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Real-Time Monitoring System and IOT Smart Parking Booking (Case study: One Hotel in Tangerang)

Yogi Valentino Nadeak[a], Patricia Ho[a], Masriah[a]

[a]Pradita University, Indonesia

E-mail: yogi.valentino@student.pradita.ac.id

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Abstract

Since cars and motorbikes are the most popular personal mobility, public spaces must always provide enough parking for every visitor. However, occasionally there are more parking spaces available than there are guests, which makes it difficult for visitors to find an empty spot and takes a while. It can be found in the case study conducted in a hotel in Tangerang. This case study informs the development of an Internet of Things (IoT) smart parking system that uses Wi-Fi and the MQTT communication protocol to monitor user behavior, identify available parking spaces, and recognize vehicle entry. The ESP8266 microcontroller serves as the sensor node. Other sensors that are used include the RFID RC-522 sensor to determine how long a car user has been in the area, the Servo SG92R infrared (IR) sensor to detect the presence of a vehicle, and the HC-SR04 ultrasonic sensor to detect parking spaces. The outcomes showed that the Things board platform's monitoring capability and the ability to reserve particular parking spaces using an MIT App Inventor app proved the smart parking system's successful implementation.

Keywords*: Smart Parking, Monitoring, MQTT*

Abstrak

Karena mobil dan sepeda motor adalah mobilitas pribadi yang paling populer, ruang publik harus selalu menyediakan cukup tempat parkir untuk setiap pengunjung. Namun, terkadang terdapat lebih banyak tempat parkir tersedia daripada jumlah tamu, yang membuat pengunjung kesulitan menemukan tempat kosong dan memakan waktu. Hal ini ditemukan dalam studi kasus yang dilakukan di sebuah hotel di Tangerang. Studi kasus ini menginformasikan pengembangan sistem parkir pintar berbasis Internet of Things (IoT) yang menggunakan Wi-Fi dan protokol komunikasi MQTT untuk memantau perilaku pengguna, mengidentifikasi tempat parkir yang tersedia, dan mengenali masuknya kendaraan. Mikrokontroler ESP8266 berfungsi sebagai node sensor. Sensor lain yang digunakan termasuk sensor RFID RC-522 untuk menentukan berapa lama pengguna mobil berada di area tersebut, sensor Servo SG92R inframerah (IR) untuk mendeteksi keberadaan kendaraan, dan sensor ultrasonik HC-SR04 untuk mendeteksi tempat parkir. Hasilnya menunjukkan bahwa kemampuan pemantauan platform Thingsboard dan kemampuan untuk memesan tempat parkir tertentu menggunakan aplikasi MIT App Inventor membuktikan keberhasilan implementasi sistem parkir pintar ini.

Kata kunci: Parkir Pintar, Monitoring, MQTT

Introduction

Vehicles such as cars and motorcycles are generally used by many people in both short and long-distance travel. According to data from Ministry of Industry as at 10 March 2023, the number of domestic purchases of four-wheeled vehicles by 2022 reached about 1,048 million units or an increase of 18% from the previous year [1]. According to the Central Bureau of Statistics, the number of cars in Indonesia increased each year from 2018 to 2020, with 14,830,698 cars in 2018, 15,592,419 cars in 2019, and 15,797,746 cars in 2020 [2]. Data provided by the Central Bureau of Statistics also indicates that the number of cars in Tangerang Regency from 2018 to 2021 was 168,626 cars in 2018, 192,302 cars in 2019, 189,087 cars in 2020, and 189,647 cars in [3]. The presence of vehicles has significantly reduced the travel time to reach various destinations.

The widespread use of personal vehicles, such as cars, for transportation to various destinations necessitates adequate parking areas to accommodate vehicles when not in use. Therefore, parking areas are essential facilities commonly found in public places such as campuses, offices, malls, tourist attractions, hotels, and more. However, the limited space allocated for parking forces drivers to search for available spots, often taking a considerable amount of time to find one [4]. With the development of technology that is useful in day-to-day living, automated systems are becoming commonplace in human existence, particularly in the industrial world. In the industrial sector, an automated system is particularly useful because it enables the control of machinery using machines that are programmed so that human labor is replaced by other automated machinery as the controller.

Automation, also known as automated systems, is the process of substituting machine power for human labor in order to carry out and regulate operations automatically, doing away with the need for human supervision (in industries and other settings) [5]. Because automatic equipment management systems are more accurate, safe, and efficient than manual ones, they are far more convenient. Automated systems are becoming commonplace in human existence, particularly in the industrial environment. The parking industry, which includes both two-wheeler and four-wheeler parking, is one of the sectors that is also seeing notable breakthroughs.

