Smart Contactless Doorbell System Using ESP32-CAM

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Abstract:
The Smart Contactless Doorbell System is a system that is designed to enhance home security and the convenience by getting rid of the need for physical contact. Leveraging Internet of Things (IoT) technology, this system informs the resident about the visitors and enables the remote access control using an android app which is developed with the help of MIT App Inventor ([1]). This system make use of IR sensor that detects motion and this triggers the ESP32-CAM to capture the photo of the visitor. This image is then sent to the resident's application, after seeing the photo of visitor they can decide whether they should unlock the door or keep it locked by just clicking the button in the application. The backend of this system is handled using Firebase, which basically stores the images of visitor and helps in communicating between ESP32-CAM and the resident's application. The door lock system is controlled using solenoid lock and it is triggered on the basis of resident's response. This system is basically designed to be user friendly, easy to use, cost-effective and highly secure, which makes it fit for smart homes. In future there will many improvements which includes enhancement of the Wi-Fi range and integration of more advanced security features.
Keywords: Internet of Things (IoT), Smart Contactless Doorbell, ESP32-CAM, App.

1. INTRODUCTION

In the era of Internet of Things (IoT) and smart homes the integration of the technology into our everyday life has now become increasingly more frequent. One of the most remarkable development and advancements in this domain is the development smart doorbell systems. The Conventional doorbell systems that needs physical interaction are becoming outdated now due to lack of hygiene and inconvenience, especially after contagious disease like COVID-19. This project mainly aligns with latest advancements in IoT- based security solutions that offers reliable and contactless alternative ([4]). The Smart Contactless Doorbell addresses these issues and provides a completely contactless solution for home with more advanced security. This system leverages the modern technologies like ESP32-CAM, Firebase, IR sensors and an application that gives secure, seamless and user-friendly experience for homeowners. ([2])

System Overview

The Smart Contactless Doorbell System is designed for the enhancement of home security and the convenience by eliminating the requirement for physical interaction. This system uses an IR sensor for detecting motion near the door, that triggers the ESP32-CAM to capturing the image of the visitor. This photo is then shared to

the android application which is developed using MIT App Inventor, where the resident can check the image and decide whether to lock or unlock the door. The backend of the system is connected with Firebase, which ensures efficient and secure communication between the android app and ESP32-CAM.
With the increasing adoption of smart home technology, traditional doorbell systems are becoming obsolete due to security concerns and hygiene factors. This project presents an innovative contactless doorbell system that ensures safety and convenience by utilizing motion sensors, camera technology, and cloud-based data storage. Unlike conventional systems that require physical interaction, this system operates remotely, reducing the risk of contamination in post-pandemic environments.

Components of the System

IR Sensor: The IR sensor is used to detect the motion near the door. When a visitor comes in front of door, the IR sensor detects their presence and it triggers the ESP32-CAM which captures an image of the visitor.

ESP32-CAM: The ESP32-CAM is a versatile microcontroller that has a built in camera. It is responsible for capturing the photo of the visitor when triggered by the IR sensor. The ESP32-CAM then sends this image to the Firebase backend.([3])

Firebase: Firebase is a backend service provided by Google that offers real-time database, authentication, and cloud storage. In this system, Firebase is basically used for securely storing the captured images and facilitate the communication between the ESP-32-CAM and the android app.

Android Application: The Android app is created using MIT App Inventor, its a visual programming environment used for creating mobile apps. This app allows the resident to view the captured images and decide whether to unlock the door or keep it locked by selecting the appropriate option.
Solenoid Lock: The solenoid lock is an electromechanical device that locks or unlocks the door based on the homeowner's response through the Android app. When the homeowner chooses to unlock the door, the solenoid lock is triggered, allowing the visitor to enter.

System Operation

The Smart Contactless Doorbell System operates through a series of well-defined steps:

Motion Detection: The IR sensor continuously monitors the area near the door for any human motion. When the visitor approaches the door, the IR sensor discovers their presence and sends the signal to the ESP32-CAM.

Image Capture: On receiving the signal from IR sensor, the ESP32-CAM captures the photo of the visitor and the image is then processed and prepared for transmission.

Image Transmission: The captured image is sent to the Firebase backend. Firebase securely stores the image and makes it accessible to the Android application.

Notification and Decision Making: The Android application receives the image from Firebase and notifies the homeowner. The resident can view the photo and decide whether to lock the door by clicking the appropriate button on the app or keep it unlocked.

