RFID-Based IoT Scanning System for Tracking Parking Slot Application

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***Abstract*—The increasing demand for parking spaces in various facilities, such as shopping centers, ports, and airports, poses a significant challenge for parking managers. Drivers waste time and fuel searching for available parking slots, resulting in increased air pollution and negative environmental and health impacts. Therefore, a new solution is needed to address these issues and improve parking management efficiency. A parking management system that utilizes RFID technology and allows for the RFID Tag on each car to display user data, user ID, and parking space reservations is needed to improve the efficiency and convenience of parking at various facilities. The proposed system design incorporates various components, including a Camera Sensor, Raspberry PI, ESP8266, UHF RFID reader, and RFID Tag. The RFID technology captures radio waves emitted by the RFID Tag, enabling individual identification through unique codes. Testing revealed high accuracy at close range but decreased effectiveness at longer distances. Internet speed and network latency affected system performance, with faster speeds enabling faster data transmission. The system, developed using Thunkable and Firebase, provides real-time parking space availability information and streamlines vehicle entry and exit processes through RFID technology. This system has the potential to greatly improve the parking experience at busy public facilities by facilitating efficient parking spot finding and enhancing overall convenience for drivers.**

Keywords: parking facilities, availability of parking spaces, RFID, tracking parking slots

I. INTRODUCTION

PARKING facilities are essential for any facility or infrastructure provider, such as shopping centers, ports, and airports. Over time, the need for parking space increases with the increasing number of visitors bringing their vehicles, particularly cars. Adequate parking facilities are necessary for the comfort of visitors, so parking managers provide large parking areas and even multi-level parking patterns. This makes drivers traverse the parking area to find an empty parking slot. While traversing the parking area, many things will be wasted, such as time and gasoline spent looking for an empty parking slot, especially when the exact location is unknown. The consequence of traversing the parking area is that the air pollution caused by vehicles will increase. With increased air pollution, the negative impacts will be more, ranging from environmental to health.

The parking issue requires a monitoring system to facilitate users in finding parking slots. The monitoring system technology itself is applied in many things, such as monitoring: environmental parameters [1]–[4], human movement and emergency buttons in home security systems [5], [6], and the use of electricity in housing [7] where all of the above systems utilize the Internet of Things (IoT) technology.

Moreover, Laumal et al. [8] utilized RFID technology to provide identification data from tags to access doors, while photodiode sensors provided data on the presence of 2-wheel vehicles in a given location. The Arduino acted as a central processing unit, processing data from the RFID and photodiode sensors. Nevertheless, the RFID system remains independent without integrating with Internet of Things (IoT) components. Rouan et al. [9] utilized RFID technology to quickly check in and out vehicles, reducing the potential for human error in access control. Chang et al. [10] utilized RFID technology for the real-time identification of vehicle license plates, which were connected to a PLC for automatic gate control. Both of these studies share a common aspect: the utilization of RFID technology to facilitate the check-in and check-out process for vehicles within a parking system. However, there is a lack of integration with user-friendly applications such as Android or web-based platforms to enhance user convenience.

Based on previous research, it is clear that a new solution is needed. The proposed solution is the "RFID-Based IoT Scanning System for Tracking Parking Slot Application." This application aims to detect the presence of cars in several parking slots and provide information on empty parking slots to drivers through an Android application. The application allows drivers to reserve a parking slot and be directed to it through the app. By displaying available parking slots and providing directions to the reserved slot, this application aims to improve parking management efficiency.

II. METHOD

A. System Design

This research project involves building a system with a sequential workflow, presented in Figure 1, starting with determining the design system. The design system has four sub-sections: Electrical Assembly, Mechanical Assembly, Vision Programming, and Application Interface and Database. The integration of Electrical and Mechanical components forms the hardware part of the system. The synchronization between the vision and interface is then carried out, followed by training data. If the training is successful, reading the parking address is executed; otherwise, data retraining is performed, contributing to the system's vision. Regarding RFID, a test is conducted to transmit a unique code to the interface, and if successful, the unique code is stored in the database, serving the purpose of the database and interface. The subsequent stage involves synchronizing the hardware, vision, databases, and interfaces, resulting in the development of an Android application for tracking parking slots.

