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Implementing a Dual Payment Method for Mobile Charging Stations in Urban Areas

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ABSTRACT

The mobile phone has become the communication device of choice for most people due to its practicality compared to other communication devices. A mobile phone requires electrical energy from its battery to function. Over time, the electrical energy stored in the battery depletes, and the phone needs to be recharged. A frequent problem arises when users are outside without a charger or have difficulty finding a safe power source. To address this issue, this final project proposes a solution: a secure mobile charging station that can be placed in public locations such as stations, hospitals, banks, hotels, malls, restaurants, and other venues. The paid mobile charging station consists of six charging lockers. Each locker is secured with a solenoid lock controlled by a Node MCU ESP32 microcontroller. Payment can be made using either coins or an RFID card. To charge their mobile phones, users must insert coins or swipe an RFID card. Once payment is made, users can charge their phones in the provided lockers for a specified period. System testing demonstrates high reliability, with a 100% success rate in coin validation, accurate RFID balance deductions, and seamless data transmission between the ESP32 and the database. The results indicate that the proposed system is a cost-effective, scalable, and secure solution for providing public mobile charging services in locations such as malls, hospitals, and transportation hubs.

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1. INTRODUCTION

The Mobile phones have become the communication device of choice for people due to their practicality compared to other communication devices. The primary benefit of mobile phones is their ability to facilitate communication. With technological advancements, mobile phones are now known as smartphones, possessing capabilities akin to computers. The number of smartphone users in Indonesia is growing rapidly. According to an e-Marketer report, the number of active smartphone users in Indonesia will increase from 55 million in 2015 to more than 100 million in 2018 and contiue to rise in the following years. By this number, Indonesia will become the country with the fourth largest number of active smartphone users in the world, after China, India, and the United States". This data indicates that mobile phones have now shifted to become a primary necessity.

As an electronic device, a mobile phone requires electrical energy from its internal battery to function. The stored electrical energy in the battery depletes over time, necessitating periodic recharging. However, problems often arise when mobile phone users are outside their homes without a charger or have difficulty finding a power source to recharge their phones. Many papers show innovative mobile phone charging system, including based on solar panel and IoT technologies [1], [2], [3], [4]. However, coin based insertion system remains paly a role for public phone charging system [5], [6], [7], [8], [9]. In addition, RFID as 'tapping' technolgy was implemented as well in this system by some researchers[10], [11], [12], [13].

This study proposes an innovative solution by creating a secure mobile charging station that can be placed in public locations such as stations, hospitals, banks, hotels, malls, restaurants, or other public places. The mobile charging station will offer two payment methods, which are coins and RFID cards.

2. METHOD

2.1` System Design

To ensure that this designed device functions as expected, it can be illustrated in Figure 1. The system design of the proposed mobile charging station integrates multiple hardware and software components to ensure smooth functionality. The core processing unit is the NodeMCU ESP32 microcontroller, responsible for handling user inputs, controlling solenoid locks, and managing payment transactions. The system operates on a 12V DC power source, step-down converted to 5V and 3.3V for different components. The MOSFET-based switching circuit ensures efficient power distribution, while the ULN2803 driver controls the solenoid locks that secure six individual charging lockers.

The system supports two payment methods: coin-based payment and RFID-based payment. Users inserting 1000 IDR coins increase their charging duration by 15 minutes, while RFID users have their balance checked and deducted via a database system. A Nextion HMI touchscreen provides an intuitive interface, guiding users through locker selection, payment confirmation, and transaction monitoring. The system is connected to a MySQL database via Wi-Fi, allowing real-time updates on locker availability and transaction history.

For security, the system implements authentication mechanisms, ensuring access through RFID verification or a security code. Additional safety features include automatic timeout alerts, overcurrent protection, and remote monitoring capabilities for administrators. The integration of real-time data storage, secure locker access, and a user-friendly interface makes this charging station a reliable and scalable solution for public use.