Smart parking is part of the Internet that uses sensors to communicate remotely via the Internet and share information using specified communication protocols [6]. Smart parking offers parking convenience that can be applied in various places, such as private parking, hospitals, hotels, shopping centers, public parking garages, and offices, to save time and avoid the difficulty of finding a parking space [7]. Drivers can reserve parking spots ahead of time and get real-time parking availability information via their mobile devices by utilizing a smart parking system. In order to enable users to evaluate available parking slots and automate the process of locating ideal parking spots, smart parking also makes use of real-time data, inexpensive sensors, and applications [7]. This decreases the amount of time needed to find parking manually. The parking systems that are still in use today are traditional ones, meaning that each arriving car is directed by parking attendants while the parking lot is used. Nevertheless, this technique frequently ignores a building's parking capacity. Due to drivers' ignorance of the location of available parking spots, this

may result in inconvenience for car owners, who may be forced to leave if they are unable to find a spot [8].

There has been a lot of research done on the creation of IoT systems for smart parking. "Design and Development of a Smart Parking System Prototype Based on IoT Using Node MCU ESP8266" is the title of one such study. The RFID sensor-based parking spot counting and addressing method is the foundation of this research's Internet of Things system. Following the counting and addressing, the results are shown on a P10 display module and can be seen wirelessly through the use of a local server. Wi-Fi is utilized as the connectivity technique [4]. Furthermore, an IoT system for tracking parking sites was created in a prior study called "Web and IoT-Based Smart Parking Information System," which used a website as a communication tool. This system makes use of Wi-Fi for networking, NodeMCU as a microcontroller, Raspberry Pi as a web server and database, and ultrasonic sensors for vehicle detection [9].

As was already said, there have been a lot of studies done on smart parking systems. The case's focus sets this study apart from others that have already been done. The purpose of this project is to create a smart parking system for a Tangerang hotel. Wi-Fi connectivity is employed in this investigation. Based on the author's observations—that is, that the hotel's location is crucial and the region is not very large—the connectivity option for this Internet of Things study was chosen [10].

Figure 1. Snapshot of a Parking Lot at a Hotel in Tangerang

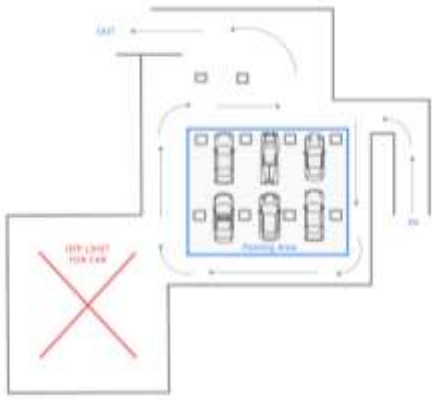

Figure 2. Layout of the Parking Lot at a Hotel in Tangerang

An Internet of Things smart parking system will be created in this study. This system will have functions to track user dwell time, identify when parking spaces become available, identify when vehicles are approaching, and enable reservations for certain parking spots. To construct the IoT system, three ESP8266 modules are used. IR (infrared) sensors of type Servo SG92R, RFID sensors of type RC-522, and ultrasonic sensors of type HC-SR04 are the sensors that are employed. The parking slot is detected

by the ultrasonic sensor. The reason this sensor was selected is that the HC-SR04 ultrasonic sensor has an absolute error of about 0.035 cm per centimeter, meaning that the real distance results in an error of up to 0.035 cm for every centimeter measured. Furthermore, the standard deviation of this sensor, which ranges from 0.1 to 0.5 cm, indicates the accuracy of the readings the sensor takes and how far it can deviate from the average value [11].

The actuators used in this system are the SG92R type servo motor and RGB LED. The SG92R servo motor is chosen over other actuators because of its fast performance and repeatable operation, making it suitable for the needs of this IoT system [12]. The selection of RGB LED in this research is due to its flexibility in producing colors and its efficiency in terms of the number of digital pins used and the number of IoT devices involved. The three ESP8266 units will be connected via Wi-Fi to implement the MQTT communication protocol. A client-server communication protocol known as Message Queuing Telemetry Transport (MQTT) allows users to publish and receive data [10]. After that, Things board and MIT App Inventor will be used to show the data and save it in the cloud to construct an application that has parking spot booking features. To obtain and receive data from the application, additional data will be transmitted to a Firebase database.

Method

In this section, the steps in this research, the system architecture, and the design of the sensor node circuit in a Fritzing diagram will be described.

a. Research Stages

Five steps were taken in conducting this investigation, as Figure 1 illustrates. The process started with problem identification, during which the author saw a hotel's parking system in Tangerang Regency. Based on the observations, it was discovered that guests were having trouble obtaining parking spaces since the hotel's parking system lacked a mechanism to verify whether any spaces were available. As a result, guests were required to navigate the lower level in order to locate a parking space. After identifying the problem, the data collection stage was carried out through a literature study on smart parking systems, particularly regarding the availability of parking slots, and IoT systems to monitor parking slots in the hotel basement area.

