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Smart Door Operation Over Blockchain Using EVM Compatible Blockchain, Website (Hostinger), Static IP, ESP32 And Arduino Mega

Sudip Chakraborty, Yash Kothari

Abstract
The integration of smart home technologies with blockchain enhances security, transparency, and remote accessibility. This paper presents a novel approach to Smart Door Operation Over Blockchain by leveraging a Static IP, ESP32, and Arduino Mega. The proposed system ensures secure, decentralized, and tamper-proof access control using blockchain for authentication while utilizing IoT devices for real-time door operations. The ESP32 serves as a communication bridge between the blockchain network and the physical door lock, whereas the Arduino Mega handles local hardware interactions. A Static IP enables remote access and seamless control without reliance on third-party cloud services, thereby reducing latency and enhancing security. Smart contract-based authentication eliminates the need for centralized access control, preventing unauthorized access and ensuring verifiable audit trails. The system's efficiency, reliability, and security are validated through experimental implementation and performance analysis. This research highlights the potential of blockchain-driven IoT solutions in modern security systems, paving the way for more secure and autonomous smart home environments.

Keywords: Blockchain, Smart Door, ESP32, Arduino Mega, Static IP, IoT, Smart Contract, Security, Authentication.

Introduction
The rapid advancement of Internet of Things (IoT) and blockchain technology has revolutionized various domains, including smart home security systems. Traditional smart door locking mechanisms rely on centralized cloud-based authentication, making them vulnerable to cyberattacks, unauthorized access, and system failures. Additionally, these solutions often require third-party service providers, leading to privacy concerns and potential security risks. To address these challenges, a decentralized, blockchain-based smart door operation system is proposed, ensuring secure, transparent, and tamper-proof access control.

This research introduces a novel Smart Door Operation Over Blockchain Using Static IP, ESP32, and Arduino Mega to enhance security and real-time accessibility. The system integrates ESP32, which acts as an intermediary between the blockchain network and the physical door lock, while Arduino Mega manages hardware control. Unlike traditional cloud-dependent solutions, the use of a static IP ensures remote access without reliance on external servers, reducing latency and enhancing security. Blockchain-based smart contracts authenticate users in a decentralized manner, eliminating the need for a centralized authority and providing immutable audit trails for access records.

By leveraging Ethereum-based smart contracts, this system enables secure access management while preventing unauthorized modifications to access permissions. The integration of cryptographic verification ensures that only authorized users can unlock the door, significantly reducing security threats such as replay attacks and unauthorized key duplication. The proposed model is tested in real-world scenarios, demonstrating its reliability, efficiency, and robustness.

Literature Review

The Internet of Things (IoT) has introduced numerous security vulnerabilities, threats, and attack vectors, as Abomhara and Køien (2015) highlight the need for robust cybersecurity measures to safeguard interconnected devices. Ahmed et al. (2017) present a taxonomy of IoT-based smart environments, identifying open research challenges in scalability and security. Al-Fuqaha et al. (2015) provide an extensive survey on IoT-enabling technologies, protocols, and applications, forming the backbone of smart ecosystems. In the context of smart home automation, Alizai, Kausar, and Riaz (2020) explore IoT-based control systems using sensor nodes. Blockchain has emerged as a potential solution for access control (Alzahrani & Bulusu, 2018) and secure firmware updates (Baza et al., 2020) in IoT networks. Buterin (2014) introduces Ethereum as a decentralized platform for smart contracts, which Dorri et al. (2017) leverage to enhance IoT security and privacy in smart homes. Further, Biswas and Muthukkumarasamy (2016) demonstrate blockchain's potential in securing smart home operations, while Chanson et al. (2019) propose a privacy-preserving method for sensor data protection. These studies underscore the interdisciplinary nature of IoT security, blockchain integration, and automation, shaping the future of decentralized smart environments.

