Automated Door Lock Control and Door Accessibility for Secured Entry System

Project GROUP - 02 (G-01)
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***Abstract*—This paper investigates the development of a Smart Door Lock System designed to improve accessibility for individuals with disabilities. Through the integration of Radio-Frequency Identification (RFID) technology into wheelchairs, the system facilitates automatic door opening upon RFID interaction, enhancing accessibility for wheelchair users. Alongside features such as a master code for user registration and the generation of One-Time Passwords (OTPs) for guest access, the system prioritizes data security through AES encryption methods.**

***Index Terms*—OTP, RFID, Disabilities, remote, Accessibility, Data security, AES.**

I. Introduction

Within the current landscape of security and accessibility solutions, an era of innovation has been precipitated by the intersection of automation, biometrics [1], and Internet of Things (IoT) [2] technologies. This convergence signifies a critical moment, driving the evolution of traditional security approaches into a more sophisticated and interconnected era. The integration of these technological domains has sparked a profound redefinition of how we conceive and implement security measures, ushering in a period where intelligent systems seamlessly collaborate to enhance the protection of physical spaces.

In [3] Pavithra Prabakaran et al. contributes to the field by proposing a smart lock system, remotely accessible through a smartphone app, catering to the needs of elderly and disabled individuals. The system includes features like door movement monitoring, visitor access control, a notification system for doorbell events, and additional security measures such as fire detection modules and intrusion alerts. They also discuss a password-based system with an external keypad. Through the collaborative integration of software and hardware, coupled with the utilization of Android software and Bluetooth technology, the project seamlessly enables door access within a predefined range, thereby obviating the necessity for traditional physical keys [4]. In [5], the author investigates IoT's role in crafting a remote-controlled "smart" door, integrating sensors, actuators, and communication protocols. It details the design, hardware, and software, emphasizing improved security, convenience, and energy efficiency. Through a real-world case study, the authors evaluate system performance and discuss implementation challenges, making a valuable contribution to IoT [2] application indoor development. In [6] Yuan Po et al. introduce key advancements in door security systems. Their work allows owners to remotely unlock electronically-controlled door locks via a computing device, conduct security checks, and enable door surveillance through automatic transmission of image data based on predefined criteria. This research enhances personal and property security. A door lock controller interfaces with an electronic lock, receiving commands from a local receiver linked to a hub via a mesh network. The hub employs a rule set to dictate lock operations, sending commands through the mesh network to the local receiver. A door state device monitors the door status, alerting users if messages aren't received or lock operations fail, prompting timely action [7]. The central unit of [8] utilizes the Raspberry Pi Zero W module, while Firebase serves as the server. The door lock mechanism incorporates an electromagnet and provides three distinct unlocking methods: RFID, mobile NFC system, and OTP.

Our study conducts an extensive analysis of an advanced Smart Door Lock System aimed at surpassing traditional standards. The system seamlessly incorporates state-of-the-art features, with facial recognition and RFID for authorized users, OTP for unfamiliar individuals, and a dynamic data logging system. Emphasizing security, the transmitted data to and from the server is encrypted using a suitable encryption algorithm. Furthermore, the system adeptly responds to emergencies through sensors capable of detecting potential hazards like fire or earthquake, leading to automatic door unlocking for swift egress. Remote access with proper authorization is facilitated by the user via the server. The system also includes provisions for detecting abnormal activities, such as prolonged door openings or attempted break-ins, triggering timely notifications to the user. This research introduces an innovative smart door lock system, uniquely integrating face recognition, data encryption, and proactive abnormal activity detection, thereby elevating overall security. The incorporation of fire sensors for emergency response and a dedicated focus on accessibility for disabled and senior citizens distinguish this system within the field.

II. Methodology

A. System Architecture and Components

The Smart Door Lock System (Fig. 2) relies on cost-effective Arduino Nano microcontroller technology, selected for its suitability and efficiency in our work. For the locking mechanism, a 12V electrical solenoid lock is utilized, aligning with prevailing standards in existing door lock systems, and ensuring secure and reliable door control. User interaction is facilitated through a keypad for code input, and an RFID sensor enhances accessibility for individuals facing physical challenges, offering an alternative entry method.