The second step is the analysis step, when system architecture and Fritzing diagrams are created prior to implementation. During the implementation phase, the Internet of Things is built, the Wi-Fi network is configured, and data from the ESP8266 module is then transmitted via Mosquito MQTT with the help of Python code as a gateway so that data can be sent to Firebase and Things board. After that, the data is transferred to Firebase and is then monitored using Things board, a cloud platform, and a booking application created at MIT App Inventor to make a reservation for a specific time slot. The final step of the inspection is to check the monitoring slot parking that is located in the basement.

b. System Architecture

The first layer is a perception layer or sensor layer, which consists of a sensor node installed in the parking area. The sensor nodes include ESP8266 as a microcontroller, an ultrasonic sensor with type HC-SR04, an IR sensor, an RFID sensor RC-522, an SG92R servo motor, and an RGB LED. The sensors installed will capture data from the parking environment, namely the distance from the sensor to the ground to check the available parking slots by giving a green sign, and detect vehicles entering and exiting the parking space and monitor how long a user is in the area. Then the data will be transmitted to the server via Wi-Fi. The second layer on the system architecture is the network and gateway layer. On this layer, the data transmitted by the sensor node in each parking slot is received by Wi-Fi.

The last layer is the application layer. This layer serves to display information from the IoT system (Hardini, 2019). In this system, the Things board cloud platform is used to store sensor data that can be accessed on a laptop for monitoring purposes. In addition, the data is also stored in the Firebase database to display data and send data from applications built using MIT App Inventor. The app created has features to check the availability of parking slots and make reservations on certain slots. In this system, sending and receiving ESP8266 data to cloud platforms and databases using the MQTT communication protocol.

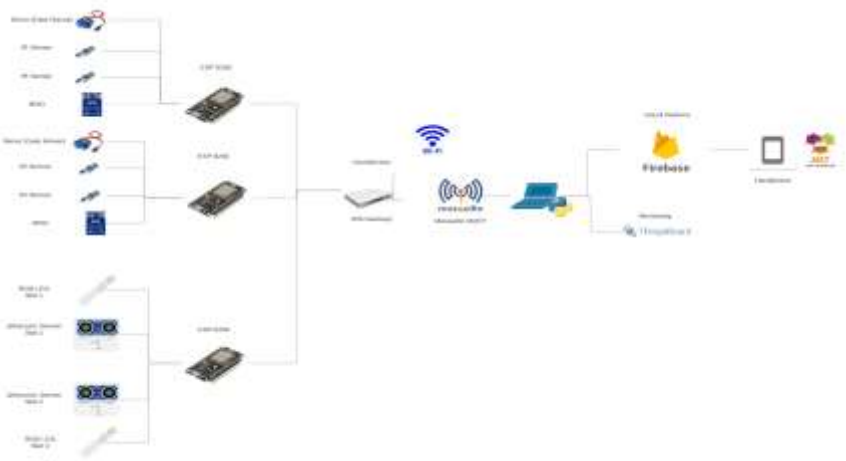

Figure 2. Architecture System

c. Fritzing Diagram

In addition to the system architecture, fritzing can be used to create an IoT system consisting of 3 microcontroller ESP8266, 2 ultrasonic sensors, 2 IR sensers, 2 Servo Motors SG92R and 2 RFID RC-522, as shown in figures 3 and 4. Each sensor is connected to the microcontroller. The first microcontroller was used to monitor the available parking slots. The D1 and D4 pins are connected to the Red pins aimed at producing the red color on the lights, the D3 and D8 pins connect to the green pins designed to produce the green color on the lamps, and the D2 and D6 pins link to the Trig pins and the Echo pins attach to the D5 and D7.

Then for the other microcontroller used for the entrance and exit parking gates. The D3 pin is connected to the RST pin on the RFID as a resetting or disabling module. The D5 pin is connected to the SCK (Serial Clock) pin, the D7 pin to the MOSI (Master Output Slave Input) Pin, and the D6 Pin to the MISO (Slave Master Input Output) pin. The SCK pin is used in conjunction with MOSI and MISO pin to implement serial communication protocols such as the SPI(Serial Peripheral Interface) to communicate with the RFID reader module. The D1 pin is used for the signal pin on the servo motor, which serves to control the position and velocity of the motor. The D2 pin is connected to the output pin of the IR sensor which aims to indicate the presence or absence of an infrared signal from an object within the range of the sensor.

