Implementation of a Smart Locker and Charging Station for a Futsal Facility in Kediri Regency

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***Abstract*— The rapid growth of the Internet of Things (IoT) has encouraged the development of smart systems to enhance security and user convenience in public facilities. Locker and device charging services in futsal facilities are still commonly managed using conventional systems that lack monitoring and access control. This study aims to design, implement, and evaluate an IoT-based smart locker and charging station system for a futsal facility in Kediri Regency, Indonesia. A Research and Development (R&D) approach was employed, including system design, prototype implementation, and performance testing. The proposed system uses an ESP32 microcontroller as the main controller, an HC-05 Bluetooth module for local communication with an Android application, an ESP32-CAM module for visual monitoring, solenoid locks for electronic access control, and Firebase as the cloud backend. Experimental results show an average image capture delay of 1.75 s, solenoid lock response times in the millisecond range, an average image transmission delay to Firebase of 4.74 s, and stable Bluetooth communication within indoor operational distances. Functional testing confirms that all application features and the charging station operate as intended. These results indicate that the proposed system is feasible as a secure and integrated smart locker solution for futsal facilities.**

***Keywords*— Bluetooth HC-05, ESP32, ESP32-CAM, Internet of Things, Smart Locker.**

I. INTRODUCTION

The development of the Internet of Things (IoT) as part of the industry 4.0 paradigm has encouraged the integration of physical devices, computing systems, and cloud-based services to create intelligent, adaptive, and real-time connected systems. IoT technology enables various devices such as sensors, actuators, and cameras to communicate with each other and transmit data to the cloud for remote monitoring and control purposes [1][2][3]. IoT implementations have been widely applied in security and access control systems, particularly in smart door locks and electronic locking systems based on ESP32 microcontrollers integrated with mobile applications and backend services [4][5][6][7].

One rapidly growing application of IoT is the smart locker system, which is an electronic-based storage system that replaces conventional lockers with digital locking mechanisms, user authentication, and network-based monitoring. Numerous studies have developed smart lockers using RFID, QR code technology, and Android applications connected to IoT systems to enhance security and usability [8][9][10][11][12]. These studies indicate that smart lockers provide better access control than mechanical systems while enabling digital logging of user activities.

Along with the increasing demand for public and commercial services, smart lockers have also been integrated with cloud storage and real-time databases such as Firebase to store access data, user images, and locker usage status online. Several studies report that Firebase is widely adopted as an IoT backend due to its ease of integration, real-time data synchronization, and cross-platform support [13][14][15][16][17][18]. However, the use of cloud backends in camera-based systems such as ESP32-CAM introduces new challenges, particularly related to data transmission latency, network stability, and system reliability under real operational conditions [17][19].

In addition to cloud-related aspects, short-range wireless communication performance is a critical factor in smart locker systems. The Bluetooth HC-05 module remains widely used due to its simple configuration and compatibility with Android devices. Nevertheless, several studies have reported that Bluetooth performance is strongly influenced by distance, indoor environmental conditions, and physical obstacles, which can result in communication delays and connection failures [1][2][19]. Therefore, empirical evaluation of Bluetooth delay and communication range in real usage environments is an important aspect that requires further investigation.

In the context of sports facilities, the concepts of smart facilities and smart stadiums emphasize the use of IoT to improve user comfort, security, and operational efficiency through integrated systems based on sensors, mobile devices, and cloud computing [7][12]. Futsal courts, as small-scale sports facilities, typically provide storage lockers for players; however, many still rely on conventional systems without real-time monitoring, digital authentication, or usage history recording. This condition may lead to security issues and reduced user convenience.

Based on the literature review, most smart locker studies focus on system design and basic functionality, while comprehensive evaluations of operational performance metrics—such as camera-to-cloud transmission latency, Bluetooth communication delay, and solenoid lock response time—are still rarely reported within a single integrated system [9][19][20]. These metrics are crucial for determining service quality and user experience in real-world smart locker implementations.

