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Smart Surveillance System

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Abstract - This project presents an innovative smart surveillance system that combines real-time security monitoring with environmental tracking while prioritizing energy efficiency. The system integrates an ESP32-CAM AI-Thinker module for visual capture, a PIR motion sensor for activity detection, and a BME280 sensor to measure temperature and humidity levels. A unique feature of this setup is its Telegram-based remote-control interface, which allows users to interact with the system seamlessly from anywhere. When the PIR sensor detects movement, the system automatically captures images and sends immediate alerts to users through Telegram, ensuring prompt notification of potential security events. Beyond security, the system continuously provides real-time environmental data, enhancing overall situational awareness. Designed with sustainability in mind, the solution utilizes solar power with Li-ion battery backup, supported by efficient power regulation through LM2596 and LM7805 voltage regulator circuits. Unlike traditional CCTV systems that operate continuously and require substantial storage capacity, this intelligent system only activates when motion is detected, significantly optimizing both power consumption and storage requirements. The integrated Telegram bot extends functionality by enabling users to manually request images, check current sensor readings, and control various features like the camera's flash control. By combining smart detection capabilities with low power consumption and remote accessibility, this system offers a practical, cost-effective, and environmentally friendly security solution suitable for residential and restricted area applications.

Key Words: ESP-32 Camera, PIR Motion Sensor, BME-280 Sensor, Real Time Monitoring, Image Capture, Motion - Detection, Flash Control, Solar Powered.

1.INTRODUCTION

In today's digital age, home security has moved beyond traditional locks and alarms, incorporating advanced technologies for enhanced protection. Conventional surveillance systems, such as CCTV cameras, often rely on continuous recording, which requires significant storage space and power. Additionally, they lack real-time threat detection and immediate response capabilities, making them less effective in preventing security breaches.

To overcome these limitations, our project introduces the Smart Surveillance System , an intelligent, energy-efficient security solution that integrates automation, real-time monitoring, and remote access. This system utilizes the ESP32-CAM AI-Thinker module, which comes with Wi-Fi connectivity and an embedded camera, enabling on-demand image capture and live monitoring. Instead of recording continuously, the system employs a PIR (Passive Infrared) motion sensor to detect movement and capture images only when motion is detected, reducing storage needs and optimizing power consumption.

A standout feature of this system is its real-time alert mechanism through a Telegram bot, allowing users to receive instant notifications, access captured images, and control features such as flash activation remotely. Additionally, it includes a BME280 sensor to monitor environmental factors like temperature and humidity, providing additional situational awareness.

For uninterrupted functionality, especially in areas with unreliable electricity, the system is solar-powered with a Li-ion battery backup. It incorporates LM2596 and LM7805 voltage regulation circuits to ensure stable and efficient power management, making it a sustainable and autonomous security solution.

Designed for flexibility and adaptability, this system is suitable for residences, workplaces, schools, hospitals, and commercial spaces. Unlike traditional security systems that require extensive manual monitoring, this smart surveillance setup automates the process, reducing false alarms and operational expenses while enhancing security.

By integrating IoT technology, motion-triggered surveillance, real-time alerts, environmental monitoring, and remote control, the Smart Surveillance System IoT Bot delivers a modern, cost-effective, and sustainable security solution. The following sections provide a comprehensive overview of its architecture, implementation, and performance evaluation, demonstrating its effectiveness in improving security across different environments.

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2.LITERATURE SURVEY

The evolution of security surveillance systems has transitioned from traditional CCTV-based monitoring to advanced IoT-driven smart surveillance solutions. Early security systems relied on continuous video recording, which required significant storage and constant human supervision, making them inefficient for large-scale monitoring. Studies have shown that while CCTV cameras help in crime deterrence, they lack real-time intelligence and automation, limiting their effectiveness in proactive threat detection. To address these limitations, IoT-based smart surveillance systems have emerged, integrating embedded sensors, cloud computing, and AI-driven analytics to enable automated threat detection, real-time alerts, and remote access.