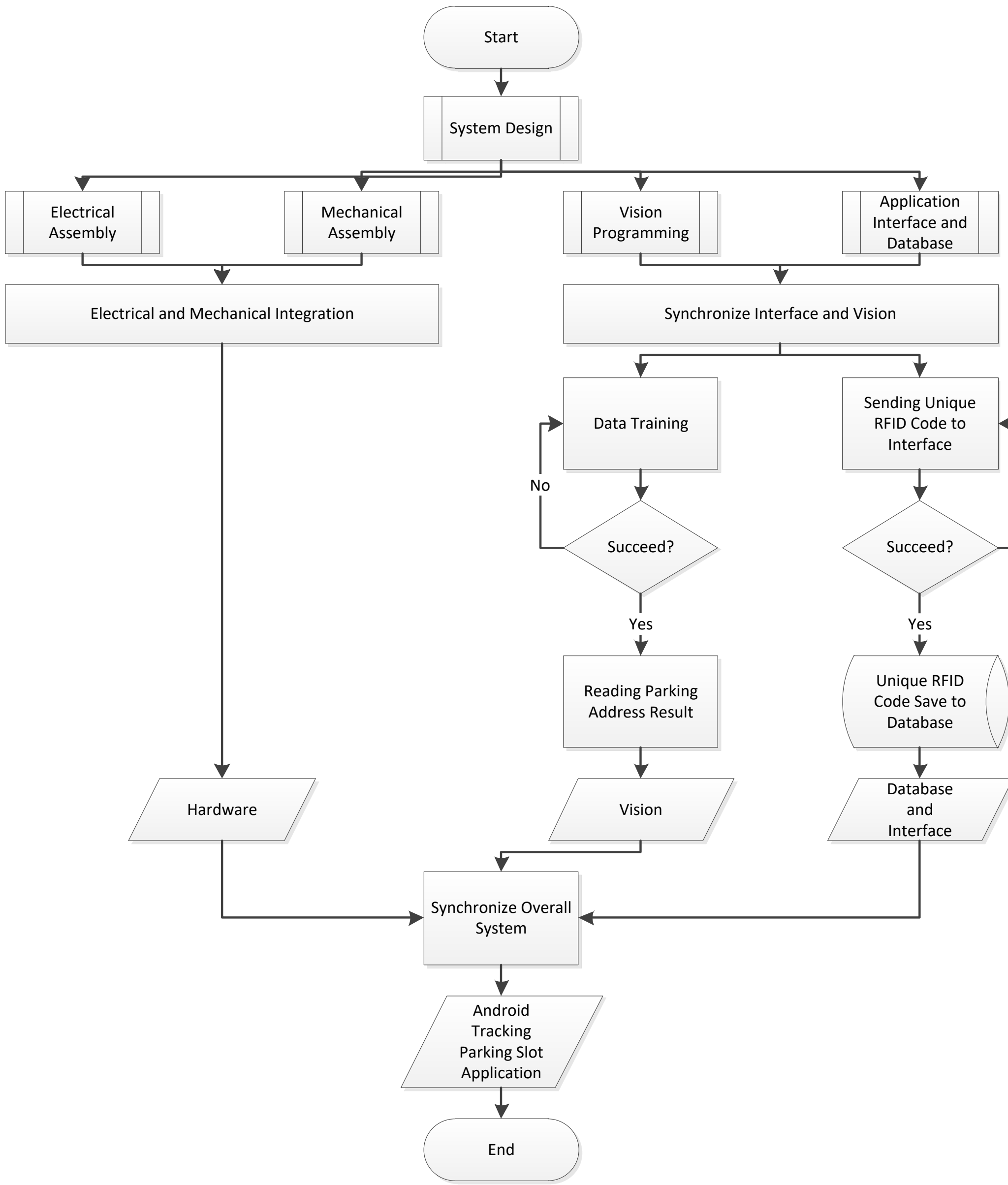


Fig. 1. Overall system design flowchart

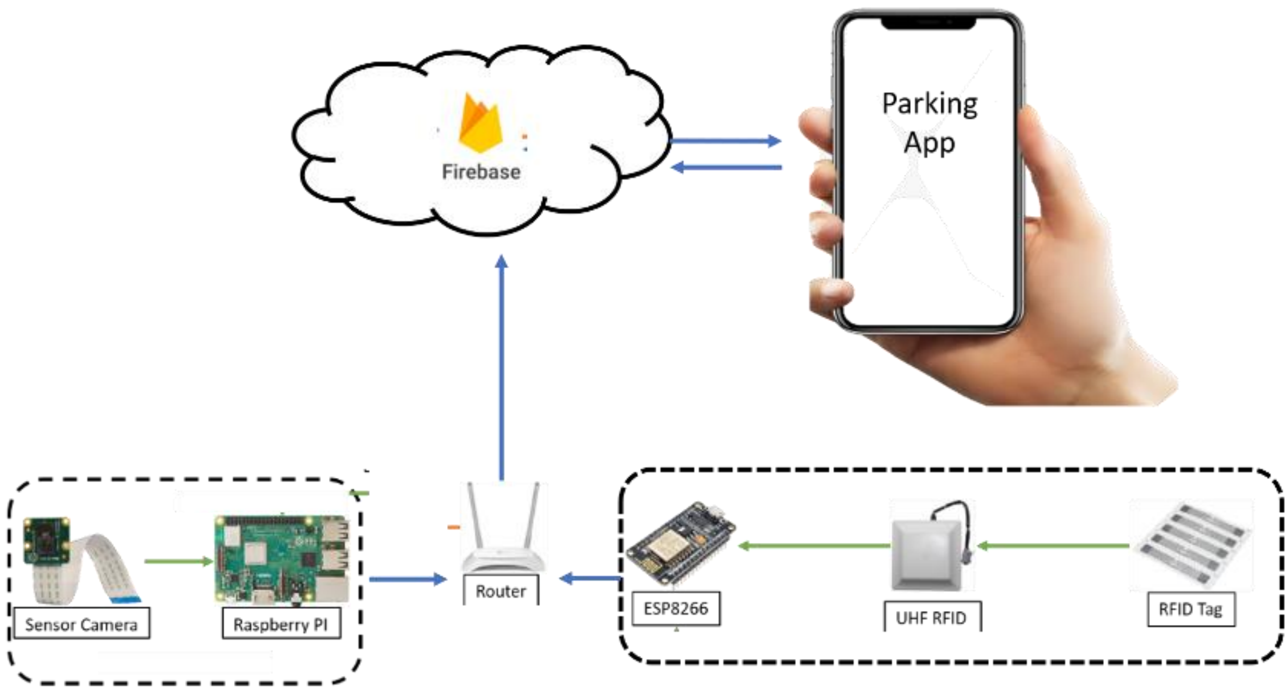


Fig. 2. Overall system topology

This system uses a Camera Sensor, Raspberry PI, ESP8266, UHF RFID reader, and RFID Tag. RFID is the main component in the scanning process by capturing the radio waves emitted by the RFID Tag on each car so that user data, user id, and parking slot location information will appear in the Android interface. The UHF RFID reader can read the RFID Tag with a frequency range of 800-900 MHz. The Raspberry PI will receive image data from the Camera Sensor. ESP8266 is used for communication between the server and the router. The overall system topology is shown in Figure 2.

Each RFID Tag placed on each car has a unique code that is different from each other as a means of identification between one user and another. An RFID reader is needed to translate the radio frequency wave into the bits that make up the RFID unique code to read the unique code on the RFID Tag. RFID will scan the tag on the car for a few seconds, after which the user can book a parking slot.

B. System Testing

There are several testing stages before the system can be declared fit. Here are the testing stages of this system:

1. Testing the RFID Reader's reading distance from the RFID Tag. The aim is to prove the extent of the impact of the integration of the system on the reading distance of the UHF RFID Reader. The testing includes the distance between the RFID reader and the RFID tag, which is 100 cm, 150 cm, 200 cm, 250 cm, and 300 cm, and five tests are conducted for each condition for each RFID tag, shown in Figure 3.
2. Testing whether the system successfully sends the unique code from microcontroller processing to the server computer and the unique code registered in the database using ESP8266. The testing is conducted on ten RFID tags, and the ten unique codes are declared if the ones stored in the database and displayed on the interface are the same.

