The Indonesian Journal of Computer Science
www.ijcs.net
Volume 15, Issue 2, April 2026
https://doi.org/10.33022/ijcs.v15i2.5073

Design of an IoT-Based Snack Vending Machine with QR Code Payment, Automatic Stock Monitoring, and QoS Evaluation

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Article Information

Received : 8 Jan 2026
Revised : 28 Feb 2026
Accepted : 17 Mar 2026

Keywords

Vending Machine, QR Code, Internet of Things (IoT), Quality of Service (QoS)

Abstract

The rapid advancement of the Internet of Things (IoT) has enabled the development of smart vending systems with advanced automation and monitoring capabilities. This study details the design and implementation of an IoT-based snack vending machine that incorporates QR code payment, automated stock monitoring, and network Quality of Service (QoS) assessment. The system employs embedded devices and wireless communication to manage transactions, monitor inventory levels in real time, and enable remote supervision. QR code–enabled digital payment is adopted to enhance transaction efficiency and user convenience, while quality of service metrics are evaluated to assess network performance and system reliability. Experimental findings indicate that the system operates reliably, delivers precise stock information, and maintains stable network performance under standard operating conditions. These results suggest that the proposed solution is both practical and effective for smart vending applications and is adaptable to other IoT-based automated service systems.

A. Introduction

The introduction includes background information on supporting beverages, lottery tickets, and related products. It is vital to save time and reduce human energy. These vending machines are developed using non-IoT and IoT-based methods. These non-IoT-based machines are not intelligent and do not operate on real-time data; they function only when a user inserts cash or a card and enters inputs (e.g., selecting items). A microcontroller controls it and distributes the given inputs. IoT-enabled machines are computerized, offer cashless payment, allow customers to order before approaching the vending machine, and can be identified by location. Simulation software and a prototype are used to validate the machines [1-2].

Information is designed for smartphone reading. QR stands for "Quick Response," indicating that the code's contents should be decoded quickly at high speed. The code consists of black modules arranged in a square pattern on a white background. The information encoded may be text, a URL, or other data. The QR code was designed to enable rapid decoding of its contents. The popularity of QR codes is growing rapidly worldwide. Nowadays, mobile phones with built-in cameras are widely used to recognize QR Codes [3-5].

Because the use of banknotes and coins on vending machines is still considered to have many shortcomings, such as requiring money in perfect condition, even new, without bending or graffiti, using the currency specified by the machine, and not being able to make refunds, which is not everyone has money that is in new or perfect condition. Therefore, a sales system or vending machine was developed that uses QR codes for payment transactions, so consumers do not need to provide new, high-quality currency. Consumers only need to ensure that the existing balance is sufficient for the Transaction [6].

While QR code–based vending machines are prevalent in commercial settings, the novelty of this research extends beyond the integration of QR code payment. This study introduces a fully integrated Internet of Things (IoT)-based vending architecture that unifies three core components within a single evaluated system: (1) QR-based digital transaction processing synchronized with a web-based database, (2) real-time automatic stock monitoring and remote supervision, and (3) quantitative network Quality of Service (QoS) evaluation to assess communication reliability and system responsiveness.

In contrast to existing vending machine prototypes that primarily address payment mechanisms or mechanical dispensing, this research systematically evaluates the communication performance between the website server and embedded hardware using QoS parameters, including delay, jitter, throughput, and reliability. Incorporating network performance analysis ensures that the system is validated not only for functional operation but also for service stability and IoT communication quality.

Additionally, the proposed system features a low-cost embedded implementation utilizing the ESP32 platform, integrated with web-based transaction validation. Mechanical actuation via servo control is triggered exclusively following successful transaction verification, thereby enhancing transaction integrity and reducing operational errors. The primary contribution of this work is the integration of automated vending functionality, real-time inventory management, and quantifiable IoT communication performance within a single practical implementation.