One key advancement in modern surveillance is motion-based monitoring using Passive Infrared (PIR) sensors, which trigger

image capture only when movement is detected. Research highlights that PIR-based systems significantly reduce storage and power consumption compared to conventional surveillance methods, making them ideal for energy-efficient security applications. In addition, the use of wireless communication technologies has improved the system's remote access features. Studies on Telegram-based alert systems demonstrate their reliability in providing instant notifications and encrypted communication, enabling users to monitor security events in real-time.

In addition to security monitoring, integrating environmental sensing has gained attention in recent research. The use of BME280 sensors for temperature and humidity monitoring enhances situational awareness, particularly in remote or hazardous areas. By combining surveillance with environmental data collection, smart security systems can provide comprehensive monitoring solutions. Additionally, energy efficiency remains a major concern for continuous surveillance operations. Solar-powered security systems with Li-ion battery backups have been explored as sustainable alternatives, ensuring uninterrupted operation even in areas with unstable power infrastructure. Research highlights that low-power components such as ESP32-CAM, combined with efficient power regulation circuits like LM2596 and LM7805, contribute to the longevity and reliability of surveillance systems.

Despite these advancements, existing surveillance solutions still face challenges related to cybersecurity, false alarms, and integration of multiple sensing technologies. Many systems lack seamless interaction between motion detection, remote monitoring, and environmental sensing, limiting their practical implementation. To address these gaps, this project introduces an IoT-based Smart Surveillance System IoT Bot that integrates ESP32-CAM for real-time image capture, PIR motion detection for efficient threat identification, BME280 sensors for environmental monitoring, and Telegram-based notifications for remote access and instant alerts. The system is designed to be energy-efficient with a solar-powered backup, ensuring continuous operation. By combining multiple smart technologies, this solution enhances security monitoring while reducing power consumption, storage requirements, and manual supervision, making it a cost-effective and scalable alternative to traditional surveillance methods.

3.EXISTING SYSTEMS

Traditional surveillance systems predominantly use conventional CCTV cameras, which, while commonly deployed, suffer from multiple inefficiencies that reduce their effectiveness. A significant limitation involves the substantial expenses and technical challenges associated with installation, as these setups necessitate costly equipment including cameras, digital video recorders (DVRs), storage units, and complex wiring networks—often requiring professional assistance. Moreover, standard CCTV systems typically record footage continuously, consuming massive storage space regardless of whether noteworthy events occur. This not only escalates data storage expenses but also complicates post-event analysis by forcing users to sift through lengthy recordings manually.
Another notable shortcoming is the lack of intelligent functionalities such as activity-triggered recording, instant alerts, and automated surveillance, leaving users to manually scan hours of video to detect security breaches. Perhaps most critically, these systems fail to provide immediate notifications, meaning potential threats go unnoticed until footage is reviewed later—a process that demands round-the-clock human oversight for reliable security. Due to these inefficiencies, traditional surveillance methods are increasingly being replaced by IoT-enabled smart security systems. These advanced solutions incorporate motion-sensing technology, live alerts, remote accessibility, and cloud storage to deliver a more responsive, automated, and cost-efficient approach to modern security and surveillance needs.

