IoT-Based Integrated Parking System Prototype using RFID and HC-SR04

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***Abstract*— Most parking system solutions developed to serve a significant number of cars, e.g., office buildings in Indonesia, do not include a feature directing the drivers to the location of available parking space that can be helpful for them. Several studies have been done regarding smart-parking systems. However, none provides integrated solutions, including membership payment, parking log, and available parking slots feature that can direct drivers to an empty parking slot. This study aims to propose an IoT-based parking system integrating the mentioned features. Radio Frequency Identification (RFID) and HC-SR04 sensors are utilized to record all cars entering parking areas and monitor them to generate empty parking slot information. The proposed system is applicable, and its functionalities work according to the system design.**

Keywords*— *Smart Parking, Internet of Things, RFID, HC-SR04, Monitoring Web

I. INTRODUCTION

In Indonesia, most parking management systems support automation, but it hasn't provided information on the available parking space. It uses ticketing or e-money to enter the gate and proceed with the amount that needs to be paid at the output gate. Some parking places provide a membership card. The vehicle doesn't need to pay using the membership card when entering the parking place. Even though this payment method and ticketing shorten the process, finding a parking spot could still be a problem because there is no information regarding the available parking slot.

Technologies regarding parking systems keep growing, and much research has been done to make a better parking system. Research from [1]–[3] reviewed building a smart-parking system. Based on [1], smart-parking systems are categorized as parking guidance and information system, transit-based information systems, smart-payment systems, e-parking, and automated parking. For e-parking and smart-payment systems, RFID can replace the ticketing and manual payment system [4], [5] by simply using the tag as the car's ID and recording it to the system. Several parking management systems also use membership and registered vehicles for payment management [5]–[7]. Research also provides smart parking features to check whether the parking system is available or unavailable [1], [8]. Several research also uses IoT systems to support this feature, e.g., [4], [9] used sensor modules that are connected to the cloud to send the available parking space on the web, and [5] and [10] on the mobile app. Some research uses infrared (IR) sensors [4], [6], and others use ultrasound sensors [1], [6], [7], [11] to give information to the management system if there is a car in the parking slot. Research [1] also compares ultrasound and IR sensors and states that ultrasonic sensor is shorter in range but cheaper than IR sensor.

However, the proposed solutions in the previous studies have some weaknesses, such as only partial features being provided for car drivers. Hence, they are unsuitable for metropolitan buildings that serve a huge number of car parking slots. Moreover, none of those studies provides a feature that can direct the drivers to the location of available parking space. This paper views that a parking system requires an integrated solution, including important features such as membership payment, parking log, and available parking slots. In this regard, the Internet of Things (IoT) can be very supportive in propagating the parking slot status to members observed by sensor nodes and reporting the status of the parking area to remotely working building management. Therefore, to follow up on this problem, this research aims to build an IoT-based integrated parking system prototype combining RFID and HC-SR04 to serve the payment and parking slot monitoring features. RFID is selected to deal with membership features. Meanwhile, HC-SR04 is selected because it has less power consumption than IR sensors [11]. HC-SR04 sensor connected to NodeMCU needs a WiFi connection so that the data read can be sent periodically to the database to provide information on the available parking slots on the website. This proposed system can benefit the building or parking area management to monitor their parking area and the car drivers to reduce the time to find an available parking slot. In summary, the main contribution of this paper is an approach to help drivers to reduce the time to find a parking spot by exploiting HC-SR04 and RFID sensors as a part of the integrated parking system module.

To implement our proposed solution, we experimented with using a miniature parking area consisting of 8 parking slots, two gateways using a motor servo, and a parking management system that records all the parking processes and the availability of the parking slot in the parking area. The result shows that the proposed system can provide better functionalities to help car drivers than previous studies, and it can be encouraged as the parking system solution in metropolitan buildings.

II. PROPOSED IOT-BASED INTEGRATED PARKING SYSTEM

This section explains the proposed IoT-based integrated parking system (IPS) as illustrated in Fig. 1. Four main blocks represent the modules used in the IPS: the entry node, exit node, microcontroller node, and presentation node. The main idea of the proposed IPS is that the system can perform parking slot monitoring functions and automation of user authentication accompanied by portal control on the Smart Parking system. The monitoring function is designed to supervise the parking slots available in the parking place, which users can access through the website.