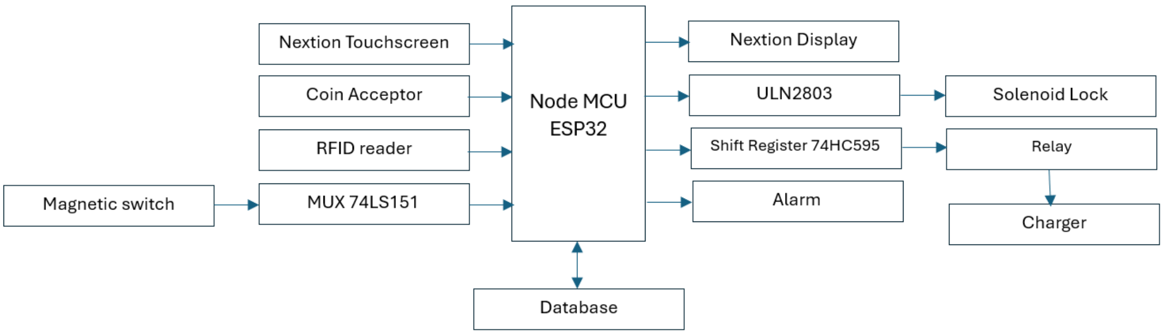

Figure 1. Block diagram

This paid mobile charging station consists of 6 charging lockers. The locking mechanism for each locker is implemented using a Solenoid lock controlled by a NodeMCU ESP32. The payment methods available for this device include two options: using coins and using RFID cards. A coin acceptor is required to read the coin denominations, whereas an RFID reader is necessary for reading RFID cards.For the coin payment method, users insert coins into the coin acceptor. The charging duration depends on the number of coins inserted. Each time a 1000 Indonesian Rupiah coin is inserted, the charging time increases by 15 minutes. After inserting coins, the user sets a security code for the locker. This code is used to retrieve the phone after charging. Once the code is set, the locker opens, and the user can proceed with charging in the reserved locker. For the RFID card payment method, users first select the charging duration. Then, they tap their RFID card on the RFID reader. Subsequently, the microcontroller reads the user's balance from the database. If the balance is sufficient, the charge is deducted according to the charging fee. After that, the charger activates, and the locker opens.

2.2 PHP Programming to Display Database

Below is the outline of the PHP programming designed to display user balance data from the database. The PHP programming in this system plays a crucial role in managing database interactions and ensuring real-time data access. It acts as a bridge between the NodeMCU ESP32 microcontroller and the MySQL database, handling user authentication, transaction logging, and locker availability status. PHP scripts enable users to check their RFID balance, update payment records, and retrieve transaction histories efficiently. Additionally, administrators can monitor system performance remotely through a web-based dashboard powered by PHP, ensuring real-time control and maintenance. This integration enhances the overall efficiency, security, and reliability of the mobile charging station.

```
<h3>Charging Station<h3>
<?php
$konek=mysqli_connect("localhost","root","","chargin
gstation");
$tampil = "SELECT *FROM saldorfid";
$hasil   = mysqli_query($konek, $tampil);

echo "<tabel>
   <tr>
   <th>Nama</th>
   <th>Satus</th>
   <th>ID</th>
   </tr>";

while($data=mysqli_fetch_array($hasil))
{
   echo "<tr>
   <td>$data[User]</td>
   <td>$data[IdNumber]</td>
   <td>$data[Saldo]</td>
   </tr>";
}
echo "</tabel>";
?>
```

Figure 2. Snippet of PHP programming

2.3 Flowchart

The following flowchart illustrates the systematic approach for developing the program in this final project. The flowchart of the mobile charging station system outlines a structured sequence of operations, starting from system initialization to user interaction and transaction processing. When the system starts, the ESP32 microcontroller initializes all components, including the RFID reader, coin acceptor, solenoid locks, and the database connection. The system then waits for user input, allowing them to choose a payment method, either inserting a coin or scanning an RFID card. Upon payment validation, the system verifies locker availability, assigns an empty locker, and unlocks it for user access. The charging process begins once the user places their mobile phone inside and closes the locker.