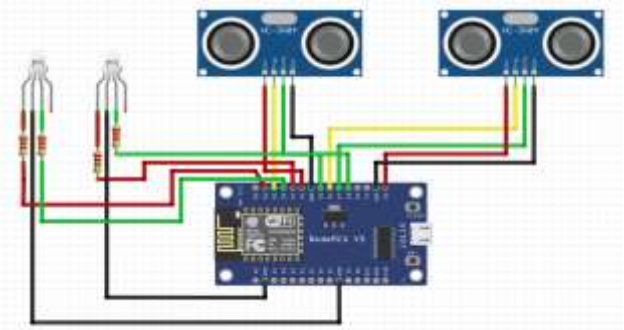

Figure 2. Diagram Fritzing System IoT Smart Parking (Slot Parkir)

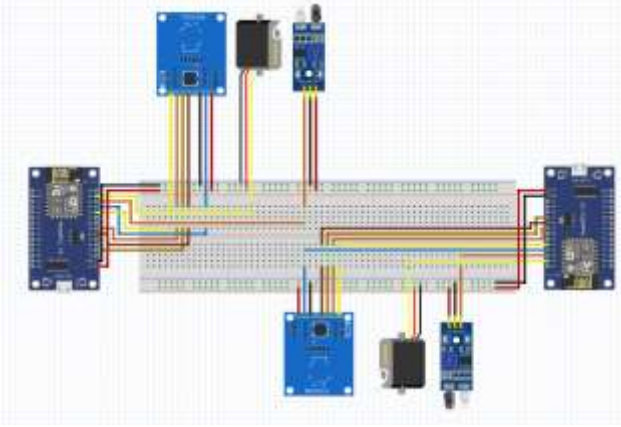

Figure 3. Diagram Fritzing System IoT Smart Parking (Gateway Parking)

Results and Discussion

a. Workflow of the Smart Parking System as a whole

Initially, three ESP8266 microcontrollers are utilized for the entrance and exit gates of the parking structure as well as for parking spot verification. Following the insertion of all of the data from the ESP8266 module into mosquito MQTT, the data will be analyzed by means of the publish and subscribe technique. (accepted information). Next, Python code serves as a connector for data sent from MQTT to Firebase, an application development platform that offers data storage services, and the Things board cloud platform. After that, Firebase will transfer the information to the MIT App Inventor-created parking reservation app. If the program shows data about empty parking slots after that, the user can then make a reservation for parking on the booking app.

b. Vehicle Entry into the Parking Lot

According to Figure 5, the flowchart depicting the process of a vehicle entering a parking lot, upon a vehicle's entry, the user scans the card with an RFID sensor. The RFID sensors then interpret the scan results, and if the card's data is registered, an IR sensor determines whether the vehicle is actually present. If it is, the servo motor actuator opens the portal. The gateway will close once more after the car succeeds in entering.

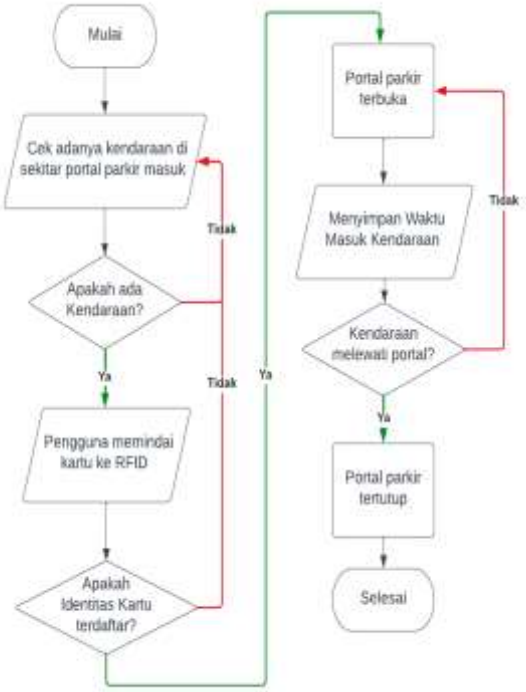

Figure 4. Parking Vehicle Flowchart

c. Parking Slot Verification Workflows

Figure 6. Explains how parking slot checking works. First, the sensor checks whether or not the vehicle is in the parking lot, if not, then the light will turn on in red, if there is then the sensor will check whether the slot has been booked by the user, otherwise the lamp will be in green while the yellow light will be lit if someone has already booked the slot. Then the sensor will re-check whether there are already vehicles in the car park that the user has booked and the user must confirm that the vehicle belongs to him. Otherwise, the lights will remain in yellow and if yes then the lamps will turn to red.