Methodology

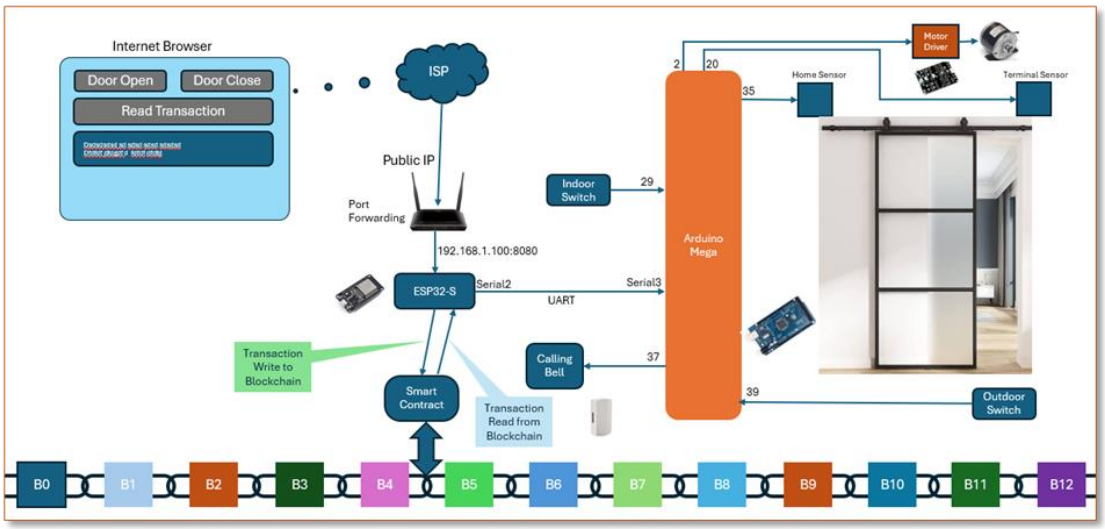

Fig. 1: Project Block Diagram.

The figure 1 illustrates a smart door operation system integrated with blockchain technology, ESP32, Arduino Mega, and IoT components. This system enables secure remote access and control of a smart sliding door while ensuring transaction logging on the blockchain for authentication and security. Below is a detailed breakdown of the components and their interactions:

1. System Components & Flow

1. User Interface (Internet Browser)
    - The system provides a web-based interface where users can:
        - Open the door
        - Close the door
        - Read transaction logs
    - The browser connects via an ISP (Internet Service Provider) to access the ESP32 module using a public IP with port forwarding.
2. ESP32-S Module
    - The ESP32-S is the central IoT communication module responsible for:
        - Receiving user commands from the browser.
        - Communicating with the Arduino Mega over UART (Serial2 and Serial3).
        - Writing and reading transaction data from the blockchain.
        - Handling calling bell events via GPIO pin 37.
3. Arduino Mega
    - The Arduino Mega acts as the controller for handling door operations and sensor inputs.
    - Functions:
        - Controls the motor driver to slide the door open or closed.
        - Reads input from:
            - Home Sensor (Pin 35) – Detects if the door is in the fully closed position.
            - Terminal Sensor – Detects if the door is in the fully open position.
            - Indoor Switch (Pin 29) – Provides manual control from inside.
            - Outdoor Switch (Pin 39) – Provides manual control from outside.
4. Door Mechanism
    - The motor driver and motor physically control the sliding door's movement.
    - The sensors (home sensor & terminal sensor) detect the door's status to ensure safe operations.
5. Blockchain Integration
    - A smart contract stores the transaction history of door operations.
    - Actions such as door open/close are recorded on the blockchain (B0 to B12 blocks).

- The ESP32 writes a new transaction to the blockchain whenever a door operation occurs.
- The system also supports reading past transactions for security and auditing purposes.

6. Networking & Remote Access
   - The ESP32 is connected to the internet via a router.
   - A static public IP with port forwarding (192.168.1.100:8080) allows users to access the system remotely.