Once the charging session is complete, the user must retrieve their phone by entering their security code or scanning their RFID card. The system then verifies the authentication details, unlocks the assigned locker, and resets it for the next transaction. Additionally, the flowchart includes fail-safe mechanisms, such as an error-handling routine if a user enters an incorrect security code or an insufficient balance warning for RFID-based payments. The structured logic of this flow ensures a secure, automated, and user-friendly experience for public charging station users.

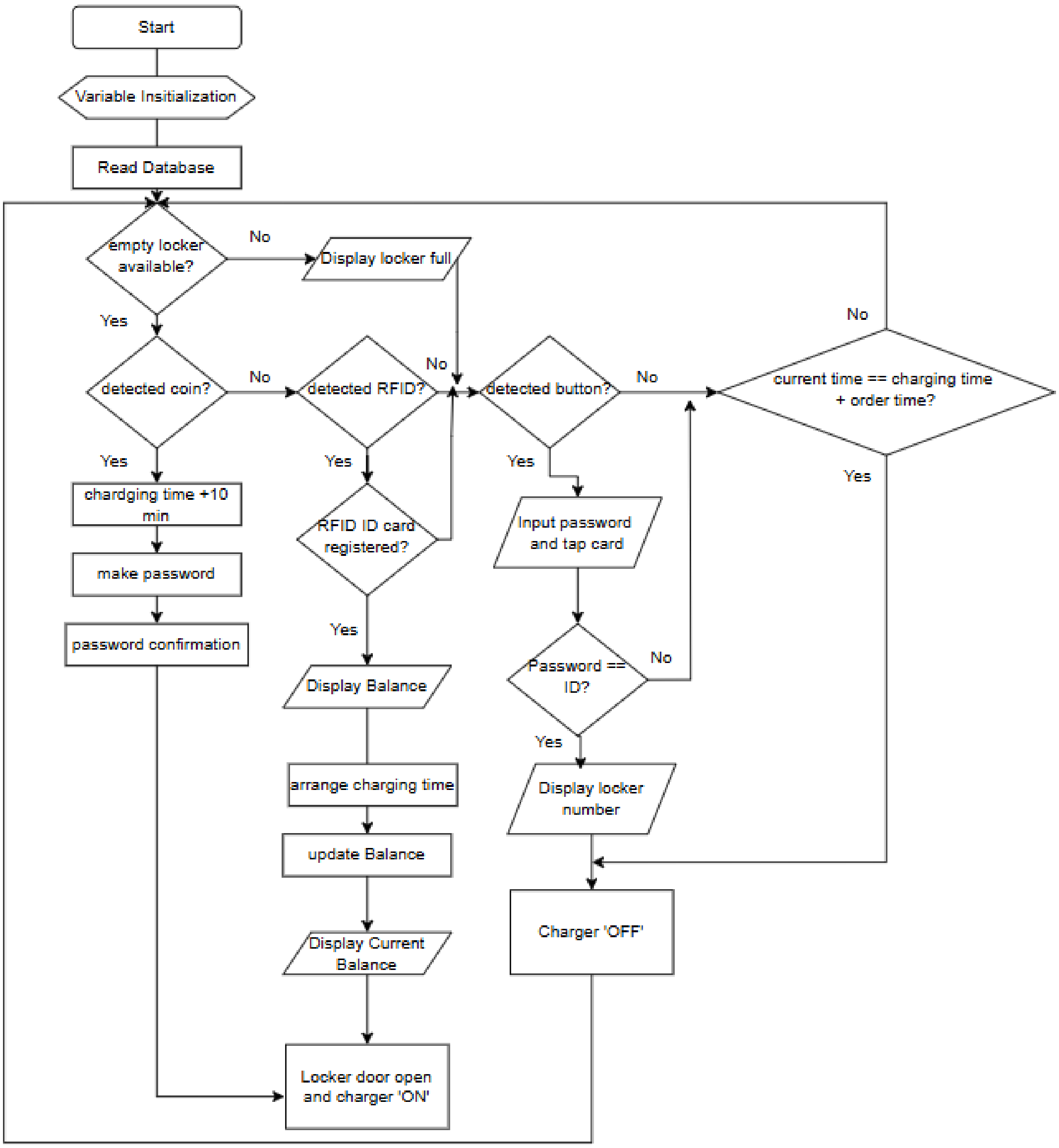

Figure 3. *Flowchart*

When the system is first started, the microcontroller will perform necessary initialization procedures. Subsequently, the microcontroller will detect the mode to be executed: coin rental mode, RFID card rental mode, or phone retrieval mode. The coin rental mode begins when coins are detected by the microcontroller. The user then sets a security code. Once the user has set the code, the locker opens, and the charger activates. The RFID card rental mode starts when an RFID card is tapped on the RFID reader. The user is then prompted to select the charging duration, and the user's balance is automatically deducted according to the selected time. Afterward, the locker opens automatically, and the charger activates. When the user wants to retrieve their charged phone, they must press the "retrieve" button on the Nextion TFT LCD. Then, the user inputs the security code or taps their RFID card on the RFID reader to open the locker. This flowchart is more complex compared to previous paper published by Sunantha et al. [14]

3. RESULTS AND DISCUSSIONS

The testing of the mobile charging station system was conducted to evaluate the efficiency and reliability of its hardware and software components. The results indicate that the coin acceptor and RFID-based payment methods performed successfully, with an accurate balance deduction and charging duration assignment. The solenoid lock mechanism responded effectively to user authentication, ensuring secure locker access. The Nextion HMI touchscreen provided an intuitive and seamless user experience, with clear instructions guiding users through the charging process. Additionally, real-time database updates ensured accurate tracking of transactions, locker availability, and user authentication logs.