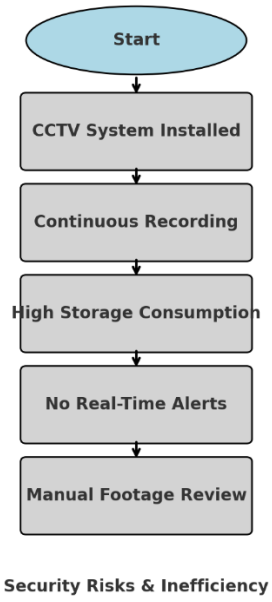

Fig-1: proposed System

4.PROPOSED SYSTEM

Our proposed Smart Surveillance System IoT Bot enhances security by integrating motion detection, real-time alerts, environmental monitoring, solar-powered operation, and remote access via a Telegram bot. Unlike conventional CCTV systems that rely on continuous recording and consume excessive storage, this solution offers an automated, cost-efficient, and scalable approach to surveillance. The system incorporates an ESP32-CAM for image capture, a PIR motion sensor for detecting human movement, a BME280 sensor for monitoring environmental conditions, and a solar panel for energy efficiency. When motion is detected, the ESP32-CAM captures an image and transmits it via Wi-Fi to a Telegram bot, providing instant alerts for remote monitoring. Additionally, the BME280 sensor tracks temperature, humidity, and pressure, minimizing false alarms caused by environmental fluctuations. To ensure sustainable and uninterrupted operation, the system is powered by solar energy, making it suitable for outdoor and remote locations. With cloud-based data storage, users can securely access footage without relying on large local storage systems, enhancing efficiency and convenience. This smart system is cost-effective, as it uses affordable IoT components, reducing installation and maintenance expenses. Its motion-triggered recording minimizes unnecessary storage usage, optimizing efficiency while AI-powered threat detection,

automated alerts, and remote monitoring ensure real-time surveillance and immediate response to security threats.

The wireless design simplifies installation and requires minimal maintenance, eliminating the complexity of traditional wired surveillance setups. Additionally, cloud-based access and instant Telegram notifications allow users to monitor their premises from anywhere, ensuring greater control and security. With its solar-powered functionality, the system is sustainable, reliable, and ideal for homes, businesses, and restricted areas, offering a modern, energy-efficient, and scalable surveillance solution.

5.METHODOLOGY

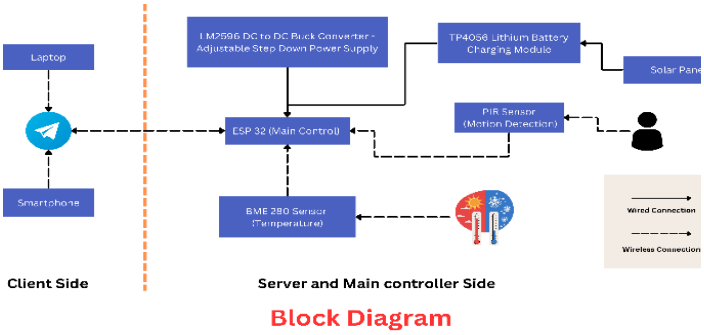

Fig-2: Block Diagram of project

The system employs an event-driven architecture centered around the ESP32 microcontroller, which dynamically coordinates security and environmental monitoring. Motion detection via PIR sensor triggers the ESP32-CAM's selective image capture, while the BME280 sensor continuously logs ambient conditions. A hybrid power system combines solar harvesting with lithium battery backup, regulated through precision DC-DC conversion for stable operation. The Telegram bot interface enables prioritized alert delivery and remote management, using adaptive data transmission to optimize bandwidth. This intelligent integration of triggered surveillance, contextual sensing, and renewable power management creates a responsive yet energy-efficient security solution that outperforms conventional continuous-monitoring systems. The design emphasizes three key innovations: conditional activation to minimize resource use, environmental context for enhanced threat assessment, and self-sustaining operation through optimized power architecture.

6.CIRCUIT DESIGN

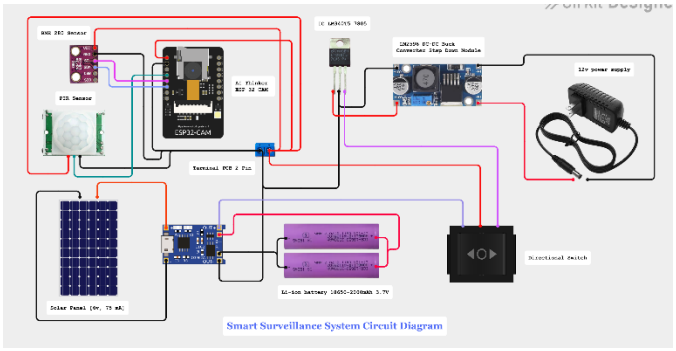

Fig-3: Circuit Diagram

The circuit diagram comprises multiple interconnected components, each contributing to the functionality of the Smart Surveillance System. At its core, the ESP32-CAM (AI-Thinker Module) acts as the primary processing unit, capturing images upon detecting motion and transmitting them via Wi-Fi for real-time monitoring. The PIR (Passive Infrared) motion sensor plays a key role in movement detection, triggering the ESP32-CAM to capture images only when activity is detected. This method eliminates unnecessary recordings, optimizing storage by focusing on relevant events.