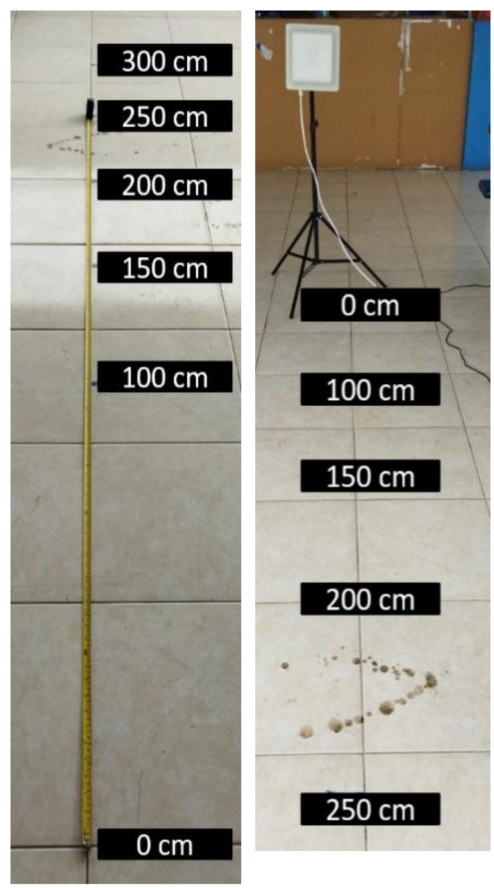


Fig. 3. RFID distance measurement process

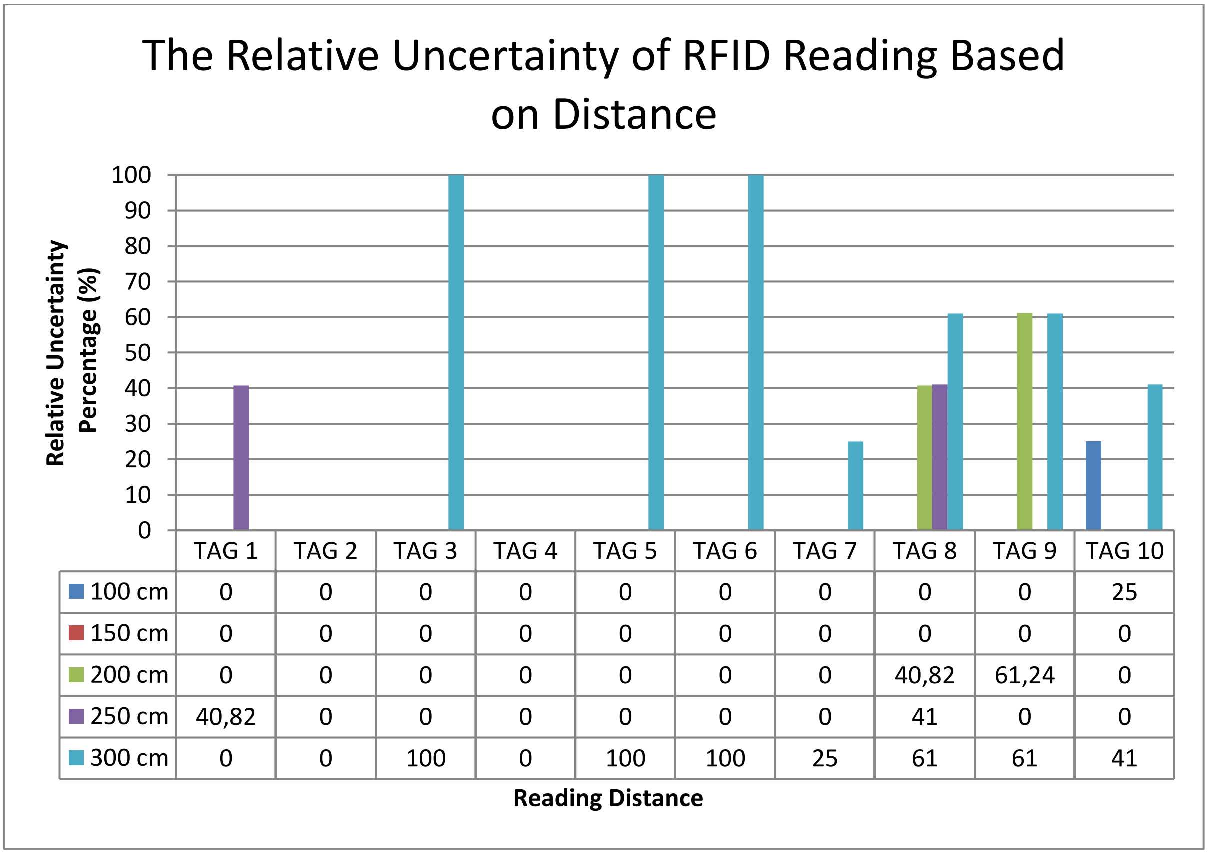


Fig. 4. Graph of relative uncertainty of RFID reading by distance

3. Testing the correlation between the internet speed level and the data transmission delay time to the Firebase-based database. The testing includes the distance between the device and the access point, which is 0.1 m, 2 m, 5 m, 7 m, and 10 m, and twenty tests are conducted for each access point condition.

III. RESULTS AND DISCUSSION

According to the data obtained from the test results, the relative uncertainty value of RFID reading was determined, which has been visualized as a graph in Figure 4. The graph shows the process of scanning ten RFID tags at distances of 100 cm, 150 cm, 200 cm, 250 cm, and 300 cm, with five tests performed for each condition on each RFID tag. The test results showed that scanning RFID tags at close distances had less uncertainty than scanning at a distance far from the RFID reader. Based on the data, relative uncertainty was found to be 100% (Tag 3, tag 5, and Tag six at a distance of 300 cm), 61.24% (Tag 9 at a distance of 200 cm), 61% (Tag 8 and Tag 9 at a distance of 300 cm), 41% (Tag 8 at a distance of 250 cm and Tag 10 at a distance of 300 cm), 40.82% (Tag 8 at a distance of 200 cm and Tag 1 at a distance of 250 