Figure 4. Design the pages of HMI nextion

To assess the performance of the device, testing was conducted on each component as follows: Relay driver erformance, solenoid lock and ULN2803 driver circuit, magnetic switch and multiplexer circuit using IC 74LS151, coin acceptor functionality, RFID reader reading performance, and database part. Performance testing of the relay driver using the 74HC595 shift register involves continuously changing data every 5 seconds and monitoring the relay output. The following table provides an example of relay driver output testing related to the locker door's open/closed status based on varying data patterns.

Table 1. Test *shift register* circuit

Data	Locker Number					
	1	2	3	4	5	6
000000	X	X	X	X	X	X
000001	X	X	X	X	X	√
000010	X	X	X	X	√	X
000011	X	X	X	X	√	√
000100	X	X	X	√	X	X
000101	X	X	X	√	X	√
000110	X	X	X	√	√	X
000111	X	X	X	√	√	√

The testing is conducted by providing specific data or conditions to the magnetic switch and ensuring that the data read by the microcontroller matches the data provided to the magnetic switch.

Tabel 2. Test *solenoid lock* and ULN2803

Data	Locker Number					
	1	2	3	4	5	6
000000	X	X	X	X	X	X
000001	X	X	X	X	X	√
000010	X	X	X	X	√	X
000100	X	X	X	√	X	X
001000	X	X	√	X	X	X
010000	X	√	X	X	X	X
100000	√	X	X	X	X	X

x = Solenoid lock in locked position,
√ = Solenoid lock in unlocked position

Table 2 shows that the output produced is as expected. This is evident as each solenoid can be controlled according to the commands issued by the microcontroller. The purpose of this multiplexer testing is to assess the success rate of data reading from the magnetic switch. The magnetic switch is used to determine whether the locker door is open or closed. Testing involves applying various conditions to the locker door and then detecting these conditions with the microcontroller.