2. Operational Workflow

1. User Initiates a Command
   - From the web interface, the user selects Door Open or Door Close.
   - The command is sent over the internet to the ESP32-S module via the public IP.
2. ESP32 Handles Communication
   - The ESP32:
     - Processes the request.
     - Sends a signal to the Arduino Mega via UART (Serial2/Serial3).
     - Simultaneously writes a transaction to the blockchain.
3. Arduino Mega Executes the Action
   - If Door Open:
     - Activates the motor driver.
     - Moves the sliding door until the terminal sensor detects that it is fully open.
   - If Door Close:
     - Activates the motor driver in reverse.
     - Moves the door until the home sensor detects it is fully closed.
4. Smart Contract Logging
   - Once the action is completed:
     - The transaction is confirmed and stored on the blockchain.
     - Users can verify past transactions using the Read Transaction button.
5. Manual Control & Safety Features
   - The indoor and outdoor switches allow manual operation.
   - The calling bell sensor (Pin 37) can trigger alerts when someone is at the door.

3. Advantages of This System

✓ Decentralized Security – Blockchain ensures tamper-proof transaction logging for door operations.

✓ Remote Access – Users can operate the door securely from anywhere using a web browser.

✓ IoT Integration – ESP32 and Arduino Mega provide seamless communication and automation.

✓ Redundant Manual Control – Indoor and outdoor switches enable control without internet access.

✓ Real-Time Status Updates – Door position is monitored using home and terminal sensors.

✓ Audit Trail – Transactions stored on blockchain enhance security and accountability.

4. Potential Enhancements

🔷 Voice Assistant Integration – Alexa or Google Assistant commands for voice-controlled operation.

🔷 Mobile App Interface – A dedicated smartphone app for enhanced usability.

🔷 Face Recognition / RFID – Biometric authentication for additional security.

🔷 AI-based Anomaly Detection – Alerts for unusual access patterns.