Therefore, this study aims to design and implement an IoT-based smart locker and charging station system for a futsal facility in Kediri Regency using an ESP32 microcontroller, an HC-05 Bluetooth module, an ESP32-CAM camera, solenoid locks, and Firebase as the cloud backend. The main contribution of this study lies in presenting an end-to-end system implementation that can be replicated using low-cost components, along with an empirical performance evaluation covering capture-to-cloud latency, Bluetooth delay and range in indoor environments, and the reliability of the electronic locking mechanism, serving as a practical reference for smart locker development in small-scale sports facilities.

II. METHOD

This study adopts a Research and Development (R&D) approach aimed at designing, implementing, and evaluating the performance of an Internet of Things (IoT)–based smart locker and charging station system for a futsal facility in Kediri Regency. The R&D approach was selected because it is suitable for technology product development involving systematic stages of system design, prototype development, and performance testing until the defined specifications are achieved. The stages of the research methodology are illustrated in Figure 1.

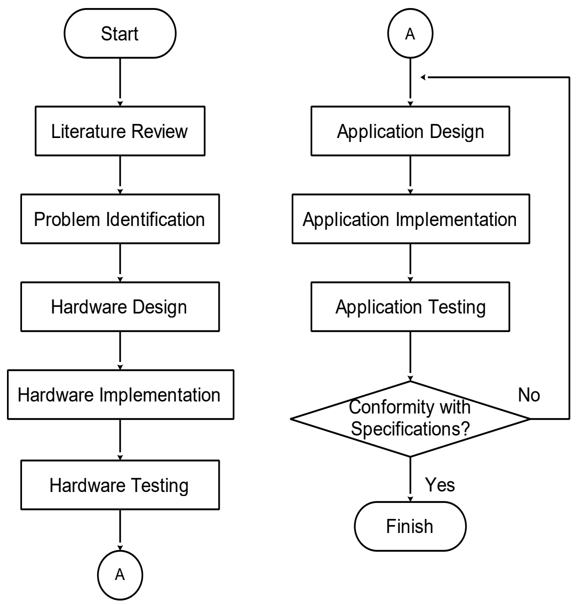

Figure 1. Research methodology workflow

The research stages in the development of the smart locker and charging station system were carried out systematically, as illustrated in Figure 1. The study began with a literature review stage, which involved examining scientific journals, conference proceedings, and technical references relevant to the development of IoT-based smart locker systems. This stage aimed to establish a theoretical foundation, determine an appropriate research approach, and identify potential opportunities for system development.

The next stage was problem identification, which focused on the conditions of futsal facilities, particularly issues related to the security of players' belongings and the limitations of conventional locker systems. The main problems identified included the absence of digital authentication–based locking mechanisms, limited monitoring of locker usage, and the lack of an integrated and secure charging facility for electronic devices.

Based on these issues, a system design stage was conducted, covering both hardware and software design in accordance with the defined functional requirements. This stage was followed by system implementation, which involved assembling and integrating all system components into a smart locker and charging station prototype. After implementation, functional and performance testing was carried out to evaluate system reliability, responsiveness, and functional conformity with the specified requirements. The final stage of the research was system evaluation, conducted based on the testing results to ensure that the smart locker and charging station system operated properly and was suitable for deployment in a futsal facility environment. The workflow of the proposed application is shown in Figure 2.