Table 3. Test magnetic switch and multiplexer circuit

Locker Number						Data
1	2	3	4	5	6	
X	X	X	X	X	X	000000
X	X	X	X	X	√	000001
X	X	X	X	√	X	000010
X	X	X	X	√	√	000011
X	X	X	√	X	X	000100
X	X	X	√	X	√	000101
X	X	X	√	√	X	000110
X	X	X	√	√	√	000111

x = Locker door in closed position
√ = Locker door in open position

From testing table 3, it is evident that the output produced aligns with expectations. This is observed from the data read by the microcontroller, which corresponds to the conditions given for the locker door. The coin acceptor testing aims to determine the accuracy of the coin acceptor in detecting inserted coins. The testing specifically focuses on 1000 Indonesian Rupiah coins. It involves inserting the 1000 Rupiah coins into the coin acceptor and repeating this process 50 times. The results of this testing yield data as shown in Table 4.

Tabel 4. Coin Rp 1000 testing

Parameter	Number
Accepted coins	50
Accepted coins and detected b MCU	50
Refused coins and automatically ejected	0
Refused coins and returned by coin ejector	0
Refused coins but detected by MCU	0

From the testing conducted on the coin acceptor using 1000 Indonesian Rupiah coins, it is evident that the coin acceptor functions effectively with a success rate of 100%. This indicates that there were no reading errors for coins with different denominations detected by the microcontroller. Moreover, next test aims to determine the reading distance of RFID cards detected by the RFID reader.

Table 5. RFID *Reader* range testing

Trial No.	Range RFID (reader and card) (cm)
1	5.5
2	5.7
3	5.7
4	5.7
5	5.9

The testing data indicates that the average detection distance of the RFID reader towards the cards is 5.7 cm. This demonstrates that the RFID reader used performs adequately in card detection.

This testing was conducted on several cards registered in the "saldorfid" database. If a card is registered, the user will be granted access. If the card is not registered, access will be denied, and the user cannot use the device. Below is the table of User IDs registered in the "saldorfid" database.

Table 6. *User* ID list

				User	IdNumber
	Edit	Copy	Delete	Mochamad Susantok	10152136
	Edit	Copy	Delete	M Budi Satria Yonda	10152465
	Edit	Copy	Delete	Rizadi Sasmita Darwis	10156181
	Edit	Copy	Delete	Cyntia Widiasari	10157816
	Edit	Copy	Delete	Noptin Harpawi	10162984
	Edit	Copy	Delete	Siska Novita Posma	10163680

To facilitate the identification of each IdNumber from the RFID tag, a Username identity is assigned. The table below shows the testing conducted on the unique IdNumbers of each RFID tag.

Tabel 7. *User* ID RFID *tag* testing

Registered card	Taped Card					
	STK	RSD	NOP	CYN	MBS	SNP
STK	√	X	X	X	X	X
STK RSD	√	√	X	X	X	X
STK RSD NOP	√	√	√	X	X	X
STK RSD NOP CYN	√	√	√	√	X	X
STK RSD NOP CYN MBS	√	√	√	√	√	X
STK RSD NOP CYN MBS SNP	√	√	√	√	√	√

x = no action
√ = action taken

"No action" indicates that the detected card is not registered in the database, thus the user cannot proceed with a booking action at the Charging Station. Conversely, "action taken" indicates that the user can proceed with booking at the Charging Station.

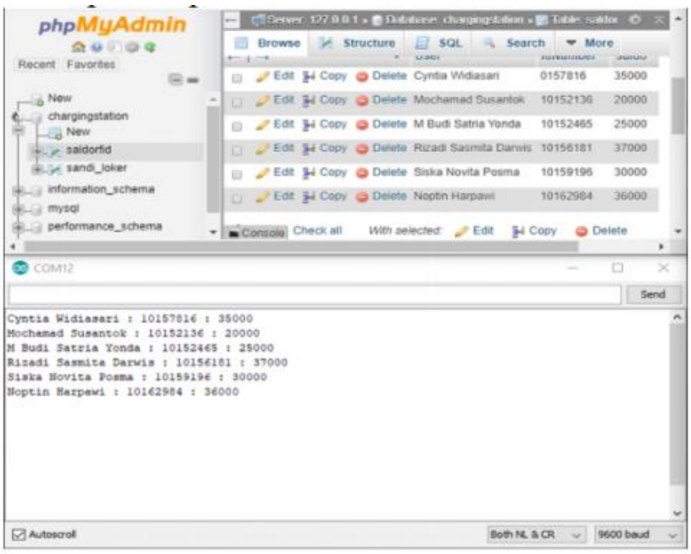

Figure 6. Test data reading from database to serial monitor

Figure 6 shows one of the data points during the conducted test. Subsequent tests involved modifying the balance data in the database and displaying it again on the Arduino's serial monitor. The results of these tests are shown in Table 8.