cm), and 0% for other tag and distance conditions. The data obtained formed a pattern in which it can be concluded that the closer the distance between the reader and the tag, the smaller the relative uncertainty level of the reading.

According to the data presented in Table 1, the internet speed measurements were obtained by considering five specific distances. When the distance was set at 0.1 m, the corresponding internet speed was 7.17 Mbps. Similarly, at a distance of 2 m, the internet speed reached 7.04 Mbps. For a distance of 5 m, the internet speed was measured at 6.68 Mbps. Furthermore, at a distance of 7 m, the internet speed exhibited a value of 5.78 Mbps, whereas, at a distance of 10 m, the internet speed decreased to 3.13 Mbps. We intentionally measured the internet speed at different distances from the access point to conduct the test. This was done to observe how the speed of the internet connection changes as we move farther away from the source. This variation in internet speed allowed us to have a diverse range of transmission rates for testing purposes.

TABLE I
THE INTERNET SPEED VS. AVERAGE DELAY BASED ON DISTANCE

Distance between Access Point and ESP8266 (m)	Internet Speed (Mbps)		Average Delay (ms)
	Download	Upload	
0.1	7.17	2.08	1551.40
2	7.04	2.05	1634.25
5	6.68	1.88	1644.50
7	5.78	2.06	2507.90
10	3.13	1.97	2597.85