The first two blocks consist of the entry and exit nodes. The proposed parking system's users are divided into members and guests. The parking process is done by tapping the RFID card when entering and exiting the parking lot. This study assumes that either member or not has an RFID card, e.g., a bank card. The system uses RFID technology on an RFID reader RC-522 to read users' cards for the authentication process [12].

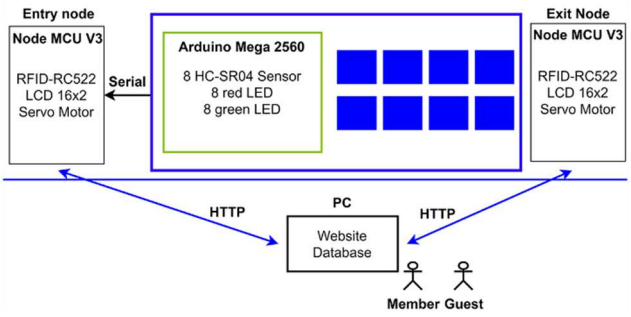

Fig. 1. The proposed architecture of the integrated parking system

When a user taps the RFID tag on the reader, the system will authenticate whether or not the user is a member by checking the ID on the user card with the list of members already stored in the database. Suppose the ID in the RFID tag matches data in the membership database and the parking slot inside the parking area is still available. In that case, the system will recognize the member, record the entry time, and open the gate for the member. The member won't charge any parking fare when the member taps the RFID tag at the exit gate.

When the guest users tap the RFID tag on the reader, as their user card's ID is not listed in the database, the system recognizes them as a non-member. If the parking slot inside the parking area is still available, the system will record the entry time, open the gate, and count the parking fare for the guest. When the guest taps the RFID tag on the reader, the system will provide information on how much parking fare should be paid.

In the presentation block, 16X2 LCD is used to display onsite parking instructions. Moreover, this prototype uses a servo motor to open a parking portal. The Servo motor's motion and instruction text on the LCD will be displayed based on the server's authentication process connected to NodeMCU. The parking slot's availability information will be displayed on the spot using LEDs located on the wall in each place. That information will also be sent periodically to the database to be displayed on the website and accessed by users everywhere.

The microcontroller block is implemented into two nodes using the Arduino Mega board series and NodeMCU V3 based on ESP8266 and uses the Arduino IDE 1.8.5 that runs on Windows 10 operating system [13]–[15]. In addition, the system also uses XAMPP to run a local server that will process system commands connected to the database. XAMPP will also run the local database, which the system will access. The prototype is equipped with an HC-SR04 sensor to track parking slot availability periodically.

In this study, hardware design is done by forming an overview of the system's build design. Start with the main hardware to electronic devices that support the system. The following block diagram of the system hardware and table shows the interface of the microcontroller pin with the component can be seen in Fig. 2.

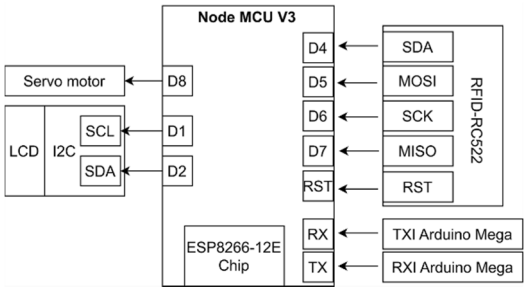

Fig. 2. MCU's block diagram for entry and exit node

The software design in this smart parking system consists of software design for NodeMCU V3 on both nodes, Arduino Mega, and the design of the program file. The tasks performed by Arduino Mega and NodeMCU will be displayed in Fig. 3. The NodeMCU is used to read the user's RFID card ID sent to the server for the authentication process, drive the servo motor, display the parking instructions on the LCD, connect the system to the Wi-Fi network, and specifically, at the entry node, sends the slot availability information to the database.