To enhance the system's capabilities, a BME280 sensor is integrated to measure environmental parameters like temperature, humidity, and atmospheric pressure. This helps in improving system efficiency by adjusting sensitivity and reducing false alarms caused by environmental changes.
For continuous operation, the system utilizes a solar panel as a renewable energy source, which charges a Li-Ion battery to provide backup power. A DC-DC buck converter regulates voltage levels to ensure that all components receive stable power. Additionally, a 12V power supply is included as an alternative power source for situations where solar energy is insufficient. A directional switch allows manual control, enabling users to operate the system as needed.
This intelligent surveillance system is designed for low power consumption, automated monitoring, and enhanced security through instant alerts and remote access. Its combination of renewable energy, smart sensing, and real-time connectivity makes it a cost-effective and scalable solution for modern surveillance applications.

7.HARDWARE COMPONENTS

1.ESP32-CAM AI Thinker – A powerful microcontroller with a 2MP camera, Wi-Fi, and Bluetooth, suitable for IoT, image processing, and surveillance applications. It supports formats like JPEG and BMP, enabling real-time monitoring and automation.

2.PIR Motion Sensor – Detects infrared radiation emitted by warm objects, identifying motion within a specific range. Frequently used in security systems, automatic lighting, and smart home applications**.**

3.BME280 Sensor – A compact sensor measuring temperature, humidity, and pressure with high precision. It is commonly integrated into weather monitoring, altitude tracking, and environmental sensing devices.

4.LM7805 Voltage Regulator – A three-terminal regulator providing a steady 5V output from higher voltage inputs. Used in microcontrollers and embedded systems to maintain stable power supply and prevent fluctuations.

5.TP4056 Battery Charging Module – A charging controller for 3.7V lithium-ion batteries with built-in overcharge and short-circuit protection. Ideal for rechargeable electronics, ensuring safe and efficient battery management.

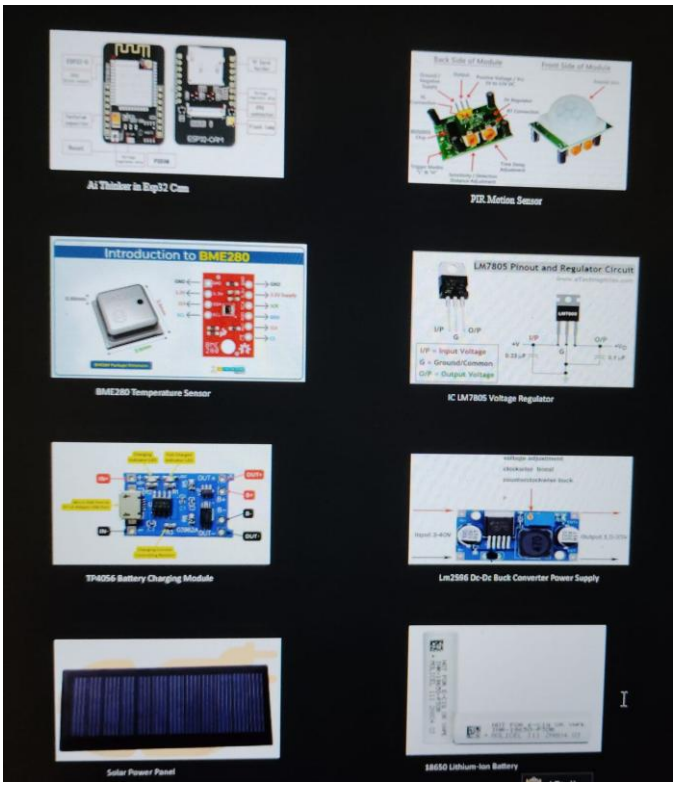

Fig-4: Hardware Components

6.LM2596S DC-DC Buck Converter – A step-down regulator converting higher voltage into a stable lower output with minimal energy loss. It supports various voltage levels, making it ideal for power management in embedded systems.