TABLE II
TRANSMISSION RATE VS. NETWORK LATENCY

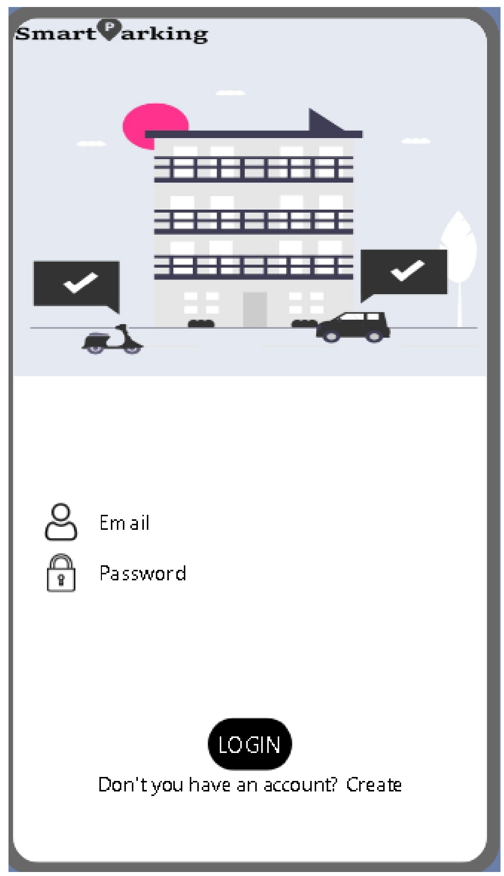
Transmission Rate (Mbps)	Network Latency (ms)
7.17	141.04
7.04	148.57
6.68	149.50
5.78	227.99
3.13	236.17

The testing data was on the correlation between internet speed and data transmission delay time to the Firebase-based database. The testing includes the distance between the device and the access point, namely 0.1 m, 2 m, 5 m, 7 m, and 10 m, carried out twenty times for each condition, which has been visualized in Table 1. The test results showed that with an access point signal speed of 7.17, the lowest transmission delay or the fastest transmission rate was found compared to other signal speeds.

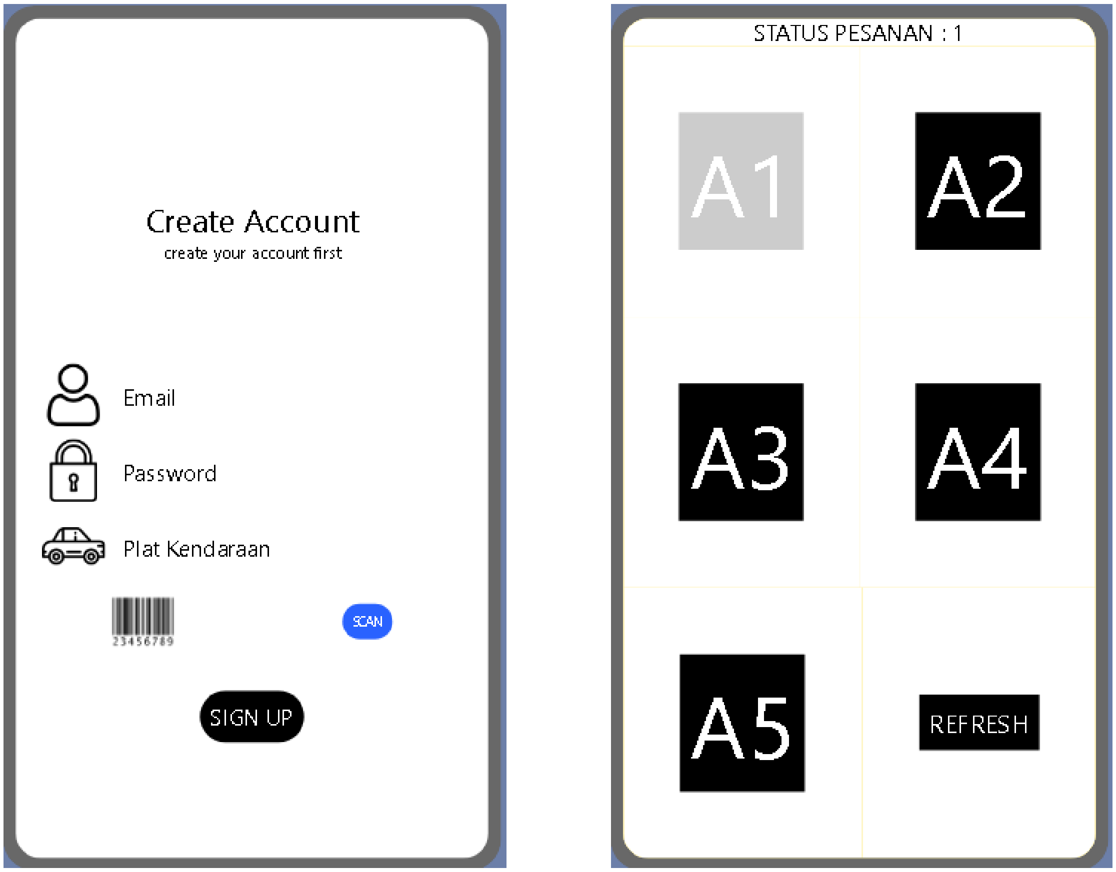
Based on the test results shown in Table 2, it can be observed that the network latency is affected by the internet transmission rate. The testing results show that the transmission rate of 7.17 Mbps had the lowest average latency of 141.04 ms compared to the other transmission rates of 148.57 ms for a transmission rate of 7.04 Mbps, 149.50 ms for a transmission rate of 6.68 Mbps, 227.99 ms for a transmission rate of 5.78 Mbps, and 236.17 ms for a transmission rate of 3.13 Mbps. It can be concluded that as the transmission rate increases, the network latency also increases, and as the transmission rate decreases, the network latency decreases.

