applications to the Blynk. The authors London investigates the mirrors with the goal to enlarge the beam-feed coverage to areas with larger dimensions, and according to the authors it is possible to introduce the laser-based integration into the systems of conventional and rather expensive voice monitors as an economical technological solution.

The study by Reshma et al. [3] (2023) introduced an IoT-enabled laser security device which consists of a combination of ESP32 microcontroller, a PIR motion sensor, and the Blynk mobile application. The fusion between motion and remote monitoring shows that increasing residential security and ease of control by sending automatic, real-time messages to their smartphones when motion or a break in a beam is detected, and thus, indicates the fusion between motion detection and remote surveillance can benefit residential security.

Sudarshan et al. [4] (2021) combined a laser security system based on ESP32-CAM with capturing the images of a potential intruder and sending the notification to gadgets connected to Wi-Fi. Using image capture and laser-based intrusion detection, they combine to make their design more situational awareness increasing in high regard over traditional alarm-only systems besides using less power.

The other studies [5], [6], [7] were devoted to adding other aspects like adding Arduino Nano, RFID modules, buzzers, and Telegram notifications. These systems not only track laser intrusions made but they also video images of intruders and dispatch real-time alerts and therefore enhanced real-time monitoring and reaction function in a home security installation.

III. METHODOLOGY

A. System Design & Planning

Define Understanding the Concept: The core idea behind this security system is straightforward: a laser beam is continuously projected, and when this beam is interrupted, it signals an alert.

B. System Architecture:

The security system consists of multiple interconnected components, as illustrated in the block diagram below. The Laser Module continuously projects a beam onto the LDR Module. The ESP32 Nano processes data from the LDR and triggers actions when the beam is interrupted.
The system can activate a Buzzer (Alarm), engage or release the Lock (Door), and send Telegram Alerts to notify the user.

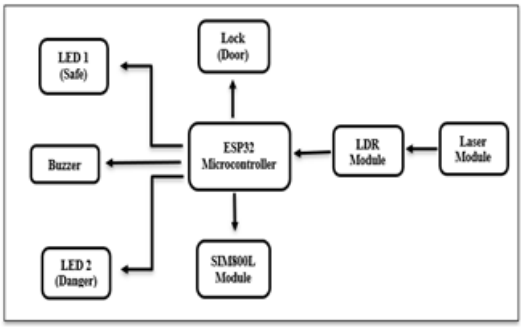

Figure 1.1

Figure 1.1: Block diagram representing the overall system architecture of the home security system.

C. Choosing the Right Components:

- **ESP32 Nano:** This microcontroller will handle data processing and control the overall operations of the system.
- **ESP32 Camera Module:** This component will take pictures of any potential intruders.
- **SIM800 GSM Module:** This module is essential for sending SMS alerts and making phone calls.
- **Laser Module:** This will emit the laser beam.
- LDR Sensor: This light-dependent resistor will detect when the laser beam is interrupted.
- **Resistor (7.5k Ohm):** This will help stabilize the readings from the LDR.
- **Power Supply (5V-12V):** This will provide the necessary power to all components.

D. Circuit Design & Hardware Setup Connecting the Components:

1) Connecting the components:

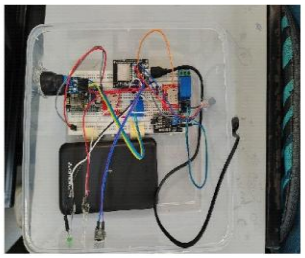

Figure 1.2

Figure 1.2: The hardware setup of the home security system, including ESP32 Nano, LDR module, laser module, relay, buzzer, and other components.

Start by setting up the ESP32 Nano as the main controller for the system [10].

- **Laser Module & LDR Sensor:** Position the laser module so that it projects a beam directly at the LDR sensor. Connect the LDR to one of the analogue input pins on the ESP32, using the 7.5k Ohm resistor to ensure stable readings.
- **ESP32 Camera Module:** Mount this camera in a way that it can capture images of the area where the laser beam is projected. Connect it to the ESP32 Nano using the appropriate GPIO pins.
- **SIM800 GSM Module**: This module should be connected to the ESP32 Nano via UART (TX and RX pins). Don't forget to insert a SIM card for SMS and call functionalities.

E. Lock Mechanism Setup:

- The ESP32 receives a command from the Telegram bot and moves the servo motor accordingly [8].
- Verify the functionality of the GSM module by sending test SMS messages and making calls.
- Debug any issues with the Telegram bot to ensure messages are sent without problems.

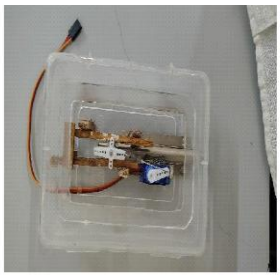

Figure 1.3

Figure 1.3: The lock system using a servo motor to control a sliding latch, which locks and unlocks the door based on Telegram bot commands.

F. Final Implementation and Deployment

1) Setting Up the System:

- If the user sends "lock", the servo motor moves to secure the latch.
- If the user sends "unlock", the servo motor retracts the latch, allowing access.
- The servo motor is controlled using PWM signals from the ESP32.
- Install the laser and LDR sensor at a secure entry point where monitoring is crucial.

G. Software & Coding (Using Arduino IDE & Libraries) Libraries Needed:

WiFi.h (for connecting to a Telegram bot)
ESP32Servo.h (if you plan to adjust the camera position)
SoftwareSerial.h (for communication with the GSM module)
ESP32Camera.h (for handling the camera module)
UniversalTelegramBot.h (for sending alerts via Telegram)

Programming Steps:

The ESP32 will continuously monitor the LDR sensor for any interruptions in the laser beam.