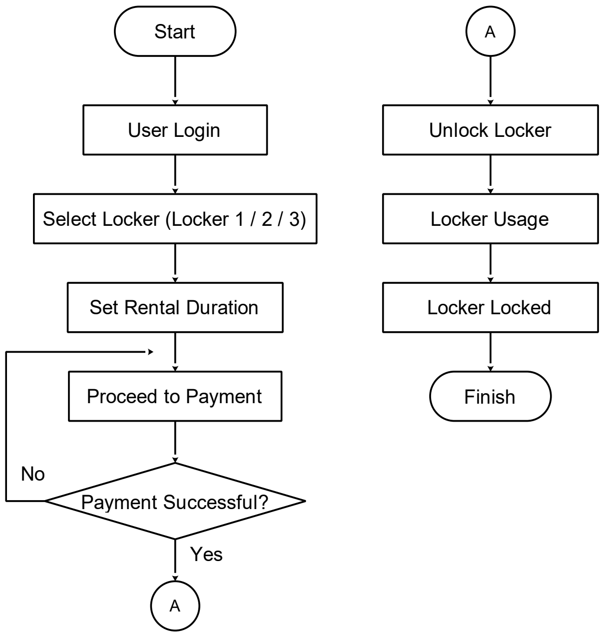

Figure 2. Application workflow

Figure 2 illustrates the workflow of the smart locker application used by users. The process begins with the user login stage to perform user authentication. After successfully accessing the system, the user selects one of the available lockers, namely Locker 1, Locker 2, or Locker 3. Next, the user specifies the desired locker usage duration according to their needs. Once the usage duration is set, the system directs the user to the payment stage. If the payment process is unsuccessful, the system returns to the payment stage until the transaction is completed successfully. After successful payment, the system activates locker access by unlocking the selected locker. During the rental period, the locker can be used by the user and will be automatically locked again once the usage duration expires. The process is then completed.

A. System Architecture Design

The architecture of the smart locker and charging station system developed in this study is designed to integrate hardware subsystems, software components, and network-based services in a unified manner. This architecture enables centralized and controlled management of locker operations, electronic locking mechanisms, user activity monitoring, and the provision of electronic device charging facilities. The block diagram of the proposed system architecture is presented in Figure 3.

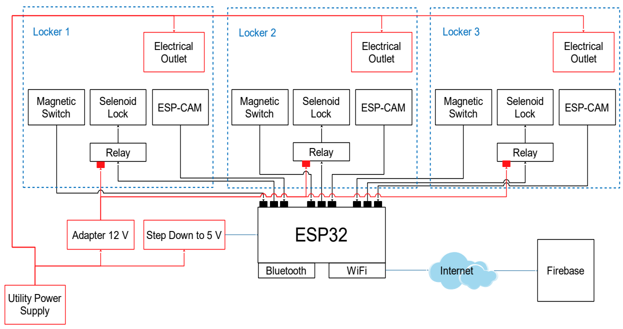

Figure 3. Block diagram of a smart locker and charging station system with Bluetooth, Wi-Fi, and Firebase Integration

Based on Figure 3, the ESP32 acts as the main controller that coordinates all system operations. The ESP32 receives input signals from magnetic switches to detect the locker door status and controls the solenoid locks via relay modules as locking actuators. Through this mechanism, the opening and closing of the lockers can be performed electronically according to system commands. The system consists of multiple locker units (Locker 1, Locker 2, and Locker 3), each equipped with a locking subsystem, an image acquisition module, and an integrated charging facility. The ESP32-CAM module is used to capture images of user activities during locker access, which are subsequently transmitted to Firebase via a WiFi connection and the internet as a cloud-based database for recording and monitoring locker usage.

In addition, Bluetooth communication is employed as a local control medium between the user application and the smart locker system, particularly for transmitting lock and unlock commands. On the power supply side, the system is powered by a utility power source that is converted through a 12 V adapter and a DC–DC step-down converter to 5 V to meet the power requirements of the ESP32 and other electronic components. Each locker is also equipped with an electrical outlet functioning as a charging station, allowing users to charge electronic devices during the rental period. The activation of both the locking mechanism and the charging station is controlled by the ESP32 via relay modules, ensuring that they are only active according to the locker usage status.

B. Hardware System Design

After the smart locker and charging station system architecture has been conceptually defined, the next stage is the realization of the design into a physical prototype and hardware configuration. This stage focuses on the practical implementation of the system, including the placement of components within the locker cabinet and the arrangement of interconnections between devices to ensure proper system operation in accordance with the designed functions. The proposed locker design is illustrated in Figure 4.