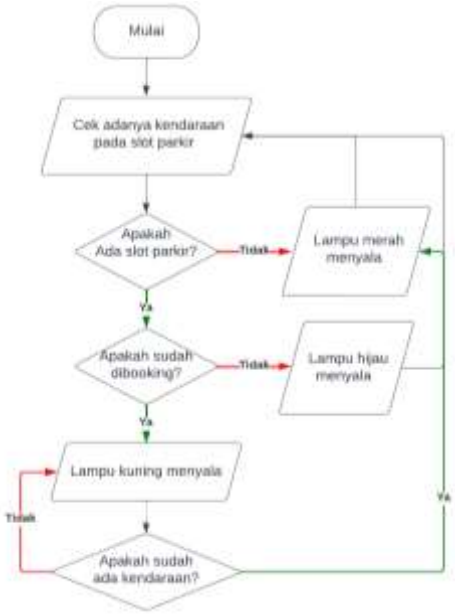

Figure 5. Flowchart Checks Parking Slots

d. Workflow Vehicle Exit Parking

According to Figure 7. flowchart vehicle exits parking, the same as the workflow of vehicle entering parking is first when a vehicle is going to exit the parking area and the user performs a member card scan to the RFID sensor, then RFID sensors will read the results of the scan and if the data from the card is registered, then the IR sensor will detect whether the vehicle really exists, if there is then the servo motor actuator will open the portal.

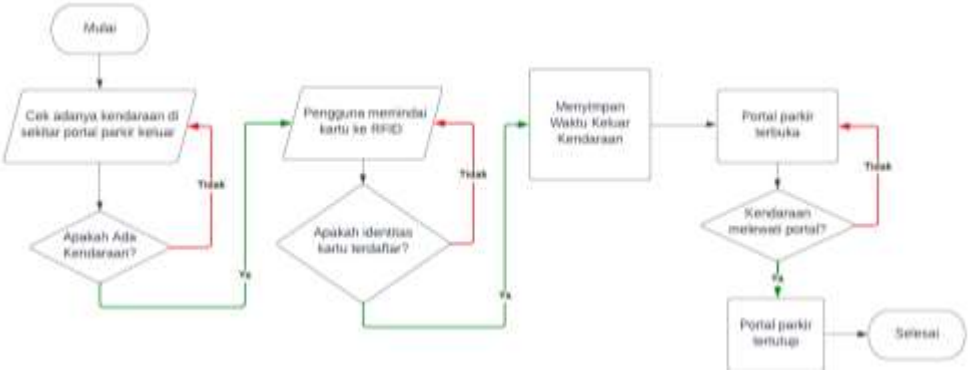

Figure 6. Flowchart Vehicle Exit Parking

e. Workflow of Parking Booking Application

Based on Figure 8. The user opens the mobile parking booking app to book an empty parking slot. Then, if there is a vacant parking slot available then the user will press the book button on the vacant slot. Once the user has successfully made a booking, then the app will display the description of the successful booking and the booking details and the lights on the booked slot will change color to yellow. Then the user will go to the booked parking lot, and upon arrival at the bookable slot will appear a confirmation notification "Does the vehicle belong to you?" If the user gives the confirmation "Yes" then there will be a "Welcome to the parking lot and complete the booking phase" notification so that the vehicle will park in the slot and the ultrasonic sensor will detect

the presence of the vehicle parked at the adjusted distance, then the indicator light on the slot will change the color of red to yellow which means that the slot has been filled. However, if the user gives a “No” confirmation then the lights in the area will remain yellow, indicating that the slot belongs to the other driver who has booked the slot.