When the beam is interrupted, the ESP32 will:

- Capture an image using the ESP32 Camera Module.
- Send an alert through a Telegram bot, including the captured image.
- Activate the SIM800 module to send an SMS and make a phone call to notify the user

H. Testing and Troubleshooting

Testing the System:

- Check the sensitivity of the LDR sensor to ensure it accurately detects interruptions in the laser beam.
- Test the ESP32 Camera to confirm it captures and transmits images correctly.
- Ensure that the ESP32, camera, and SIM800 module are housed in a secure, weatherproof enclosure to protect them from the elements.
- Power the system using a reliable source, whether it's a battery or an adapter.
- Conduct real-world tests to evaluate the system's performance under different conditions to ensure reliability.

IV. RESULTS AND DISCUSSIONS

A. System Design & Planning

The Laser-Safe security system was designed to provide a real-time, cost-effective intrusion detection mechanism using a laser module and an LDR sensor. Performance evaluation was conducted by analyzing response time, accuracy, and efficiency under various environmental conditions.

B. Testing and Observations

Multiple test cases were performed to validate the efficiency of the Laser-Safe system. The main observations include:

Breach Detection: The system successfully detected laser beam interruptions with over 95% accuracy in controlled conditions.

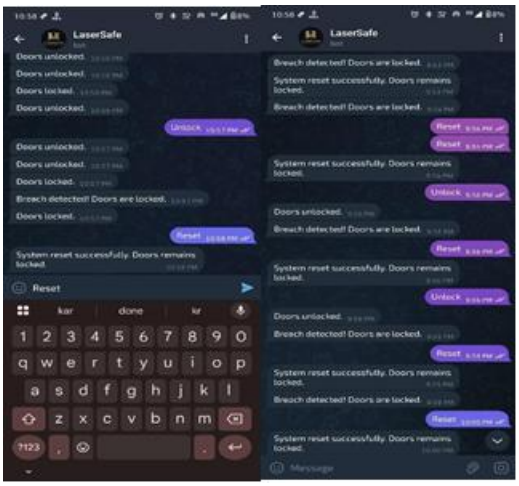

Figure 1.4

This figure 1.4 shows the Telegram bot logs, displaying various system events such as:

- Doors unlocked – The system received an unlock command.
- Doors are locked. – The system detected an intrusion, locked the doors, and sent an alert. System reset successfully. Doors remain locked. – The system was reset after an event.
- The user manually reset the system using the "Reset" command.
- The system responded accurately with real-time status updates.

Response Time: The Telegram notification with the message about breach was sent within 1-2 seconds, and the ESP32-CAM image was taken and sent within 3-5 seconds.

Automatic Locking: The servo motor lock-up once a violating parameter was detected so as to achieve a secure lock-up.

Power Consumption: The system could be powered stably on a 5V power supply, although the ESP32-CAM needed a separate 2A power source to prevent fluctuation of power.

C. Challenges and Solutions

There were a number of difficulties faced in testing as well as measures taken to enhance performance:
False Alarms because of Ambient Light: Threshold voltage adjustment in the code and or shielding of the LDR sensor reduced the number of false alarms.

Wi-Fi Connection Problems: This was implemented using the auto-reconnect option of the ESP32 and this ensured that the device remained connected at all times so that real-time feedback could be received.

Delayed Image Transmission: discrete image reduction and optimization of the camera buffer setup showed a significant improvement on the transmission speed.

D. Comparative Analysis

The Laser-Safe system was contrasted with the traditional security systems, including motion sensor alarm and cameras:

Cost Saving: The Laser-Safe is far less expensive than an expensive CCTV system and notifies breaches in real-time [9].

Power Consumption: ESP32-based system has light power consumption thus can be used in battery-powered utilities.

Automation Internet surveillance: Compared to the conventional security alarms, the Laser-Safe system provides additional security control as the current model can automate locking and send real-time notifications via Telegram.

V. FUTURE SCOPE

The proposed smart home security system that uses an IoT can also be improved to make it more functional, intelligent and convenient to its users. One of the ways through which the system may be improved in future is by adding AI surveillance capabilities that involves the use of computer vision and artificial intelligence in detecting motion and facial recognition. This would allow the system to identify the human, pets and other movements thus reducing false alarms.

Moreover, in addition to real time video streaming and image capture, the camera incorporation may be used to offer the visual verification of the security breach. One can also consider cloud connection as a solution to safe data storage, remote access towards data and updating any system so that the users can also monitor their activities and have a glimpse of what has formed in the past.

Moreover, voice assistant application and integration with different mobile apps, like Amazon Alexa and Google Assistant could increase the functionality in interaction and ease of access. Inclusion of machine learning-based predictive analytics will also be beneficial to the case of security since there will be the ability to detect the unusual activity pattern, and note down the suspicious activity pattern to alert the homeowner before occurrences of these risks.

A final possible solution is energy optimization by using renewable sources, one of which is solar power to increase sustainability in the system and provide an operational system during electricity failure.

VI. CONCLUSION

The discussed IoT-driven smart home security shows an effective, stable, and affordable design to improve the security of residence by using the smart system of automation. The system, combining ESP32 Nano, laser and LDR modules, built-in buzzer, electronic lock and Telegram bot, will provide the real-time notification of intrusion and immediate notification to a homeowner. Integration of IoT connectivity with the use of the automatic door lock system has great enhancements in the responsiveness and minimization of human actions thus enhancing the overall level of security.

This system is the perfect solution in the contemporary homes that could be facing a challenge of trying to find an affordable replacement to the traditional security systems due to its full power usage, low cost and simplicity during installation. It can further be enhanced with future technologies, such as AI-assisted surveillance, camera implementation, and cloud-based home observation that can be considered a monumental progress towards introducing a smarter and more adjustable home protection system.

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