Tabel 8. Database - Serial monitor testing

Experiment	Saldo in Database					
	CYN	STK	MBS	RSD	SNP	NOP
1	35000	20000	25000	37000	30000	34000

2	**30000**	20000	25000	37000	30000	34000
3	30000	**25000**	25000	37000	30000	34000
4	30000	25000	**20000**	37000	30000	34000
5	30000	25000	20000	**32000**	30000	34000
6	30000	25000	20000	32000	**25000**	34000
7	30000	25000	20000	32000	25000	**29000**

Experiment	Balance is read on the monitor screen					
	CYN	STK	MBS	RSD	SNP	NOP
1	35000	20000	25000	37000	30000	34000
2	**30000**	20000	25000	37000	30000	34000
3	30000	**25000**	25000	37000	30000	34000
4	30000	25000	**20000**	37000	30000	34000
5	30000	25000	20000	**32000**	30000	34000
6	30000	25000	20000	32000	**25000**	34000
7	30000	25000	20000	32000	25000	**29000**

Figure 8 presents the results of writing data to the database using the NodeMCU ESP32. This figure demonstrates the effectiveness of the ESP32 in transmitting data to the database, ensuring real-time updates and accurate record-keeping for transactions and user balances. The successful implementation of this feature highlights the system's ability to maintain synchronization between the hardware and database, which is crucial for reliable operation. This process ensures that payment records, locker availability, and charging sessions are accurately logged, enhancing the overall efficiency and security of the mobile charging station.

User	IdNumber	Saldo
Mochamad Susantok	10152136	20000
M Budi Satria Yonda	10152465	50000
Rizadi Sasmita Darwis	10156181	30000
Cyntia Widiasari	10157816	35000
Noptin Harpawi	10162984	36000
Siska Novita Posma	10163680	50000

User	IdNumber	Saldo
Mochamad Susantok	10152136	20000
M Budi Satria Yonda	10152465	50000
Rizadi Sasmita Darwis	10156181	30000
Cyntia Widiasari	10157816	5000
Noptin Harpawi	10162984	36000
Siska Novita Posma	10163680	50000

Figure 8. Test data writing from ESP32 to database

The results obtained from testing confirm that the proposed mobile charging station system meets its intended design specifications, offering an efficient and secure charging solution. The integration of RFID-based authentication, coin-based transactions, and real-time monitoring ensures usability and reliability for public environments. With its user-friendly interface and robust security features, this system has the potential to enhance accessibility to mobile charging services while maintaining operational efficiency. Future improvements may focus on expanding payment options and integrating advanced analytics for usage monitoring and optimization.

4. CONCLUSION

After testing and analyzing the system developed in this research, the following conclusions can be drawn: From the testing, it was found that the average reading distance of the RFID reader used is 5.7 cm.The performance of the coin acceptor used in this project is satisfactory. This can be observed from the test results where only valid coins, matching the reference coins placed in the coin acceptor, were accepted. The Solenoid lock requires a 12-volt power supply, whereas the digital output from the NodeMCU ESP32 is only 3 volts, thus unable to directly power the Solenoid lock. To control the Solenoid lock, an IC ULN 2803 is needed.The multiplexer circuit is employed to conserve digital pin usage on the NodeMCU ESP32. The IC used is the IC74LS151, which is an 8-to-1 multiplexer IC. The shift register circuit used in this project is aimed at reducing the digital pin usage of the NodeMCU ESP32.

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