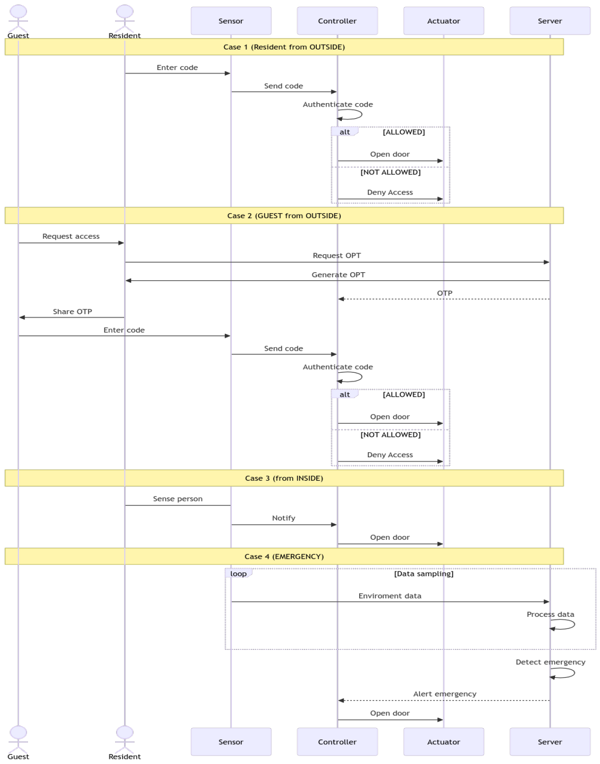

Fig. 1: **Case 1 (Resident Entry):** Residents entering from outside input a code via a keypad. The code is sent to the microcontroller for authentication. Upon a correct match, a signal is relayed to the actuator to open the door; otherwise, access is denied, prompting the resident to re-enter the code. **Case 2 (Guest Entry):** When guests arrive, they request a passcode from the resident. The resident, in turn, requests the server to generate a One-Time Password (OTP) and forwards it to the guest. The guest utilizes the OTP similarly to Case 1, with the code valid for 15 minutes. **Case 3 (Internal Entry):** Upon pressing the door button from inside, the door automatically opens, allowing entry without needing a code or key. **Case 4 (Emergency):** Sensors continuously monitor the environment, detecting emergencies such as fire or earthquake. The controller is notified upon detection, and the actuator promptly opens the door to ensure swift egress. **Case 5 (Accessibility Feature):** For elderly or physically challenged individuals unable to use the keypad or door button, a wearable RFID provides easy access, offering an alternative means of entry and exit.