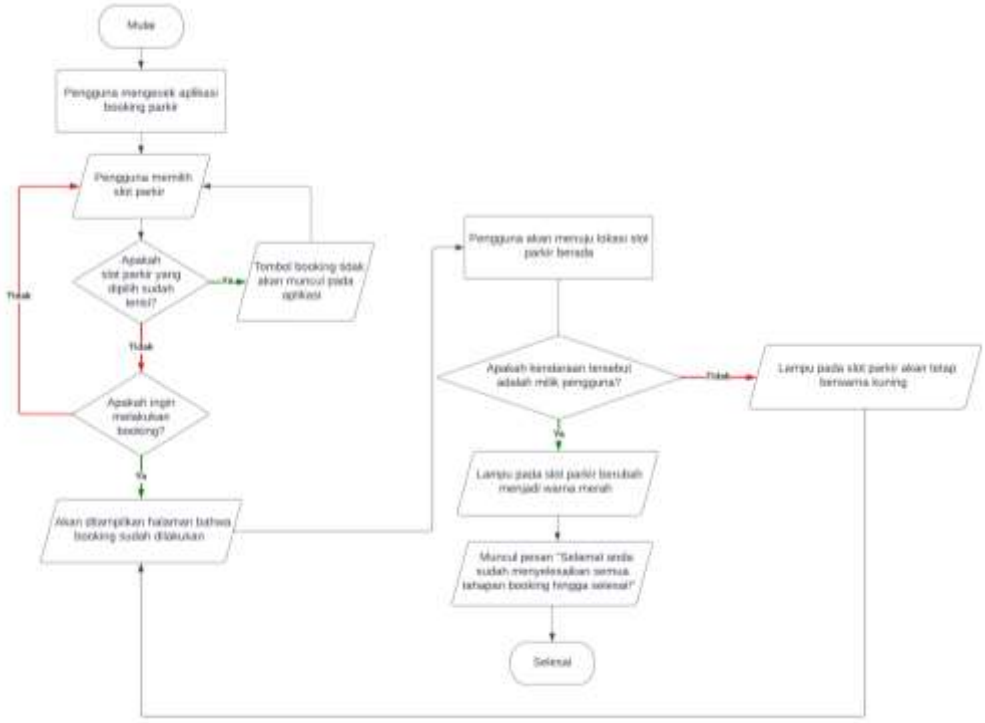

Figure 7. Flowchart Booking Parking

f. The complete network

Based on Figure 9. The entire series of Smart Parking, there are miniatures made of cardboard material whose base part is covered with cardboard used as a basement, Styrofoam as an ultrasonic sensor suspension and also LED lights, ice cream sticks used as an entry and exit portal, and small cubes made of carton used as portal suspension. The condition in Figure 9. describes the picture when the parking space is empty and not booked so that the indicator light gives a green output.

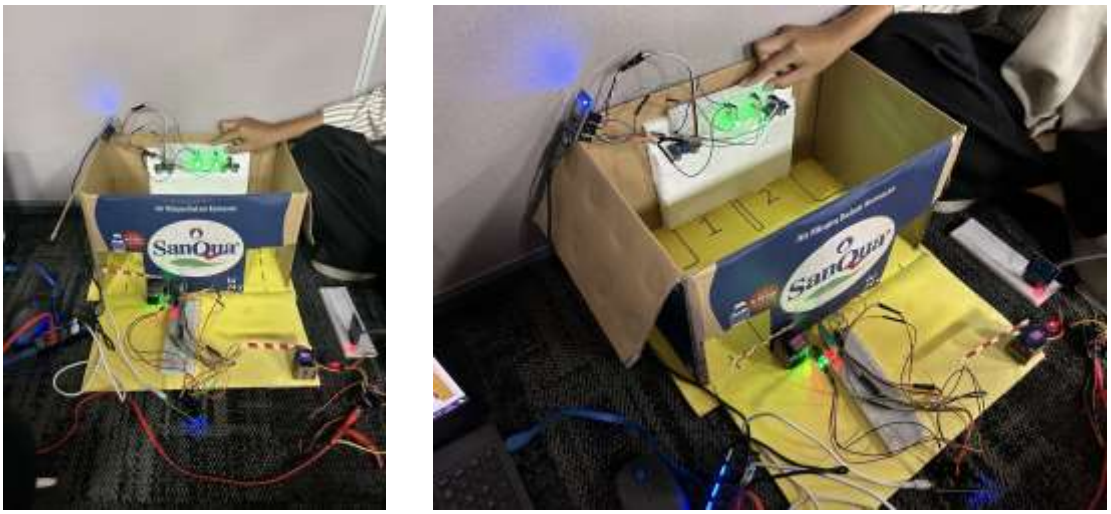

Figure 8. Smart Parking Overall Network

g. Sensor testing

After the sensor has been tested, the Things board, as depicted in Figure 10, can be used to monitor the IoT system. Information is obtained from this Things board, including the number of available slots, whether the entrance or exit gates are open, the distance between the sensor and the object that indicates whether the object is present or absent in the parking slot area, and the entry and exit times when the vehicle opens the portal as shown in Figure 10.

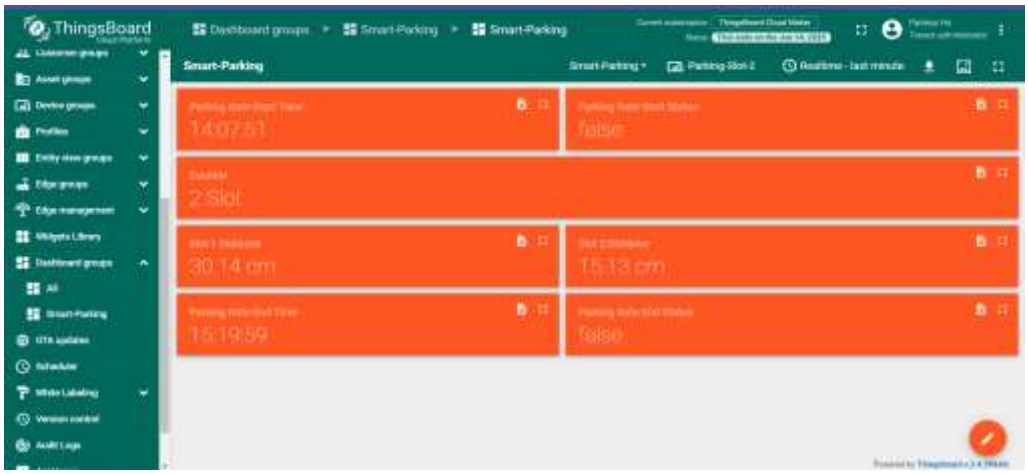

Figure 9. Monitoring with Things board

In Figure 11. Firebase, there is a display of data stored in real-time, where in the image below there are data about the available parking slots accompanied by distance and booking details. In addition, firebase also stores the time when entering and exiting the parking lot.