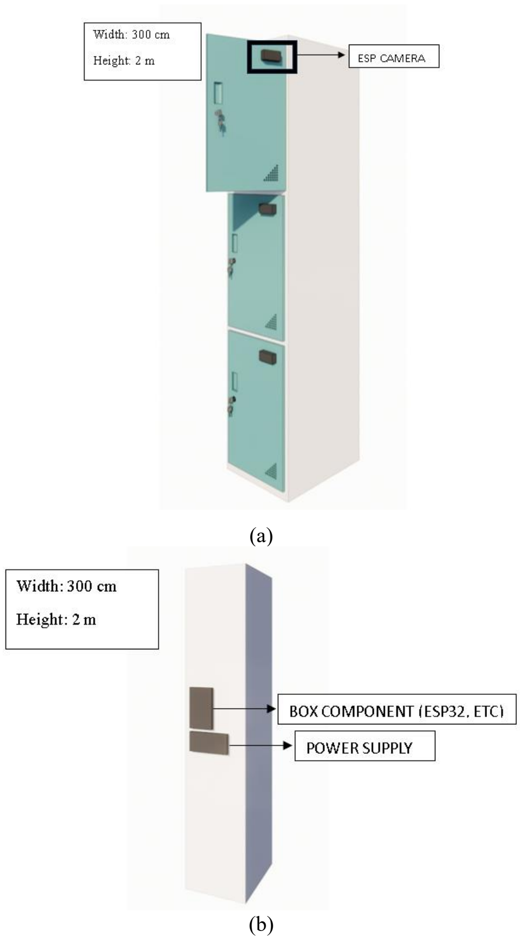

Figure 4. Physical design of the smart locker system: (a) Front view of the smart locker, (b) Side view of the smart locker

To support the hardware implementation of the smart locker and charging station system, proper interconnection among components integrated with the ESP32 microcontroller as the main controller is required. The pin configuration is designed to ensure reliable sensor data acquisition, actuator control, and communication with supporting modules, in accordance with the functional requirements of each component. Table 1 presents the ESP32 pin configuration used in the smart locker and charging station system.

TABLE I
PIN CONFIGURATION OF THE ESP32 IN THE SMART LOCKER SYSTEM

No	Component	ESP32 Pin	Function
1	Magnetic Switch 1	GPIO 16	Detects the status of Locker 1 door
2	Magnetic Switch 2	GPIO 17	Detects the status of Locker 2 door
3	Magnetic Switch 3	GPIO 18	Detects the status of Locker 3 door
4	Solenoid Lock 1	GPIO 25	Locking actuator for Locker 1
5	Solenoid Lock 2	GPIO 26	Locking actuator for Locker 2
6	Solenoid Lock 3	GPIO 27	Locking actuator for Locker 3
7	Relay Module	GPIO 33	Controls the solenoid locks
8	ESP32-CAM 1	GPIO 32	Image acquisition for Locker 1
9	ESP32-CAM 2	GPIO 34	Image acquisition for Locker 2
10	ESP32-CAM 3	GPIO 35	Image acquisition for Locker 3
11	Power Supply (5 V)	VIN	Power supply for ESP32
12	Ground	GND	System reference

C. Application Design and Implementation

The application was developed to provide a user interface that supports structured and secure interaction between users and the smart locker system. The application is designed to manage user authentication, locker selection, usage duration settings, and payment processing before locker access is granted. In addition, the application serves as a communication medium between users and the hardware system via a Bluetooth connection and supports integration with network-based services for data logging and management. During the implementation stage, the application was developed on the Android platform with considerations for usability and system reliability. Each application function follows the workflow defined in the application flow diagram, ensuring that the locker rental process operates systematically from user login to payment confirmation. The user interface of the developed application is shown in Figure 5. The interface is designed to be simple and intuitive to ensure ease of use for users during the locker rental process. Clear navigation and visual indicators are provided to guide users through each step, from authentication to payment confirmation.