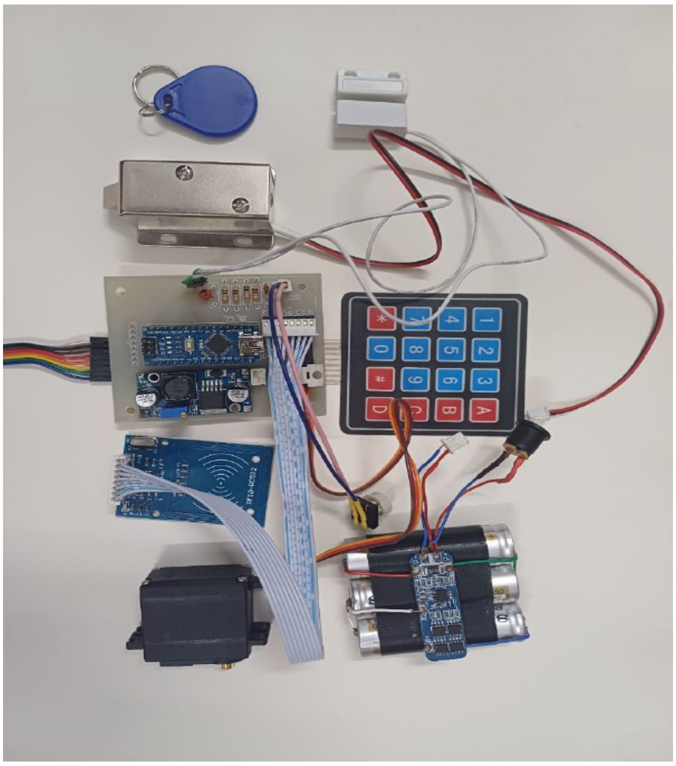

Fig. 2: Developed prototype of smart Lock system

The system integrates environmental sensors, including flame, smoke, and temperature sensors continuously monitoring surroundings for prompt emergency detection. In case of an emergency, the door is programmed to open automatically. A reed sensor detects prolonged door openings, and a vibration sensor identifies potential intrusions, triggering timely alerts. The system is primarily powered by local electricity, ensuring continuous and reliable operation. Rechargeable batteries serve as a backup power source to address unforeseen power failures, especially during emergencies like fires.

B. OTP and RFID integration

In the context of OTP and RFID integration, a master code is designated for user registration. However, when users opt not to share the passcode with certain guests, a guest can request a One-Time Password (OTP) through our server. The generated OTP remains valid for 15 minutes from the time of request. Upon using the OTP, the microcontroller undertakes authentication, subsequently granting access to the guest by opening the door.

Moreover, users are provided with the alternative of utilizing Radio-Frequency Identification (RFID) for authentication. This secure method enables registered users to authenticate themselves and access the system using their RFID credentials. Notably, for individuals encountering physical challenges, RFID serves as a particularly advantageous alternative for authentication. This functionality enhances overall accessibility, allowing registered users facing physical challenges to effortlessly and securely authenticate themselves through the use of RFID credentials, ensuring a streamlined and secure access experience to the smart door system.

C. Data Encryption and Security Measures

For data encryption and security, we utilize an encryption algorithm inspired by the widely respected Advanced Encryption Standard (AES). This encryption protocol, known for its industry-standard security, operates through a substitution-permutation network (SP network), which consists of a series of interconnected operations involving input substitution and bit manipulation.

To initiate the encryption process, first transform the password into a 3 by 3 matrix. Subsequent calculations take place in the Galois field (GF) of order pn, where 'p' represents a prime number. The encryption unfolds through distinct steps, including SubBytes, where each matrix value undergoes substitution using an S-box derived from the multiplicative inverse over GF(28). ShiftRows cyclically shifts bytes in each row,

```
The password        Hex value in ASCII
5 9 3 1 7     ->    35 39 33 31 37
.
.
.
After mapping the values into a 3 x 3 matrix:
 35 39 33
 31 37 43
 eb fb b5
```

```
Substituting the values using S-box (Round 1)
 35 39 33         e1 13 e2
 31 37 94   ---> a1 da 88
 47 7d a7         9f a0 7a
Shifting the rows (Round 1)
 e1 13 e2         e1 13 e2
 a1 da 88   ---> 88 a1 da
 9f a0 7a         a0 7a 9f
Mixing up the columns (Round 1)
 e1 13 e2         9 2e 5b
 88 a1 da   ---> 91 cf 35
 a0 7a 9f         fa 83 f1
Adding round key (Round 1)
 9 2e 5b          ac 8b fe
 91 cf 35   ---> 34 6a 90
 fa 83 f1         5f 26 54
    .
    .
 7 more similar rounds
    .
    .
The encrypted password is ac ba c9 b4 f6 7b 78 cf 89
```

Fig. 3: Password encryption steps

```
Adding round key (Round 8)
 b7 b6 5e          12 13 fb
 86 11 70   ---> 23 b4 d5
 b0 cd 34          15 68 91
Inverting the columns mixing (Round 8)
 12 13 fb          e1 13 e2
 23 b4 d5   ---> 11 a1 da
 15 68 91          20 5f 3f
Shifting back the rows (Round 8)
 e1 13 e2          e1 13 e2
 11 a1 da   ---> a1 da 11
 20 5f 3f          3f 20 5f
Substituting the values using inverse S-box (Round 8)
 e1 13 e2          35 39 33
 a1 da 11   ---> 31 37 85
 3f 20 5f          bc e4 1c
The decrypted hex value: 35 39 33 31 37
The decrypted password: 5 9 3 1 7
```

Fig. 4: Password decryption steps

MixColumns combines three bytes of each column through an invertible linear transformation, and AddRoundKey combines a key with each matrix element. These steps are iteratively executed for 8 rounds.