Door Control: Based on the homeowner's response, the Android app sends a command to the solenoid lock. If the homeowner chooses to unlock the door, the solenoid lock is triggered, allowing the visitor to enter. If the homeowner chooses to lock the door, the solenoid lock remains engaged, keeping the door secure.

Advantages of the System

Contactless Operation: The most significant advantage of the Smart Contactless Doorbell System is its contactless operation. By eliminating the need for physical interaction, the system promotes hygiene and reduces the risk of spreading contagious diseases.

Enhanced Security: The system requires the homeowner's explicit approval to unlock the door, ensuring that only authorized individuals can gain access. Additionally, the usage of the firebase ensures that all the communication is secure and efficient.

User-Friendly Interface: The Android application is designed to be intuitive and easy to use. Homeowners can quickly view the captured image and make a decision with just a few taps on their smartphone.

Cost-Effective Solution: The components used in the system, such as the IR sensor, ESP32-CAM, and solenoid lock, are affordable and widely available. This makes the system a cost-effective solution for enhancing home security.

Easy Installation: The system is designed in such a way that it is easily installed and set up. Residents can quickly integrate the system into their existing door setup without the need for extensive technical knowledge.

Technical Details

IR Sensor: The IR sensor used in the system is a PIR (Passive Infrared) sensor. These PIR sensors are commonly used for the motion detection applications since they are sensitive to the infrared radiation that are emitted by the humans and animals. When a visitor comes near the door, this sensor detects the change in the radiation and then sends the signal to the ESP32-CAM.

ESP32-CAM: The ESP32-CAM is a low cost microcontroller that has built in camera. It is based on the ESP32 chip, which features Wi-Fi and Bluetooth connectivity. The ESP32-CAM is programmed that captures the image when IR Sensor triggers and shares the images to the Firebase using Wi-Fi.

Firebase: Firebase is a comprehensive backend service that provides real-time database, authentication, and cloud storage. In this system, Firebase is used to store the captured image and facilitate communication between the ESP32-CAM and the Android application. Firebase's real-time database ensures that the image is immediately available to the Android app as soon as it is uploaded by the ESP32-CAM.([2])

Android Application: The Android app is created using MIT inventor that allows users to create the mobile apps without having prior coding knowledge. The app is designed to receive the captured image from Firebase and display it to the homeowner. The app also includes buttons for unlocking and locking the door, which send commands to the solenoid lock via Firebase.

Solenoid Lock: The solenoid lock is an electromechanical device that locks or unlocks the door based on an electrical signal. When the resident chooses to unlock the door through the Android app, the signal is then sent to the solenoid lock which causes the door to allow to open. When the homeowner chooses to lock the door, the solenoid lock engages, securing the door.

Implementation and Testing

The implementation of the Smart Contactless Doorbell System involves several steps, including hardware assembly, software development, and system integration.

Hardware Assembly: The first step in implementing the system is to assemble the hardware components. This includes connecting the IR sensor, ESP32-CAM, and solenoid lock to a power source and ensuring that they are properly configured to communicate with each other.

Software Development: The next step is to develop the software for the ESP32-CAM and the Android application. The ESP32-CAM is programmed to capture an image when triggered by the IR sensor and send the image to Firebase.

System Integration: Once the hardware and software components are ready, they are integrated to create the complete system. This involves configuring Firebase to store the captured image and facilitate communication between the ESP32-CAM and the Android application. The system is then tested to ensure that all components are working correctly and that the system operates as intended.

Testing and Validation: The last step is to check and validate the system. This can involve testing the system under different conditions and edge cases to ensure that it is reliable and secure. This system is tested for its ability for detecting the motion, capturing the images, transmitting images to firebase and controlling the solenoid lock based on the resident’s response.

2. Literature Review

Several research works have been conducted on IoT-based doorbell systems and security solutions. Below are some relevant studies that provide a foundation for this project:

- **Title: "Configuring the Telegram App for WiFi Door Lock"**

Overview: This study discusses the configuration of the Telegram app for remote interaction with IoT-based door lock systems. While this project uses an Android app developed with MIT App Inventor, the principles of

remote communication and control are similar. The study highlights the importance of secure communication protocols and user-friendly interfaces for IoT systems.

- **Title: "Programming ESP32-CAM with Arduino IDE"**

Overview: This research provides a detailed guide on programming the component ESP32-CAM using the Arduino IDE. It is a versatile microcontroller that has built in WiFi and its camera capabilities which makes ideal for the IoT Projects. The study emphasises the importance of proper coding practices and the use of libraries such as WiFi and Firebase for efficient communication.