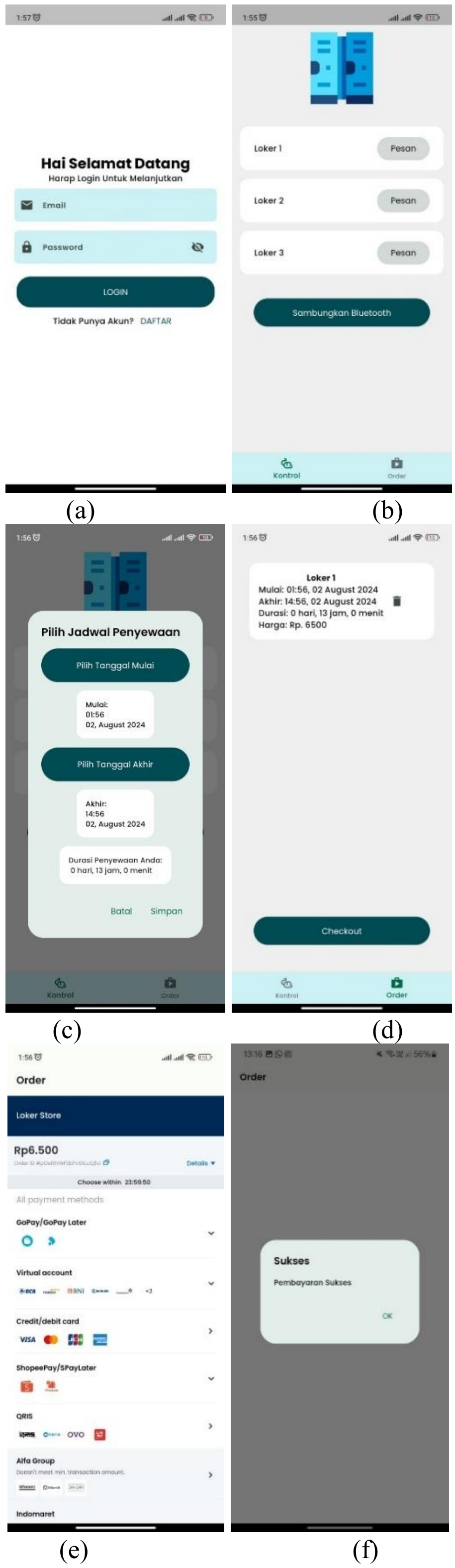

Figure 5. User interface of the smart locker application: (a) Login page, (b) Bluetooth connection selection page, (c) Locker rental page, (d) Locker rental process page, (e) Payment page, (f) Payment success page

D. System Testing Method

System testing was conducted to evaluate the performance and reliability of the implemented smart locker and charging station system. The testing focused on key parameters related to system responsiveness, communication speed, and the performance of actuators and supporting modules. The evaluated parameters included Bluetooth communication delay between the user application and the smart locker system, image capture delay of the ESP32-CAM module, image data transmission delay from the ESP32-CAM to the Firebase cloud service, and the response time of the solenoid lock during locker opening and locking operations. These parameters were selected because they directly affect user convenience and system security.

All tests were carried out in an indoor futsal facility environment in Kediri Regency to represent real operational conditions. Each testing parameter was measured repeatedly ten times to obtain consistent data and minimize measurement errors. The delay and response time values were recorded for each trial, and their average values were calculated as performance indicators of the system. The testing results were subsequently analyzed in the results and discussion section to determine whether the smart locker and charging station system met the specified performance requirements.

III. RESULTS AND DISCUSSION

A. Hardware Implementation Results

This subsection presents the results of the physical implementation of the smart locker and charging station system developed for futsal facilities. The hardware realization was carried out based on the system architecture and hardware design that were explained in the previous section. Each locker unit is equipped with an ESP32-CAM module installed on the front panel, as shown in Figure 6.