In the encryption process (Fig. 3), the initial password "59317" undergoes various transformations. It is represented in hexadecimal ASCII as "3539333137" and mapped into a 3x3 matrix. Cryptographic operations, including substitution, shifting rows, mixing columns, and adding a round key, are performed in one round and iterated for 7 more similar rounds. The final encrypted password is derived as "acbac9b4f6tb78cf89."

For decryption (Fig. 4), additional rounds, such as adding a round key, inverting columns mixing, shifting back rows, and substituting values using an inverse S-Box, are executed. The decrypted password "59317" is obtained after these meticulous cryptographic processes.

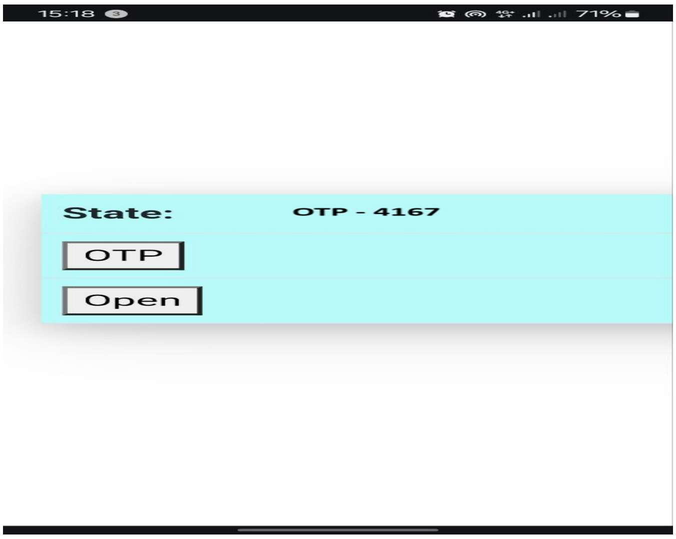

Fig. 5: In the server, users have the option to authenticate guests by generating One-Time Passwords (OTPs). Additionally, remote access is facilitated, allowing users to open the door through the server.

D. *Emergency Response Mechanism*

The installation of a modern smart door system greatly improves safety during emergencies. Three strategically positioned sensors detect potential hazards such as fires, smoke, and temperature changes. When an emergency is detected, these sensors send a signal to a central microcontroller. This microcontroller then activates a motorized door system, allowing for quick and automated evacuation. By placing sensors on the interior side, the risk of manipulation by potential intruders is minimized. This ensures that genuine emergencies are reliably detected while unauthorized access attempts are deterred.

E. *Remote Accessibility and Authorization*

We delve into the aspect of Remote Accessibility and Authorization within the Smart Door Lock System, emphasizing the detailed process of door opening through server-mediated interactions. The implemented system enables users to access the door remotely, contingent upon proper authorization, requiring a secure and streamlined protocol facilitated by the central server (Fig.5).

Components	Price (in BDT)
Arduino Nano (x1)	350
Solenoid Lock	550
Keypad	60
RFID	100
Battery (4x)	240
Flame Sensor	70
Smoke Detector	150
Temperature Sensor	200
Miscellaneous cost	500
Total	**2220 (Approx.)**

TABLE I: Approximate cost breakdown so far. Costs may vary depending on location and quantity.