7.Solar Panel – Converts sunlight into electrical energy using photovoltaic cells, providing renewable power for off-grid applications. Used in solar chargers, IoT devices, and sustainable energy solutions.

8.18650 Lithium-Ion Battery – A high-capacity rechargeable battery known for efficiency and long life. Commonly used in laptops, flashlights, and power banks due to its reliability and energy density**.**

8.IMPLEMENTATION

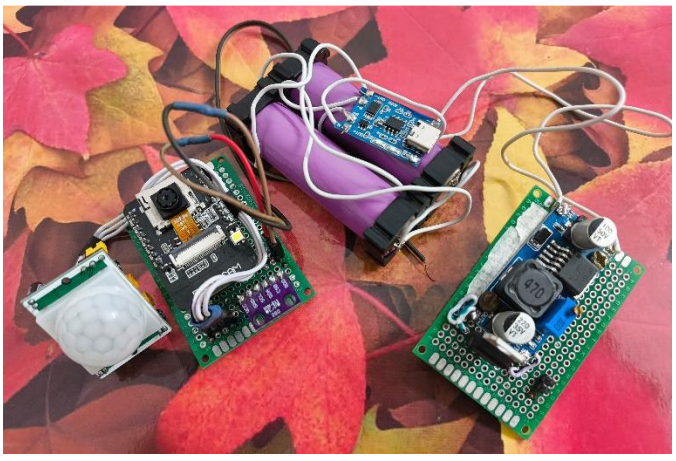

Fig-5: Implementation of Circuit Diagram

The ESP32-CAM AI-Thinker board, integrated with essential algorithms, serves as an efficient solution for operational monitoring. The system begins by powering up the board and its peripherals, establishing a Wi-Fi connection for remote communication, and setting up a Telegram bot for messaging. The sensor monitoring loop continuously checks temperature and humidity levels using the BME280 sensor, while the PIR motion sensor detects movement. Upon detecting motion, the system captures an image and sends a notification to the user via the Telegram bot, including the captured image and real-time weather data. Additionally, users can remotely request live images, sensor readings, and control the device's flash through the bot. For archival purposes, data logging is an optional feature that allows images and sensor readings to be stored on a microSD card. The system incorporates error-handling mechanisms to address connectivity failures, sensor malfunctions, or camera startup issues, ensuring that any detected problems are reported to the user through Telegram. This integrated approach makes the system highly reliable for security and surveillance applications.

The primary power source for the system is a solar panel, which converts sunlight into electrical energy. Two Li-ion batteries, connected either in series or parallel, ensure a stable power supply. A terminal PCB 2-pin connector facilitates battery charging or switching to an external power source. The LM2596 DC-DC Buck Converter is responsible for stepping down higher voltage levels to meet the power requirements of the ESP32-CAM and its components, while the LM7805 linear voltage regulator provides a stable 5V output. The regulated power from either the LM2596 or LM7805 supplies the ESP32-CAM. The BME280 sensor transmits temperature and humidity data through the I2C interface, while the PIR sensor detects motion and signals the ESP32-CAM to respond accordingly.

The microcontroller receives power either from the batteries or an external source, managed via a directional switch that allows seamless transition between battery and solar or external power. Proper voltage regulation and secure wiring connections are essential to ensure the safe operation of all components while preventing short circuits or other electrical issues.

9.CIRCUIT SIMULATION EVALUATION

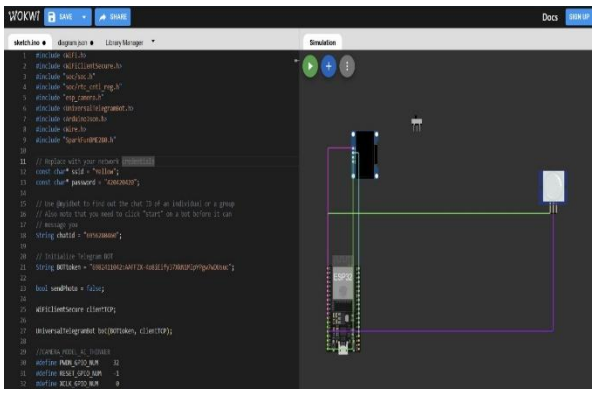

Fig-6: Circuit Simulation

Before hardware implementation, the Smart Surveillance System undergoes thorough simulation testing to validate all functionalities. The Arduino firmware is executed in a virtual environment to verify Wi-Fi connectivity, Telegram Bot communication, sensor data accuracy, and image-capturing

logic. This step helps identify and resolve issues like sensor errors, network failures, or code flaws early in the development cycle.