As the transmission rate decreases, the network latency increases. This means that when the data is transmitted slower, it takes more time for the network to process and deliver the information. The graph shows a trendline that slopes upward in the low transmission rate range. This supports the earlier statement that lower transmission rates correspond to higher network latency, while higher transmission rates correspond to lower network latency.

(a) Landing page



(b) Login menu



(c) Sign up menu (d) Menu slot order map

Fig. 5. Tracking parking slot Android application

Following is a discussion regarding the interface and functionalities of the Android application designed for tracking parking slots. In Figure 5, section (a) displays the landing page of the smart parking application, featuring a visually appealing and simplistic design to ensure a positive user experience. Section (b) showcases the login menu, where users must input their email address and password for security and authentication. Once the email and password are entered, a login button becomes available. For users without an account, section (c) provides the option to create a new account. The account creation process includes entering an email address, password, and vehicle number or license plate, serving as an essential initial step for users.

Additionally, a feature for scanning RFID cards is available, allowing users to tap their NFC-enabled Android smartphones on the parking gate or NFC system when seeking parking. The registration data is then sent to the database server upon clicking the Sign Up button. In section (d), one of the test results is displayed, indicating that parking slot A1 has already been booked, resulting in the display showing the availability of slots A2, A3, A4, and A5 for other users. The slot order map menu also includes a refresh option, enabling users to obtain the most up-to-date information on available parking slots.

IV. CONCLUSION

Based on the results and discussion of the system in the Internet of Things-based parking slot tracking application, several conclusions can be drawn, including The RFID scanning system has a reading characteristic that tends to have a pattern, namely the closer the RFID tag is to the RFID reader, the greater the success rate of a scan and the smaller the uncertainty value, and vice versa. The scanning data at a distance of 100 cm can have a success rate of 80%-100%, while the scanning at a distance of 300 cm has a success rate of 20%-60%. There were some cases where the RFID tag failed to be scanned; based on analysis and related literature, this was caused by signal interference as the RFID used has a sensitive frequency, namely UHF 840-960 MHz, which makes it possible for interference from other electronic devices and the condition of the RFID tag is not good considering the tag is in the form of a sticker. The higher the internet speed value (transmission rate), the smaller the network delay and latency. The lower the internet speed value (transmission rate), the greater the network delay and latency. A transmission rate of 7.17 Mbps proves this with an average delay of 1551.4 ms and latency of 141.04 ms, while a transmission rate of 3.13 Mbps has an average delay of 2597.85 ms and latency of 236.17 ms. Moreover, the discussed Android application for tracking parking slots offers a visually appealing and user-friendly interface, allowing users to log in conveniently, create accounts, and utilize RFID card scanning for parking access. The system provides real-time availability updates on parking slot availability, enhancing the overall user experience and efficiency of parking management.

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