III. Scalable Design for Existing Locks

The design of our Smart Lock System incorporates scalability by aligning with existing door lock structures found

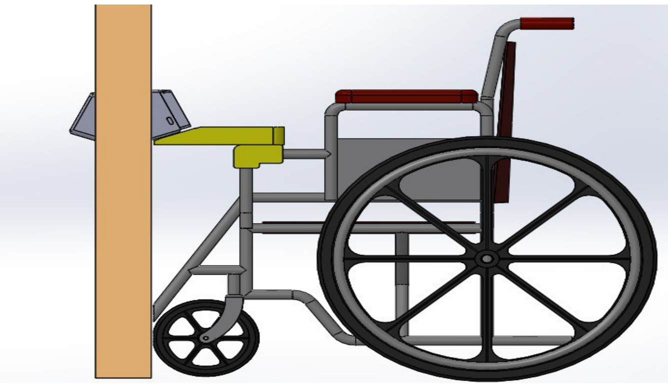

Fig. 6: Mounted RFID with wheelchair

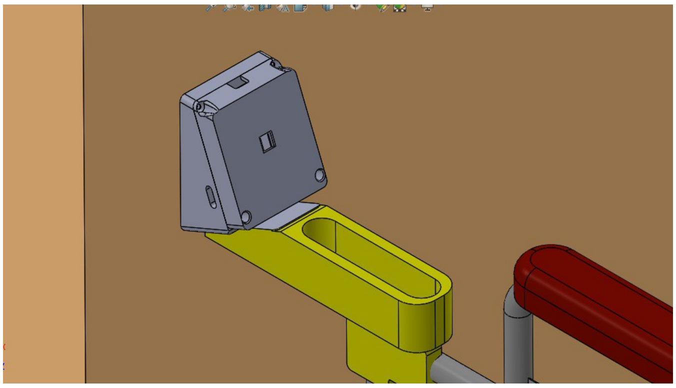

Fig. 7: Mounted RFID with wheelchair

in households. This intentional design allows for the seamless replacement of conventional locks with our smart lock system, emphasizing ease of integration. The system is crafted to be cost-effective, ensuring affordability, and compactness in size, contributing to the scalability of the design for diverse door lock configurations. Furthermore, the integration of emergency mechanisms and robust data encryption enhances the system's adaptability to various settings. Notably, our smart door lock system maintains its intelligence even in non-smart home environments.

IV. Accessibility for disabled people

In our efforts to enhance accessibility for individuals with disabilities, we have developed a system where RFID technology is integrated into wheelchairs (Fig. 6, 7). Using Computer-Aided Design (CAD), we meticulously crafted this system to ensure its effectiveness. The RFID technology embedded in the wheelchair has a range of approximately 20 cm. When a person using the wheelchair approaches a door equipped with a sensor, the RFID chip within the wheelchair interacts with the sensor, triggering the automatic opening of the door. This seamless integration of RFID technology into wheelchairs greatly facilitates the mobility of individuals with disabilities, allowing for smoother and more convenient access to various spaces.

V. Future Directions for Advancements in Smart Door Lock System

In an era where sustainability is paramount, the integration of solar power as a backup source presents a compelling avenue for future development. Leveraging solar panels to harness renewable energy not only aligns with environmental conscientiousness but also ensures the system's operability during power outages, especially in emergency scenarios. This sustainable approach not only contributes to a reduced carbon footprint but also enhances the system's resilience, ensuring continuous functionality even in adverse circumstances. The significance of data logging cannot be overstated in the context of security systems. Future iterations of our Smart Door Lock System will benefit from the implementation of an advanced data logging mechanism, where comprehensive logs of user entries, system events, and potential security breaches are securely stored on a dedicated server. This approach facilitates meticulous monitoring, analysis, and auditing of system activities, enabling timely responses to abnormal occurrences and contributing to the refinement of the system's overall security posture. Furthermore, the integration of server-based data logging enhances accessibility, allowing authorized users to remotely review and manage system logs, contributing to a more sophisticated and user-friendly experience.

VI. Conclusion

In summary, our study aimed to improve accessibility and security for individuals with disabilities through the development of a Smart Door Lock System. By integrating Radio-Frequency Identification (RFID) technology into wheelchairs, we facilitated automatic door opening upon RFID interaction, providing greater convenience for wheelchair users. The system's features, including a master code for user registration and One-Time Passwords (OTPs) for guest access, were designed with simplicity and security in mind. Additionally, our focus on data security through robust encryption methods underscores our commitment to protecting user privacy. Looking forward, we aspire to continue exploring innovative solutions that prioritize accessibility and security for all.

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