Figure 10. Firebase

g. Mobile Applications

In order to save users, the trouble of searching for open parking spaces, a mobile app was developed to make booking parking spaces easier. Users only need to utilize the app to reserve the times they want, as displayed in pictures 12 to 15, and then they simply

need to show up at the designated time to verify that the car has been placed where they have reserved.

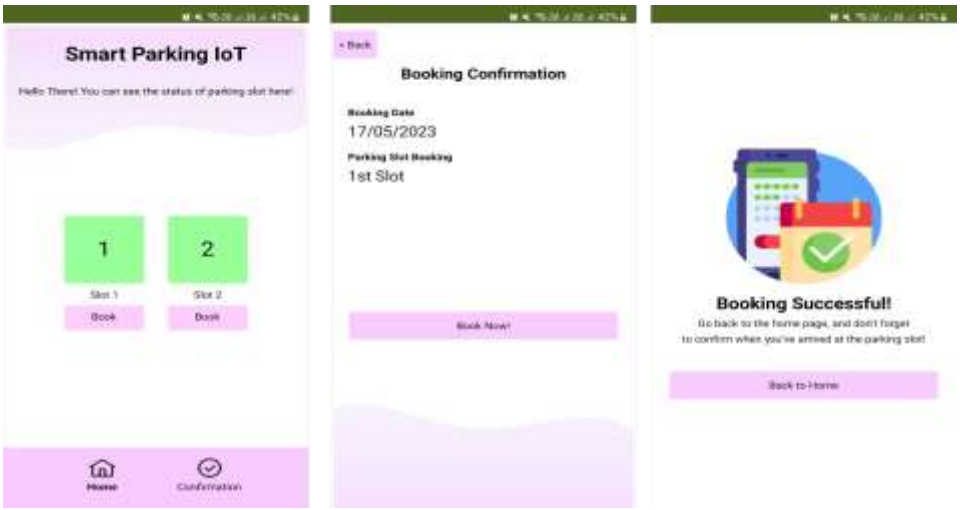

Figure 11. The Display of the Mobile app when Booking Parking Slots 1

g. Output after making a booking for Slot 1

Based on Figure 13. After the user makes a booking in the app, then the LED light will give a yellow output.

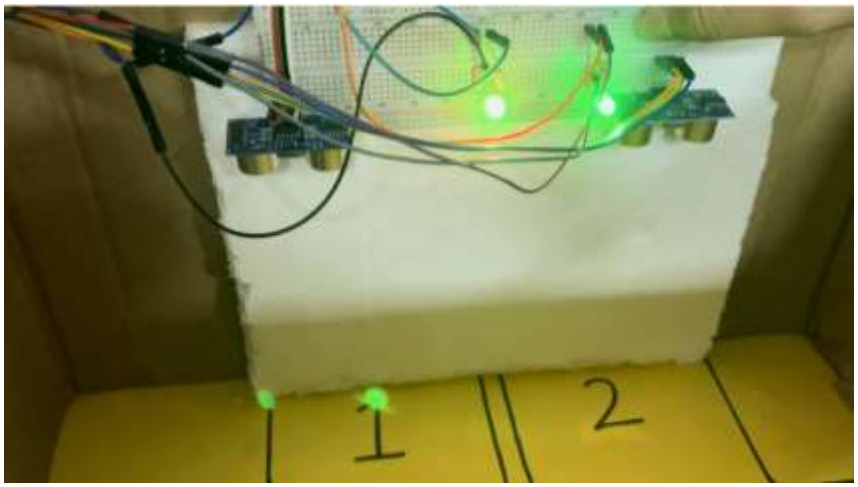

Figure 12. Output after Slot 1 Has Been Ordered

g. Confirmation View for Users

Once the user arrives in the parking area and fills in the previously booked slot, the app will have a confirmation notification to verify whether the vehicle belongs to the user who has made the booking.