B. Research Method

This research comprises several stages, including a literature review, system planning, system testing, analysis, and conclusions. The following are the stages of this research:

B.1. Literature Review

A literature study was conducted by reading and understanding various journals and books related to this research. Some of the literature studied concerns the creation of a vending machine using an ESP32 and servos, with cashless payments. The issues raised in this study, along with some solutions proposed by researchers, were derived from this preliminary study. Several studies have been conducted previously.

In 2022, Anggie Desiana Putri conducted a study titled "Design and Development of an IoT-Based Rice Vending Machine" that aimed to create an automatic rice vending machine controlled by a mobile application [7].

In 2021, Muhammad Assadullah conducted a study titled "Design and Development of a Pharmacy Vending Machine as a Medication Supply Facility During the Covid-19 Pandemic." This study aims to develop a vending machine that dispenses medications during the pandemic, with card payments [8].

In 2020, Ikhlasul Amal Salahuddin conducted a study entitled "Design and Development of a Traditional Snack Vending Machine." This research developed a vending machine design that sells traditional snacks using electronic ID cards (E-KTP) with an RFID sensor to detect the UID on the E-KTP and the user's balance, enabling a cashless method [9].

B.2. System Planning

The system design involves several key steps:

Block Diagram System

The system planning for this research is based on the diagrammatic blocks shown in Figure 1.

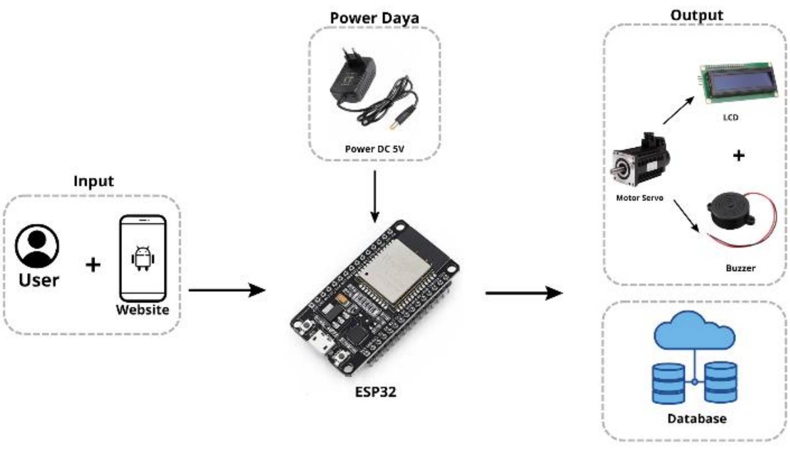

Figure 1. Block Diagram System

Figure 1 outlines the flow of an IoT-based sales system. Starting from using the website to make snack selections and payments, so that when the Transaction is successful, the transaction result data will be stored in the website database. Based on this data, the hardware will receive a command from the ESP32 to run the servo motor, moving the wire containing snacks so it falls into the provided space [10]. When you move the wire, the LCD and buzzer simultaneously display a warning or an information message indicating that snacks can be taken and that the Transaction is complete.

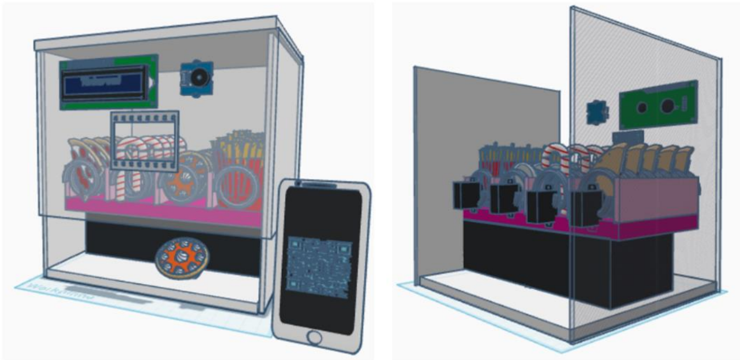

Figure 2. Prototype Hardware System

The following presents a hardware and mechanical design integrated with electronic systems. The result of the design and structuring tools and components will be shown in Figure 2. This prototype is constructed from cubes, comprising an ESP32, servo motors, a board, and wire springs. At the same time, other components, such as the LCD and the website's QR codes, are located on the prototype's exterior.