Figure 6. Front view of the smart locker hardware implementation

The ESP32-CAM module functions as a visual monitoring component to record user activities when accessing the locker, thereby enhancing security aspects and usage documentation. The placement of the camera on the locker door enables direct image capture during both locker opening and closing events. At the rear side of the locker cabinet, the main control and power supply components are installed. This section contains the ESP32 microcontroller as the central system controller, a relay module used to drive the solenoid lock, and an HC-05 Bluetooth module that serves as a local wireless communication interface between the system and the mobile application. In addition, a power supply unit is installed to convert the AC input voltage into a regulated DC voltage suitable for operating the ESP32 and other supporting components.

B. ESP32-CAM Image Capture Delay

The ESP32-CAM image capture delay test was conducted to evaluate the time required by the system to capture images when the locker is opened. The test was performed ten times under normal operating conditions in an indoor futsal facility environment. This parameter is important because it is directly related to the system’s ability to document user activities in real time. The results of the ESP32-CAM image capture delay testing are presented in Table 2.

TABLE II
ESP32-CAM IMAGE CAPTURE DELAY

No	Delay (s)
1	1.76
2	1.72
3	1.69
4	1.74
5	1.75
6	1.82
7	1.67
8	1.67
9	1.73
10	1.73
Average	1.75

Based on Table 2, the test results show that the average image capture delay is 1.75 s. This value indicates that the ESP32-CAM is capable of performing image acquisition with a relatively stable response time.

C. Solenoid Lock Response Time

The solenoid lock response time test was conducted to measure the system’s speed in electronically unlocking and locking the locker. The test was performed 12 times for each operating condition, namely open and close. This parameter serves as a key indicator of the reliability of the locking mechanism in the smart locker system. The solenoid lock response time test results are presented in Table 3.

TABLE III
SOLENOID LOCK RESPONSE TIME

No	Open Delay (ms)	Close Delay (ms)
1	29	32

No	Open Delay (ms)	Close Delay (ms)
2	31	30
3	33	32
4	31	30
5	43	43
6	44	43
7	41	45
8	44	43
9	55	58
10	58	56
11	56	57
12	58	56
Average	41.08	38.83

Based on Table 3, the solenoid lock response time test results indicate that the average response time is 41.08 ms for the unlocking process and 38.83 ms for the locking process. These values can be considered fast and demonstrate that the locking system is capable of responding to control commands in a near-instantaneous manner.

D. ESP32-CAM to Firebase Transmission Delay

This test aims to measure the time required by the ESP32-CAM to transmit captured images to Firebase as the cloud backend. The test was conducted 10 times using a Wi-Fi connection in an indoor environment. The results of the image transmission delay test to Firebase are presented in Table 4.

TABLE IV
ESP32-CAM TO FIREBASE TRANSMISSION DELAY

No	Delay (s)
1	4.47
2	5.01
3	4.55
4	4.61
5	4.93
6	4.69
7	4.72
8	4.90
9	4.01
10	4.60
Average	4.74

The average image transmission delay to Firebase was 4.74 s. The observed delay variations were influenced by Wi-Fi network conditions and cloud communication processes. Nevertheless, this delay remains acceptable for non-real-time monitoring systems and indicates that the integration between the ESP32-CAM and Firebase operates reliably.

E. Bluetooth Communication Delay

Bluetooth communication delay testing was conducted to evaluate the effect of distance on the connection time between the user application and the Bluetooth HC-05 module. The tests were performed at distances ranging from 1 to 4.9 meters. The results of the Bluetooth delay measurements as a function of distance are presented in Table 5.

TABLE V
BLUETOOTH COMMUNICATION DELAY

Distance (m)	Delay (s)
1.0	0.43
2.0	2.46
3.0	3.65
4.0	2.89
4.9	5.11
Average	2.91

Based on Table 5, the test results indicate that the communication delay increases as the distance increases. The average delay of 2.91 s is still considered acceptable for smart locker applications, given that Bluetooth communication is only utilized during the authentication process and locker control operations.

F. Application and Charging Station Functionality Testing

Functional testing of the application and charging station was conducted to ensure that all system features operate according to the specified requirements. The testing focused on user authentication, locker rental processes, payment transactions, locker lock and unlock control, and the availability of the charging facility. The results of the functional testing of the charging station system are presented in Table 6.