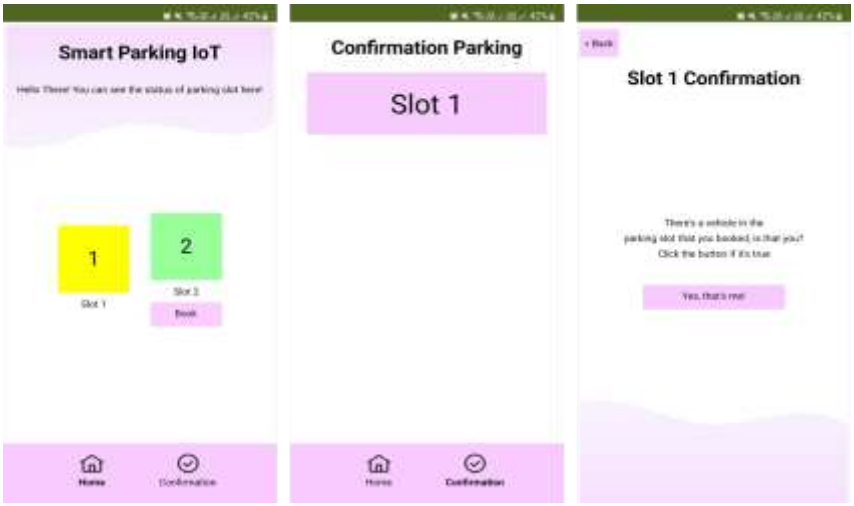

Figure 13. The Display of The Mobile App When the User Confirms the Vehicle is Already in the Parking Slot 1

g. Output After Slot Filled

Based on Figure 15. After the user vehicle fills the previously ordered slot, then the LED light will give a red output.

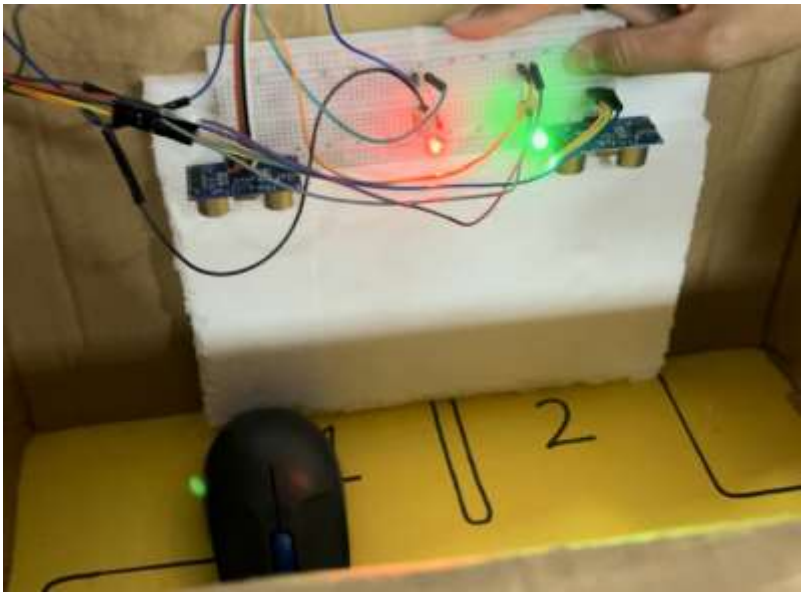

Figure 14. Output Generated After Slot 1 Has Been Ordered and Filled by User Vehicle

g. Test Results

Table 1 shows the test results with different conditions that exist in smart parking. The test indicators present in this study are the number of available slots and the status of the slots marked by the color emitted by the RGB LED.

Table 1. IoT Test Results

No	Testing	Slot 1		Slot 2		Slot	Result
		Distance	Status (RGB LED)	Distance	Status (RGB LED)		
1	There's a vehicle on the slot.1	12.39	Red	15.80	Green	1	Ok
2	There's a vehicle on the slot.2	15.89	Green	13.79	Red	1	Ok
3	There's a vehicle on the slot.1 and 2	13.45	Red	12.59	Red	0	Ok
4	Slot 1 ordered	15.79	Yellow	15.26	Green	1	Ok
5	Slot 2 ordered	15.85	Green	15.23	Yellow	1	Ok
6	Slot 1 booked and there is a vehicle in slot 2	15.47	Yellow	11.12	Red	0	Ok
7	Slot 2 is booked and there is a vehicle in slot 1	13.35	Red	15.30	Yellow	0	Ok
8	Slot 1 booked and slot 2 booked	15.41	Yellow	15.35	Yellow	0	Ok
9	No vehicles	15.90	Green	15.63	Green	2	Ok

Conclusion

The study centers on the utilization of MIT App Inventor to develop parking reservation and monitoring systems. Three ESP8266 microcontrollers, each supporting WIFI, Bluetooth, an IR sensor, a servo motor, and two RGB LEDs, were employed by the researchers in this investigation. Along with using MQTT as a communication mechanism between the microcontroller and the firebase and things board, the researchers also used Firebase to store data that would subsequently be used by the MIT App Inventor and Things board to monitor the complete IoT system network that they constructed. For further research, additional features can be applied to the booking system such as the time limit that the user has to reach a particular parking slot and detect whether the vehicle on the parking slot that has been booked corresponds to the user who has made the booking. The use of microcontrollers with better specifications is recommended to improve the efficiency of smart parking.

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