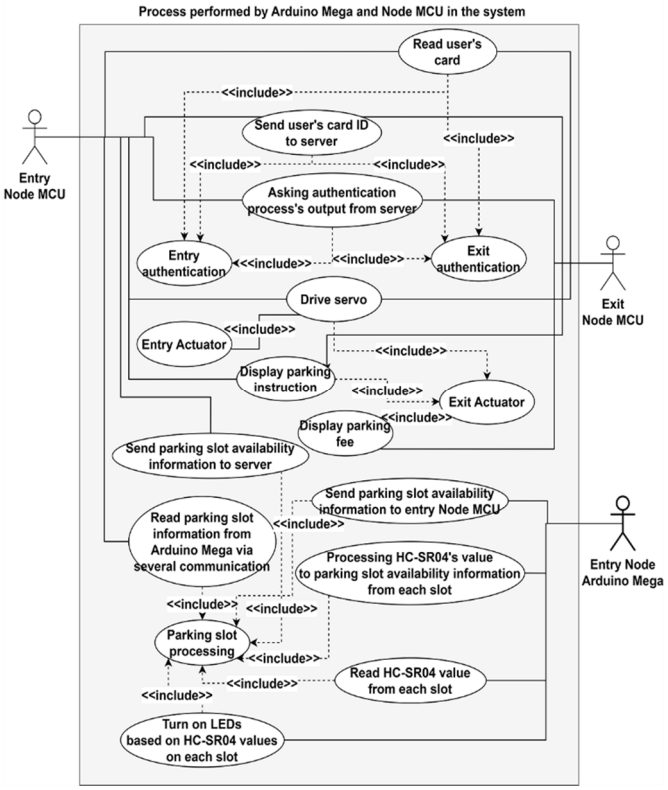

Fig. 3. Use Case Diagram of NodeMCU and Arduino Mega's Processes on The System

The software design in NodeMCU produces two principal flow diagrams: void authentication() and void actuator(). Specifically, a void read sensor() for the entry node called the needed library, such as ESP8266, RFID Reader, 16X2 LCD, and Servo. The software design in Arduino Mega produces two main flow diagrams, void ping() and void loop(), called the HC-SR04 library. All processes in NodeMCU will not run if it is not connected to WiFi. It requires a connection with a server accessed via the internet to run. However, the process in Arduino Mega continues because it does not require communication with the server.

III. Result and Discussion

A. System Implementation

To implement the proposed IoT-based IPS, this research experimented with several scenarios. The first scenario involves a member who wants to enter the parking area but has no slot available. The second scenario is a member who wants to enter the parking area with an available parking slot. The third is a guest who wants to enter the parking area with an unavailable parking slot, and the last is a guest who wants to enter a parking area with an available parking slot inside.

Using the proposed IoT-based parking system, drivers can check the availability of parking spaces anywhere on the web using their mobile devices. The web will provide the availability of parking slot information for the driver. The driver can go to the parking area if there is an available parking slot.

The situation for all scenarios is the same at the entrance. All drivers, either a member or not, tap their cards on the provided board (see the left figure in Fig. 4). The experiments showed that the authentication function is working by displaying the information on LCD whether a user can enter the parking area or not and the motor servo that will open the gate or keep closing based on the available parking slot given from the sensor modules. If there is an available parking slot, and the user already enters the parking area, the system will record the entry time to the database.

The user then will search for the available parking slot inside the parking area by seeing the green LED color in the parking slot (see the middle and right figure in Fig. 4) or monitoring it via the website as in Fig. 5. If the user parks the car into a parking slot, the green LED will change into red. The sensor will send the alteration status of the parking slot to the database, and the information on the website will also change.

When the user moves out from the parking slot, the red LED will be back to red, so the sensor sends the status to the database, and the information on the web will be back to available. At the exit gate, a user with membership status won't need to pay any charge. The system only records the exit time. A user with a guest status needs to pay the parking fee shown on the LCD at the output gate. When the user pays the parking fee, the system triggers the servo motor to open the exit gate. At last, the system records the payment process and the exit time of the user.

Fig. 4. Hardware Implementation of The Prototype

Arduino Mega is set to display the text of parking slot availability on the serial monitor based on HC-SR04 sensor measurements in each parking slot. If the HC-SR04 sensor measurement is <= 4cm, then the text printed on the serial monitor is "unavailable" and turns on the red LED, whereas if the height is > 4cm, the printed text is "available" and turns on the green LED. And if the reading results <= 0cm or > 200cm, then the text printed on the monitor serial is "unreachable," and all LEDs are off.

Parking Information

/-----/-----/Parking Slot Information : /-----/-----

Information	Entry Hour :
Guest	2019-12-11 20:08:00
Member	2019-11-27 23:32:47
Guest	2019-11-26 23:08:43

Maximum parking capacity : 8

Available Parking Slot : 5

/-----/-----/Parking Slot Information : /-----/-----

Date and hour: 2019-12-13 22:13:20

Real-time parking slot information

Time	Parking Slot
2019-12-11 20:38:43	Slot1:unavailable, Slot2:unavailable, Slot3:available, Slot4:available, Slot5:unavailable, Slot 6:available, Slot7:available, Slot8:available

Fig. 5. Website Interface Parking Slot Reading Results

After being measured, the HC-SR04 sensor measurement values will be sent to the database. In the parking slot reading testing, the system will be tested for several aspects, such as the measurement results of HC-SR04 sensors, sending information to the database results, and the time of transmitting data from the hardware to the database. The following pictures and tables test the parking slot reading.