TABLE VI
APPLICATION AND CHARGING STATION FUNCTIONALITY TESTING

Feature	Expected Result	Test Result
User login validation	Valid / invalid detection	Successful
Locker selection	Correct locker assignment	Successful
Payment process	Transaction completed	Successful
Locker unlock/lock	Responsive operation	Successful
Charging station activation	Power available during rental	Successful
Feature	Expected Result	Test Result

Based on Table 6, the test results indicate that all features of the application and charging station function as designed. The charging station is activated only during the locker rental period, thereby enhancing operational security and improving power usage efficiency.

G. Discussion

This discussion section examines the performance of the smart locker and charging station system based on the testing results presented in the previous section. The analysis refers to the performance graphs of each testing parameter to evaluate system stability, responsiveness of the main components, and the feasibility of deploying the system in a futsal facility as a public environment that requires fast, secure, and controlled access.

Based on the ESP32-CAM image capture delay graph shown in Figure 7, it can be observed that the time required by the system to capture images remains relatively stable across all trials. The delay values fall within a narrow range, with no extreme spikes, and an average of approximately 1.75 seconds. This relatively flat graph pattern indicates that the ESP32-CAM module is capable of consistently performing image capture during locker opening and closing events. Such stability is crucial to support visual monitoring functions, as it ensures that user activity documentation can be carried out without causing significant disruption or delay in the locker usage process.

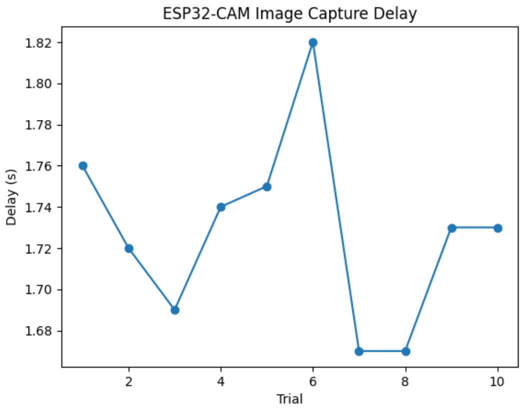

Figure 7. ESP32-CAM image capture delay across multiple trials

The analysis of the electronic locking mechanism was conducted by examining the solenoid lock response time graph during opening and closing operations, as shown in Figure 8. The graph indicates that the solenoid response time is in the range of tens of milliseconds, with relatively small differences between the unlocking and locking processes. This fast and consistent response confirms that the solenoid actuator operates reliably in executing commands issued by the control system. With these characteristics, the implemented electronic locking system is considered capable of meeting user security and convenience requirements, particularly in futsal facilities where locker access frequency is relatively high.

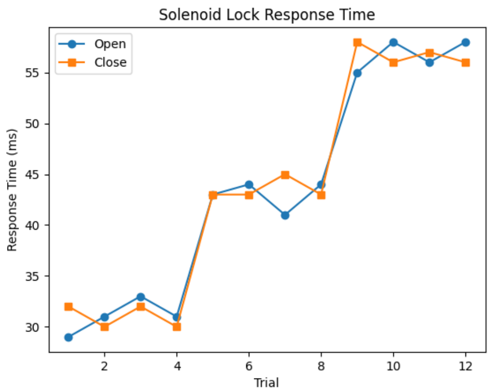

Figure 8. Solenoid lock response time for opening and closing operations

The performance of the integration between the ESP32-CAM module and the Firebase cloud service was analyzed based on the image transmission delay graph shown in Figure 9. The graph illustrates variations in transmission time across different trials, with the observed delays influenced by Wi-Fi network conditions and the image upload process to the cloud server. Despite these variations, the average delay remains within an acceptable range for non–real-time monitoring and user activity logging applications. Therefore, the proposed system is considered sufficiently reliable to support centralized recording of locker usage history and user activity monitoring through cloud-based services.