The simulation ensures the ESP32-CAM correctly connects to Wi-Fi, sends real-time alerts via Telegram, and transmits images without errors. It also confirms proper circuit design, stable power supply integration, and firmware reliability. Additionally, stress tests evaluate performance under varied conditions, such as multiple motion triggers, power efficiency, and system stability.

Only after successful simulation—confirming seamless operation and robustness—is the system deployed on physical hardware for real-world surveillance. This method minimizes hardware risks and ensures optimal performance before field implementation.

10.TELEGRAM CONNECTIVITY

This project implements a Telegram bot as the primary interface for real-time communication between the ESP32-CAM system and users. The bot is created through Telegram's @BotFather service, which provides a unique API token for secure authentication. Users obtain their Chat ID via @get_id_bot, enabling personalized notifications. The ESP32-CAM firmware integrates these credentials using the Universal Telegram Bot library to establish encrypted HTTPS connections.

When motion is detected, the system automatically captures images and transmits them with timestamped alerts to authorized users. The bot supports two-way interaction, allowing commands like "/photo" for instant captures or "/sensors" for environmental data. To optimize performance, images are compressed before transmission, reducing bandwidth usage while maintaining clarity. The system ensures reliability through automatic retry mechanisms for failed transmissions and watchdog timers to handle network disruptions.

Additionally, the bot features multi-user management, enabling administrators to control access and configure alerts. Security is prioritized with Telegram's built-in encryption, protecting data integrity. This integration provides a responsive, low-bandwidth communication channel, making the system ideal for remote monitoring with limited connectivity. By combining real-time alerts with remote control capabilities, the Telegram bot enhances the surveillance system's usability and effectiveness.

Fig-7 : Telegram SetUp

11.RESULT

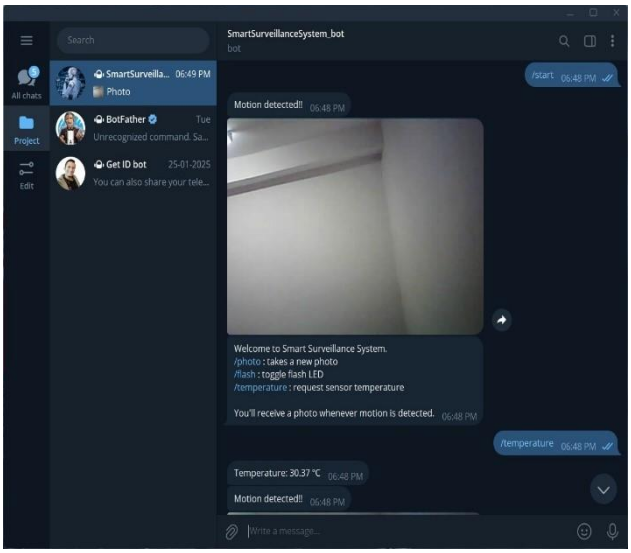

Fig-8 : Implementation of Smart Surveillance System using telegram Bot

12. CONCLUSION

Overall, this project was clearly able to design and implement a smart security surveillance system through an ESP32-CAM using a BME280 and PIR sensor with remote control through telegram. It has brilliantly fused motion detection, image capturing, environmental monitoring, and interactivity between users into an affordable and reachable solution. The project also provides an effective means of augmenting domestic security and giving terrifically beneficial environmental data by exploiting the combined power of ESP32-CAM and telegram accessibility. This project, while capable of providing the baseline, could be further enhanced in its capability as an improvement of image processing, integration with other smart home systems, and more advanced encryption protocols. In general, smart security surveillance systems provide promising solutions to improving security and environmental awareness in home settings or even in commercial applications.

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