- **Title: "Sensor Integration in ESP32-CAM Systems"**

Overview: This study explores the integration of various sensors, including IR sensors, with the ESP32-CAM module. The use of IR sensors for motion detection is a key component of this project, and the study provides valuable insights into sensor integration and data processing.

- **Title: "Security Considerations in IoT-Based Door Lock Systems"**

Overview: This research discusses the security challenges associated with IoT-based door lock systems. The study focuses the importance of secure communication protocols, like H TTPS and MQTT along with TLS, for protecting the data transmission between IoT devices and Firebase.

- **Title: "Case Studies: Implementations of ESP32-CAM in Security Systems"**

Overview: This section provides case studies of successful implementations of the ESP32-CAM in various security systems. These case studies highlight practical challenges and solutions, offering valuable insights for new projects.

- **Title: "User Experience and Interface Design for Smart Door Lock Systems"**

Overview: This study examines the design and usability of mobile interfaces for controlling IoT-based door lock systems. The research emphasises the importance of clear notifications, intuitive controls, and responsive interactions in enhancing user satisfaction.

- **Title: "Energy Efficiency in IoT Devices: ESP32-CAM Power Management"**

Overview: This research discusses power management strategies for IoT devices, including the ESP32-CAM. The study highlights the importance of optimizing code and using low-power modes to reduce energy consumption.

- **Title: "Future Trends in IoT-Based Security Systems"**

Overview: This study explores emerging trends in IoT-based security systems, including the integration of artificial intelligence and blockchain technology. These trends indicate the evolving landscape of smart security solutions.

3. PROPOSED METHODOLOGY

The proposed system operates as follows:

- The IR sensor detects motion near the door.
- The ESP32-CAM captures an image of the visitor.
- The image is sent to the homeowner's Android application via Firebase([5]).
- The resident views the image and chooses whether to unlock the door by choosing appropriate button or keep it unlocked.
- The solenoid lock is triggered based on the homeowner's response, either unlocking or locking the door.

The flowchart of the system is shown in Figure:1. The program initialises all the sensors and hardware that are connected with ESP32-CAM. When the sensor detects the motion, the ES32-CAM captures the image immediately and sends that to Firebase. The app retrieves the image from the Firebase and it displays it to the resident. The homeowner then can click the “Unlock” or “Lock” button on the app. And that sends the command back to the ESP32-CAM through Firebase. Then it triggers the solenoid lock to either lock or unlock the door.

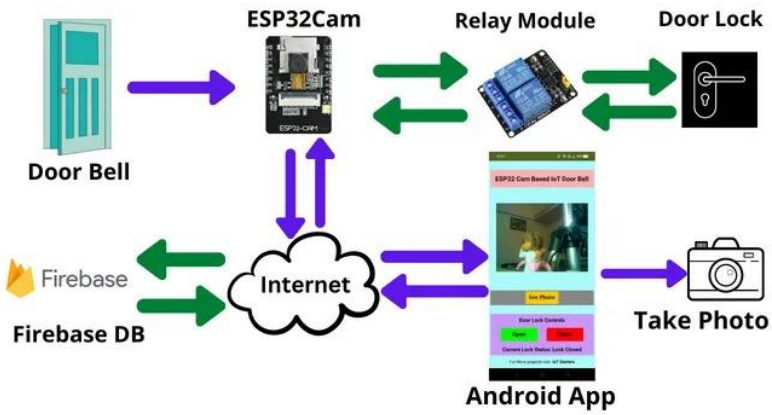


Figure 1

Hardware Components

The hardware components used in this project are listed in Table 1. These components include the ESP32-CAM, IR sensor, solenoid lock, relay module, and various connectors. Each component is carefully selected to ensure compatibility and efficiency.

Software Components

The software components include the Arduino IDE for programming the ESP32-CAM, MIT App Inventor for developing the Android application, and Firebase for backend communication and data storage. The Arduino IDE is used to write and upload the code to the ESP32-CAM, while MIT App Inventor is used to create a user-friendly interface for the Android app. Firebase acts as the backend, storing images and facilitating communication between the ESP32-CAM and the Android app.