B.3. System Testing

Testing conducted on the hardware involves verifying that the prototype device successfully receives commands from the website via the ESP32. This allows the provided program to operate the servo motor so that the snacks fall into place, and the LCD and buzzer give warnings. Meanwhile, website testing involves displaying images of snacks and their corresponding QR codes for each snack type, managing stock, and displaying sales data. Website testing is also conducted to verify that data entered on the website can be transmitted to the database server, enabling the seller to view the sales history of the snacks they have purchased.

B.4. Analysis

The test results were analyzed to assess system performance, component accuracy, website speed in data delivery, and the accuracy of the transmitted data. The conclusions are based on the analysis of the prototype's success.

Table 1. Main Device Specifications Used

No	Identity	*Type*	*Specifications*
1	ESP32	ESP-WROOM-32	RF certification: FCC, CE, RED; WiFi: IEEE 802.11 b/g/n (up to 150 Mbps), 2.4 GHz; Bluetooth: v4.2 BR/EDR & BLE; Reliability test: HTOL, TCT, ESD; Green certification: RoHS [8].
2	Servo	MG966R Continuous Servo	360°, 4.8–7.2 V, continuous rotation, PWM control, torque ±9–11 kg·cm, speed ±50–60 RPM, metal gear [9].
3	LCD	I2C 16x2	4.5–5.5 V DC; display format 16 characters × 2 lines; controller HD44780 compatible; interface I2C (PCF8574); I2C address 0x20–0x27 or 0x38–0x3F; backlight LED; operating temperature −20 °C to +70 °C [10].
4	Buzzer	Piezoelectronic	3–5 V DC; rated voltage 5 V; current consumption ≤30 mA; sound output ≥85 dB @ 10 cm; frequency 2–4 kHz; type active [11-14].

C. Result and Discussion

After planning and creating the device, this research will conduct several tests. The tests are carried out in several stages. The first test is performed on each component, followed by testing of the overall system or the integrated system, and the quality of service method.

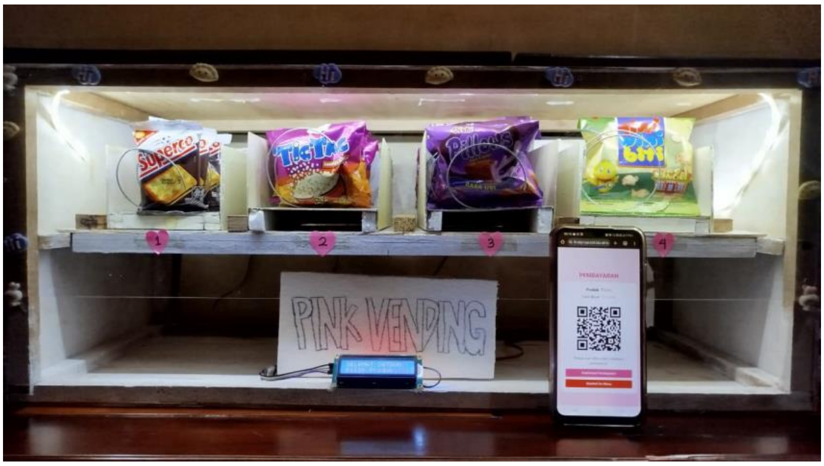

Figure 3. Result of Hardware and Software System

C.1. Testing of Servo

Testing the success of the four servo motors used as actuators per spring so that the snack products can fall as the spring moves in a 360-degree rotation. The following are the servo motor component testing data shown in Table 2.