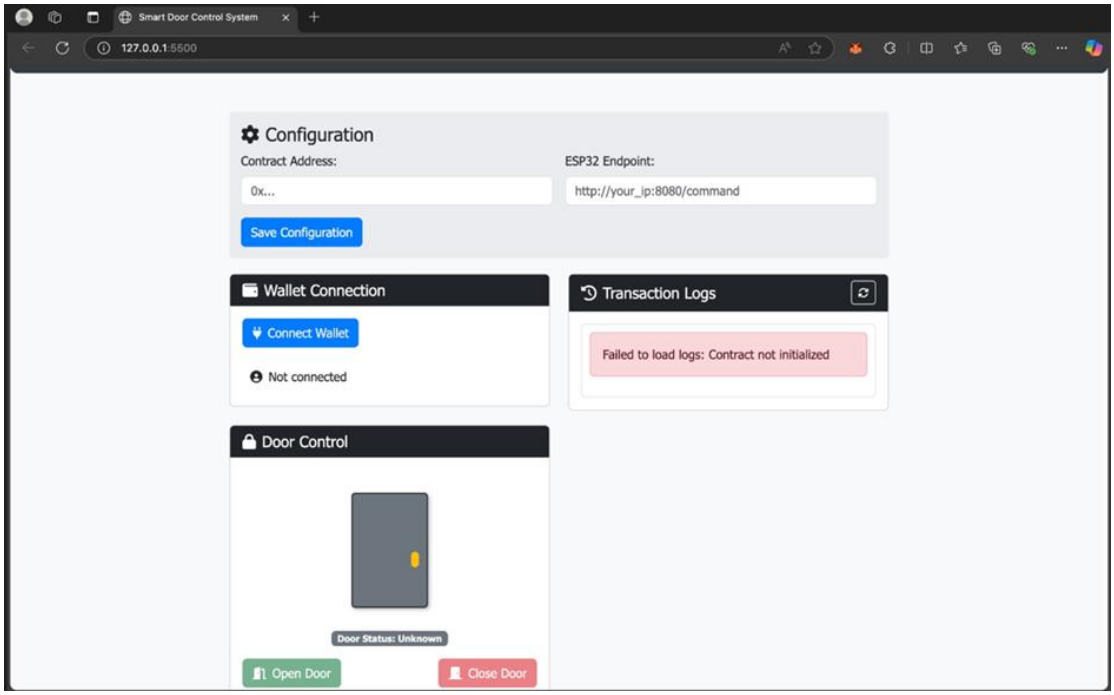

Figure 2: Web Interface for the project.

Figure 2 depicts the web interface, which is designed to remotely control a smart door using blockchain technology and IoT hardware such as the ESP32 and Arduino Mega. The interface facilitates secure authentication and logging of door operations on an EVM-compatible blockchain.

Breakdown of the Interface Components:

1. Configuration Section (Top)
   - Contains fields for:
     - Contract Address: A blockchain address (starting with 0x...) where the smart contract governing the door operations is deployed.
     - ESP32 Endpoint: A URL pointing to the ESP32 module acts as the IoT controller for sending commands to the door mechanism.
   - "Save Configuration" Button: Saves the provided contract address and ESP32 endpoint.
2. Wallet Connection Panel
   - A "Connect Wallet" button allows users to connect their Web3-enabled wallet (such as MetaMask) to interact with the smart contract.
   - Status: Displays "Not connected," indicating that no wallet is connected.
3. Transaction Logs Panel
   - Shows transaction logs related to the door's blockchain operations.
   - It displays an error message: "Failed to load logs: Contract not initialized," suggesting that the smart contract address has not been set or that the contract has not been deployed yet.
4. Door Control Panel
   - It displays a graphical representation of the door with a status indicator labeled "Door Status: Unknown," meaning the system has not yet retrieved the door's current state.
   - Two action buttons:
     - "Open Door" (Green Button): Sends a blockchain transaction to trigger the door-opening mechanism.
     - "Close Door" (Red Button): Sends a blockchain transaction to close the door.

Key Observations:

1. Blockchain Integration:
   - The system depends on a smart contract deployed on an EVM-compatible blockchain to manage door operations securely.
   - The wallet connection is required to interact with the contract.
2. ESP32 IoT Integration:
   - The ESP32 module serves as an endpoint that executes the door commands received from the blockchain.
   - The static IP mentioned in the project title suggests that the ESP32 is accessible online.
3. Possible Issues to Resolve:
   - The contract address is not yet initialized, preventing log retrieval.
   - The wallet is not connected, so transactions cannot be executed.
   - The ESP32 endpoint URL (http://your_ip:8080/command) is a placeholder and needs to be replaced with the actual IP.

The project code is available from:
https://github.com/sudipchakraborty/Smart-Door-Operation-Over-Blockchain.git

Conclusion

Integrating blockchain technology with IoT-based smart home automation presents a transformative approach to enhancing security, transparency, and decentralized access control. This research builds upon existing studies by addressing the vulnerabilities of traditional smart door systems, which often rely on centralized authentication methods and are prone to cyber threats. By leveraging ESP32, Arduino Mega, and a static IP, the proposed smart door operation system ensures secure, real-time, and tamper-proof access management without relying on third-party cloud services. Adopting blockchain-based authentication using smart contracts eliminates unauthorized access risks, providing an immutable and verifiable access log. Furthermore, the decentralized nature of blockchain enhances security while ensuring data integrity. However, challenges such as scalability, energy consumption, and transaction latency remain areas for further research. Future work may focus on optimizing blockchain protocols for IoT applications, integrating lightweight consensus mechanisms, and improving hardware efficiency to support large-scale deployment. Overall, this study demonstrates the potential of blockchain-powered IoT solutions in smart home security, paving the way for secure, automated, and decentralized access control systems that enhance privacy and operational reliability.

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