TABLE I. HC-SR04 Object Distance Measurement Test

X	LED							
	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8
0	off	off	off	off	off	off	off	off
1	R	R	R	R	R	R	R	R
2	R	R	R	R	R	R	R	R
3	R	R	R	R	R	R	R	R
4	R	R	R	R	R	R	R	R
5	G	G	G	G	G	G	G	G
6	G	G	G	G	G	G	G	G
7	G	G	G	G	G	G	G	G
10	G	G	G	G	G	G	G	G
15	G	G	G	G	G	G	G	G

X = Object distance in centimeters
R = Red LED on
G = Green LED on

B. Scenario Analysis

The scenario analysis is conducted using the four scenarios from section A. The analysis examines the performance of HC-SR04 in detecting objects, parking slot availability detection, and the time required to update the status since sensors send the data until the web is updated.

Based on the test results in Table I, it can be concluded that the distance readings results carried out by the HC-SR04 sensor against the object barrier are done well; the system has been proven to turn on the correct LED based on the results of the HC-SR04 sensor distance measurement. Cars must park in the slots properly to close the sensor so that the parking slots are in the used condition.

In Table II, the system is proven to send parking slot information into a database with the same value as visual information. In Table III, the time for sending information on parking slot availability is displayed, with 3-4 seconds if there is no initial authentication process. If there is an authentication process, it will take between 9-10 seconds. Based on these three tests, we can conclude that the system's parking slot reading is going well.

TABLE II. PARKING SLOT AVAILABILITY FOR DATABASE DATA TEST

Parking Slot Information		Description
Visual	*Database*	
Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:available,Slot6:available,Slot7:available,Slot8:available,	Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:available,Slot6:available,Slot7:available,Slot8:available,	Visual information = database information
Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5: available,Slot6:available,Slot7:unavailable,Slot8:available,	Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5: available,Slot6:available,Slot7:unavailable,Slot8:available,	Visual information = database information
Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:unavailable,Slot6:available,Slot7: unavailable,Slot8:available ,	Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:unavailable,Slot6:available,Slot7: unavailable,Slot8:available ,	Visual information = database information
Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:unavailable,Slot6:available,Slot7: unavailable,Slot8:available ,	Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:unavailable,Slot6:available,Slot7: unavailable,Slot8:available ,	Visual information = database information
Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:unavailable,Slot6:available,Slot7: unavailable,Slot8:available ,	Slot1:unavailable,Slot2:available,Slot3:unavailable,Slot4:available,Slot5:unavailable,Slot6:available,Slot7: unavailable,Slot8:available ,	Visual information = database information

TABLE III. PARKING SLOT AVAILABILITY TO DATABASE TIME TEST

No	Database Entrance Time	Time Deficit with Previous Data	Description
1	20:37:35	3 second	No authentication
2	20:37:38	3 second	No authentication
3	20:37:47	9 second	Authentication
4	20:37:51	4 second	No authentication
5	20:38:00	9 second	Authentication
6	20:38:03	3 second	No authentication
7	20:38:06	3 second	No authentication
8	20:38:16	10 second	Authentication
9	20:38:19	3 second	No authentication
10	20:38:22	3 second	No authentication

The system authentication process starts when a user taps the RFID tag into the reader at the entrance gate. The user's role is authenticated according to data stored in the database. At the exit gate, an examination is conducted to see whether the calculation of the parking fare was correct.

TABLE IV. PARKING FEE COUNTING TEST

No	Entrance	Exit	Parking Time	Parking Fee
1	20:54:13	20:54:30	0 min	0
2	20:56:20	20:57:19	0 min	0
3	20:56:24	20:58:10	1 min	1500
4	20:56:31	21:01:25	4 min	6000
5	21:02:05	21:12:08	10 min	15000
6	21:03:17	21:06:01	2 min	3000
7	21:07:40	21:16:08	8 min	12000
8	21:07:55	21:10:55	3 min	4500
9	21:10:16	21:33:08	22 min	33000
10	21:11:08	22:20:22	69 min	103500

In Table IV, the system has been able to calculate the user's parking rate correctly. The parking fee calculation is based on the length of parking at a rate of 1500 per minute. If the user has parked for less than 1 minute, the rate is 0. This proves that the authentication process on the system has been running well and within a satisfactory period.