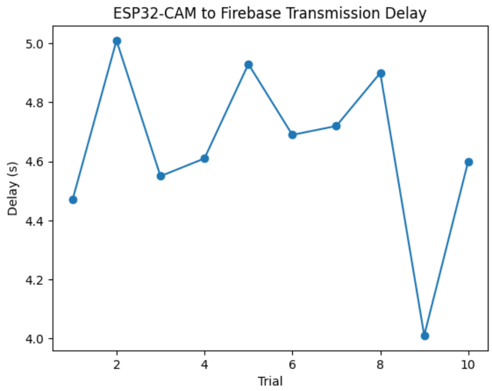

Figure 9. ESP32-CAM to firebase image transmission delay

The performance of Bluetooth communication was analyzed based on the relationship between communication distance and delay, as illustrated in Figure 10. The graph indicates that communication delay tends to increase as the distance between the user's mobile device and the HC-05 Bluetooth module becomes greater. At shorter distances, the delay remains relatively low, whereas a more significant increase in delay is observed as the distance approaches the maximum Bluetooth operating range. Nevertheless, stable communication can still be maintained up to a distance of approximately five meters under indoor conditions. These results indicate that the use of the HC-05 Bluetooth module as a local control medium for the smart locker system is appropriate, considering that user interaction with lockers in futsal facilities typically occurs at close range.

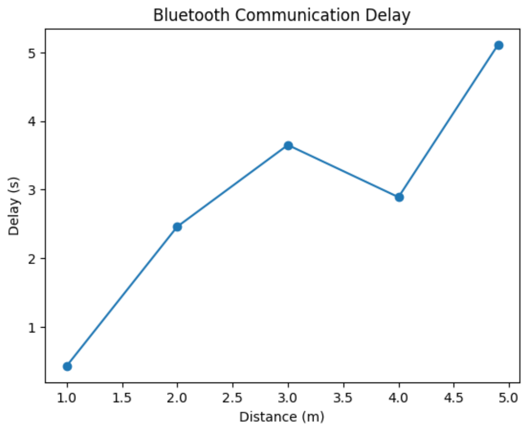

Figure 10. Bluetooth communication delay versus distance

In addition to hardware and communication performance, the results of application functionality testing indicate that all main system features operate in accordance with the designed specifications. User authentication, locker selection, usage duration configuration, payment processing, and locker lock–

unlock control function properly. The integration of the charging station, which is controlled based on the locker usage status, ensures that the power outlet is activated only during the rental period. This approach not only enhances power usage security but also provides added value for futsal facility users who require electronic device charging during their activities.

Overall, the analysis of performance graphs and testing results demonstrates that the developed ESP32-based smart locker and charging station system exhibits stable, responsive, and well-integrated performance. Each major subsystem—including the camera module, locking mechanism, Bluetooth communication, cloud integration, and charging station—shows consistent operation and effectively supports the overall system objectives. Therefore, the proposed system is considered feasible for implementation as a secure and integrated solution for item storage and electronic device charging in futsal facilities in Kediri Regency

IV. CONCLUSION

This study successfully designed and implemented an Internet of Things (IoT)–based smart locker and charging station system for a futsal facility in Kediri Regency using an ESP32 microcontroller, Bluetooth HC-05 module, ESP32-CAM camera, solenoid lock, and Firebase as the cloud backend. Experimental results indicate that the system demonstrates stable and responsive performance, as reflected by an average ESP32-CAM image capture delay of 1.75 s, solenoid lock response times in the order of milliseconds, an average image transmission delay to Firebase of 4.74 s, and reliable Bluetooth communication within typical indoor operating distances. All application functionalities—including user authentication, locker selection, payment processing, lock–unlock control, and charging station activation—operate according to the designed specifications. The integration of the charging station, which is controlled based on locker usage status, enhances both power usage security and energy efficiency. Therefore, the proposed system is considered feasible as a secure, integrated, and low-cost solution for item storage and electronic device charging in futsal facilities or similar public environments.

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