Table 2. Testing of 4 Servo Motors

Data Receiver	Test Result	360-degree rotation time (s)
Servo 1	Success	2
Servo 2	Success	2,3
Servo 3	Success	2,3
Servo 4	Success	3,5

This testing aims to assess the components' performance, particularly the servo motor. Based on the tests conducted, all servo motor components functioned well and optimally, resulting in minimal delay [15-17].

C.2. Testing of the LCD

The LCD will display the message 'Welcome' before the Transaction begins. After the Transaction is completed successfully, the LCD will display the message 'Please Take' for 3 seconds. The following is the data on the accuracy of data transmission from the website, as shown in Table 3.

Table 3. Testing of LCD Display

LCD Display	Test Result	Time (s)
Selamat Datang!	Success	Idle
Silakan Diambil	Success	1,2
Product : “product name”	Success	1,8

C.3. Testing of the Delay Data Delivery System

The following is a test for each delay with different internet speeds. This test uses a network speed of 72 Mbps, which is higher; consequently, the resulting delay is very small, and transactions are likely to succeed without failure [18].

Table 4. Testing of Delay Data Delivery

Network Speed: 72 Mbps	
Testing Sequence	**Delay (ms)**
1	120
2	135
3	128
4	140
5	132
6	145

7	138
8	130
9	142
10	136
Average	**134,6 ms (Great)**

C.4. Testing the Quality of Service Methods

The Quality of Service (quality of service) method is used to test and measure network quality in a web-based vending machine system [19]. Since this vending machine is connected to the internet and communicates data for ordering and payment [20], network performance will significantly affect the response speed of the servo, LCD, and buzzer during the transaction process.

Table 5. Testing the quality of service

Parameters	Testing	Standart	Result (Average)	Description
Delay (Latency)	Measuring the time from when the website sends data until the machine moves the servo	< 150 ms.	134,6 ms	Great
Jitter	Testing each Transaction to see variations in delay	0 ms – 75 ms	9,78 ms	Good
Throughput	Counting the number of transactions within a specific time period	–	10x transactions	9 minutes 54 seconds
Reliabilty	Calculating the success percentage in 10 consecutive transactions	100%	100%	Great

C.5. Testing of Website System

Website testing assesses the accuracy of each command executed on each web page. An active database on the Sales History admin page stores product sales data.

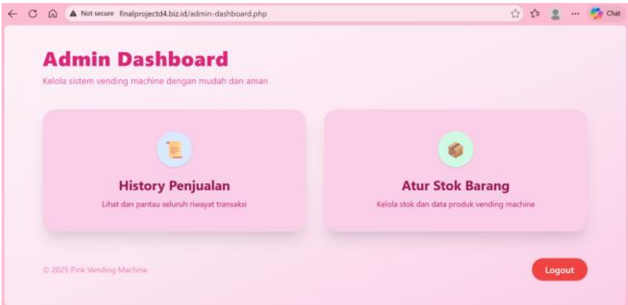

Figure 4. The Display When Admin Successfully Logs In

Figure 5. Display Change When Out of Stock

Figure 6. The Display when the Transaction is successful

D. Conclusion

Based on observations during the design, implementation, and testing stages of the developed system, several conclusions can be drawn for future development. Data transmission from the website to the ESP32 was successful, and the transmitted data matched the quantity and type of goods selected, as indicated by the transaction data received. Data processing on the ESP32 is highly dependent on the WiFi connection, resulting in communication delays that vary with network conditions, with an average reception delay of 134.6 ms. In addition, servo motor calibration requires adjusting the input current, as it significantly affects performance; an insufficient current supply can cause the motor to fail to rotate correctly.

E. Acknowledgment

During the implementation of this research, the author followed guidance from academic supervisors and other relevant parties, who provided support and assistance until the study was completed. Therefore, the author expresses sincere gratitude to Politeknik Elektronika Negeri Surabaya for its support throughout the research process.

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