Table V shows the result of the authentication process. When a user taps the RFID tag into the reader, the system checks the availability of the parking slots inside the parking area, checks the ID in the database, displays the output on the LCD, and records the parking process.

TABLE V. AUTHENTICATION TESTING

Parking Availability	Gates	User Type	User Status	Output	Description
Full	Entrance	Member	In	Full Parking	match
Full	Entrance	Member	In	Full Parking	match
Full	Exit	Member	In	Please Enter	match
Full	Exit	Member	Out	Not Yet Tap In	match
Full	Entrance	Guest	Out	Full Parking	match
Full	Entrance	Guest	In	Full Parking	match
Full	Exit	Guest	In	Please Enter, and the Parking Rate	match
Full	Exit	Guest	Out	Not Yet Tap In	match
Available	Entrance	Member	Out	Please Enter	match
Available	Entrance	Member	In	Not Yet Tap Out	match
Available	Exit	Member	In	Please Enter	match
Available	Exit	Member	Out	Not Yet Tap In	match
Available	Entrance	Guest	Out	Please Enter	match
Available	Entrance	Guest	In	Not Yet Tap Out	match
Available	Exit	Guest	In	Please Enter, and the Parking Rate	match
Available	Exit	Guest	Out	Not Yet Tap In	match
Full	Exit	Unregistered	-	ID not found	match
Full	Entrance	Unregistered	-	ID not found	match
Available	Entrance	Unregistered	-	ID not found	match
Available	Exit	Unregistered	-	ID not found	match

Based on the test results in Table V, out of the 20 conditions, the outputs sent by the local server to NodeMCU are all by the desired outcome. Based on the experiments that use the four scenarios as showcases, it can be inferred that the proposed system can work as expected, as defined in the system design.

C. Actuator Test Results

The system will be tested to drive the servo motor and display text on the LCD for both nodes in actuator testing. Servo motor and LCD testing will be divided into entry and exit nodes. Input from the test comes from the output text sent by the local server. The test will be carried out by observing

the motion of the servo motor and displaying text on the LCD by the input processed by NodeMCU

TABLE VI. ENTRY GATE TESTING

No	Output	Servo Move	Text on LCD	Description
1	Please Enter	90º	Please Enter	match
2	Not Yet Tap Out	0º	Not Yet Tap Out	match
3	Full Parking	0º	Full Parking	match
4	ID Not Found	0º	ID Not Found	match

TABLE VII. EXIT GATE TESTING

No	Output	Servo Move	Text on LCD	Description
1	Please Enter	90º	Please Enter	match
2	Please Enter and Parking Rate	90º	Please Enter, and the Parking Rate	match
3	Not Yet Tap In	0º	Not Yet Tap Out	match
4	ID Not Found	0º	ID Not Found	match

Based on the test results in Table VI and Table VII, all Actuators work according to the desired conditions and function correctly. This proves that the actuator control process in the system has been running well.

D. Integration Testing

After testing the parking slot reading, authentication testing, and actuator testing, the entire system is tested by combining all devices on the two nodes into a system that can monitor, control, and communicate. Table VIII shows the results of the overall testing system.

TABLE VIII. INTEGRATION TESTING

No	Parameter	Results
1	The system can authenticate users automatically	Succeed
2	The system can differentiate between member users and guest users based on the ID of the card used.	Succeed
3	The system can control the servo motor and LCD in both nodes automatically based on the input of the RFID card authentication.	Succeed
4	The system can send and store information from the authentication process to the database on the server sent by both nodes.	Succeed
5	The system can calculate guest parking fees based on parking time	Succeed
6	The system can control LED lights to indicate parking slot availability based on HC-SR04 sensor readings.	Succeed
7	The system can display parking instructions for users on the LCD on both nodes.	Succeed

IV. CONCLUSION

This study proposed an IoT-Based Integrated Parking System combining RFID and HC-SR04 sensors. RFIDs are placed at the entry and exit nodes and can communicate with the data server. HC-SR04 is used for sensing the car in the parking slot. This sensor is used to check the availability of the parking slot. It connected with the NodeMCU and sent the information regarding the availability of the parking slot to the database. The website then showed the information to the user. Based on our experiments, the results showed that the system could work accordingly using several scenarios given.

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