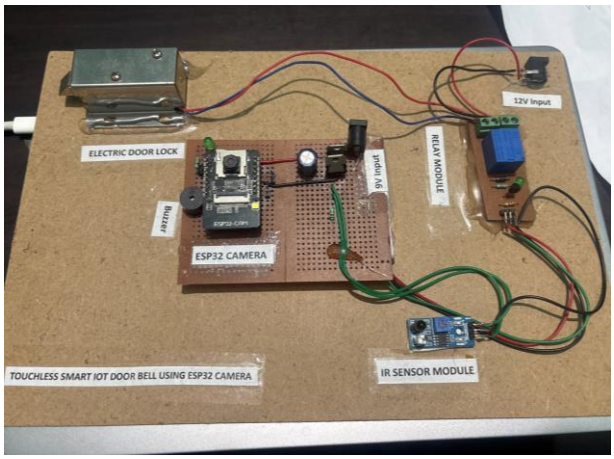
4. EXPERIMENTAL RESULTS & DISCUSSION

ESP32-CAM Testing System

The ESP32-CAM was tested to ensure it could accurately capture images and send them to Firebase. The system was tested with 10 trials, and the results are shown in Table 2. The ESP32-CAM successfully captured and sent images in all trials, with an average response time of 4.87 seconds.([6])

No. of Experiment	Result	Response Time (seconds)
1	Image Sent Successfully	4.85
2	Image Sent Successfully	4.91
3	Image Sent Successfully	4.87
4	Image Sent Successfully	4.82
5	Image Sent Successfully	4.92

Android App Testing



The Android app was tested to ensure it could receive images from Firebase and send commands back to the ESP32-CAM. The app successfully received images and sent commands in all trials, with an average response time of 4.87 seconds.

No. of Experiment	Image Received	Command Sent	Response Time (seconds)
1	Yes	Unlock	4.85
2	Yes	Lock	4.91
3	Yes	Unlock	4.87
4	Yes	Lock	4.82
5	Yes	Unlock	4.92

Solenoid Lock Testing

The solenoid lock was tested to ensure it could be triggered by the ESP32-CAM based on commands from the Android app. The lock successfully unlocked and locked the door in all trials.

No. of Experiment	Command Sent from App	Solenoid Lock Response	Response Time (seconds)
1	Unlock	Door Unlocked Successfully	1.2
2	Lock	Door Locked Successfully	1.1
3	Unlock	Door Unlocked Successfully	1.3
4	Lock	Door Locked Successfully	1.2
5	Unlock	Door Unlocked Successfully	1.1

Figure 2

5. CONCLUSION

The Smart Contactless Doorbell System Using ESP32-CAM is a highly effective solution for enhancing home security and convenience. The system provides a contactless way to control the access of the door and stay safe. Te use of motion detection sensor, ESP32-CAM for capturing image and the Firebase for backend

communication ensure that the system is secure and convenient to use. The resident can check anytime and anywhere whether the door is locked or unlocked. The system is very cost effective and easily installable which makes it more suitable for smart homes.

Key Points:

- **Contactless Operation:** This system does not need physical interaction which promotes hygiene and convenience, especially in the context of contagious diseases like COVID-19.
- **Enhanced Security:** The system requires the homeowner's explicit approval to unlock the door, ensuring that only authorized individuals can gain access.
- **User-Friendly Interface:** The android app provides a intuitive and user friendly interface for residents for viewing the images and control the door lock.
- **Cost-Effective:** This system uses components that are affordable which makes it accessible for wide range of users.
- **Efficient Communication:** The use of Firebase ensures secure and efficient communication between the ESP32-CAM and the Android app.
- **Reliability**: The system was rigorously tested, with the solenoid lock and Android app demonstrating high reliability and accuracy in all trials.

Future Improvements:

- **Wi-Fi Range Enhancement:** The use of directional antennas can be used to explore for increasing the Wi-Fi range of the ESP32-CAM.
- **Advanced Security Features:** Integration of additional security features, such as multi-factor authentication, could further enhance the system's security.
- **Energy Efficiency:** Implementing low-power modes and optimizing code could reduce the system's energy consumption.
- **Scalability:** The system could be scaled to include multiple doors and users, making it suitable for larger residential or commercial properties.

In conclusion, the Smart Contactless Doorbell System Using ESP32-CAM is a robust, secure, and user-friendly solution for modern smart homes. Its contactless operation, combined with efficient communication and reliable

performance, makes it an ideal choice for enhancing home security and convenience. Future improvements could further enhance the system's capabilities, making it even more versatile and secure.

6. REFERENCES

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