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Real-time Product Availability Information with Passive NFC Tag System for Offline Shops

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ABSTRAK *– Offering a seamless shopping experience is essential in today's cutthroat retail environment. This paper describes a system built to tell customers about product availability in offline stores, explicitly addressing the issues related to customer reluctance and the store's physical space restrictions. The system was designed, observed, and tested to evaluate its performance. According to the findings, the system can recognize various NFC tag types at reading distances of up to 3.5 cm, 1.5 cm, and 2 cm for a card, keychain, and sticker kinds, respectively. On an average of 3.39 seconds, the server and microcontroller can establish a connection to send and receive responses from the server. Additionally, the system has a 100% success record in displaying precise product stock data based on the chosen size and color. Furthermore, the system has a 100% success rate in telling registered from unregistered NFC tags. The internet network's speed also impacts updating database data, with faster internet connections being processed first. In conclusion, the system's effectiveness demonstrates its potential to be used in retail settings to give customers real-time product availability tracking.*

Kata Kunci *– NFC tag; microcontroller; Android; Product availability; Offline shops.*

1. INTRODUCTION

Despite the rapid expansion of online shopping in recent years, many individuals still like traditional brick-and-mortar stores for various reasons. One argument is that purchasing goods in actual places enables shoppers to view, touch, and try them on before deciding [1]. When it comes to things like apparel, footwear, or cosmetics, where customers want to inspect the color, texture, or fit physically, this sensory experience might be necessary. The tactile sensation of visiting an actual store might be crucial for some products. For instance, before purchasing apparel or shoes, shoppers frequently want to physically inspect the item to determine its color, texture, size, and fit. Customers can learn how an item feels on their body, if it is comfortable, and whether it fits appropriately by wearing clothing or shoes. Customers might also want to touch and see a product in person before purchasing it to get a better idea of its quality or robustness.

However, due to leasing restrictions, small firms with tight resources frequently find it challenging to give the product selection and demonstration they want [2]. Because of this, many stores can only display a select few representative items while keeping the remainder in the warehouse. This condition substantially impacts the customer's need for a sensory experience. Additionally, when a customer requests a different size or color, the staff may need to look for the item without knowing whether it is offered, which can cause stress and discontent.

Making the store feel cozy and welcoming without relying on one-on-one customer service is one possible approach to this problem [3] . Businesses can also employ technology to improve client experiences without hiring much extra staff. With technology, retailers may enable customers to assist by offering clear and detailed signs, pricing, and product information. At the same time, technology may give customers confidence and control over their purchasing experience, removing the need for staff members.

The security, usability, and applicability of NFC technology have all been covered in previous research. The usability of NFC technology has been researched in the past, emphasizing user acceptance and experience [4]. According to the findings, users usually perceive NFC technology as user-friendly and practical for various uses, including mobile payments and access control. Healthcare, logistics, and retail are just a few industries where NFC technology has been used. To identify patients and provide access to medical records, for instance, NFC technology has been deployed in the healthcare industry [5]. NFC technology has been applied to logistics inventory management and asset tracking[6]. For mobile payments, customer loyalty programs, and product information displays, NFC technology has been applied in the retail sector [7].

We may create inexpensive, programmable IoT devices that gather and send data over the internet by combining Arduino boards with sensors and wireless communication modules. The board has created new opportunities for systems used in intelligent home automation, environmental monitoring, and industrial control systems [8]–[10]. In one investigation, the Arduino Uno was used to monitor and regulate the temperature and humidity of a greenhouse [11]. The researchers interfaced the board with sensors that gauged the greenhouse's temperature and humidity levels, and the board was then programmed to modify the ventilation system's settings in response to the measurements. Another study [12] looked at how Arduino Uno may be used to create an automated crop irrigation system. The researchers used the board to operate a water pump and valve coupled to several soil moisture sensors. According to the sensor data, the board was programmed to turn on the pump and valve, giving the crops the ideal amount of water.

According to a study, an Arduino Uno and Ethernet Shield created a remote monitoring system for photovoltaic power facilities [13]. The system could monitor real-time data, including the amount of energy produced and the temperature of the solar panels, the authors discovered, and send notifications to the user if any irregularities were observed. In [14], the authors used an Arduino Uno and Ethernet Shield to create an automated irrigation system. The device kept track of the soil moisture content and managed irrigation based on a predetermined threshold. According to the authors, the technique enhanced crop yields and allowed for efficient water use. The intelligent water management, monitoring, and regulating system of Arduino-based Ethernet systems in the Internet of Things (IoT) sector was covered in a review article [15]. The authors emphasized the benefits of employing Ethernet-based connectivity, including its stability and fast data transfer rates.

The authors of this study developed a method for boosting the customer experience for small retail businesses by integrating real-time information on product availability for offline stores. The dynamic and immediate status of a product's availability in retail is called real-time product availability information. Our strategy uses technologies like Near Field Communication (NFC) and IoT sensors to deliver continuous and real-time updates on the availability of products on the store shelves, in contrast to traditional inventory systems that may update intermittently or at specific intervals.

The system makes use of NFC technology, which has the potential to give each product in the retail store showcase a unique identification (ID). Before purchasing an item, customers need to tap the NFC tag from the display in the store's NFC reader. The customer can then read information about the product's available variation on a smartphone installed in the store to check product attributes, such as size and availability, without asking a store clerk. Using NFC technology rather than more conventional methods like barcodes was a key component of our study strategy. NFC has some particular advantages that meet the requirements of our project, even though barcodes are frequently used and have proven successful in many applications. These advantages include interactivity and richness, durability and longevity, security, user-friendly engagement, and real-time interaction.

2. RESEARCH METHODS

In this section, we will comprehensively materials and methods used in the research.

Materials

1. *Near Field Communication (NFC)*

Near Field Communication (NFC), a wireless method, facilitates short-range communication between two devices [16]. Recently, there has been a notable surge in interest in technology due to its inherent convenience and vast array of potential applications. The essential concept underlying NFC technology is using electromagnetic fields to enable communication between devices. The technology in question exhibits similarities to radio frequency identification (RFID) technology yet distinguishes itself by providing enhanced security measures and a reduced communication range. Near Field Communication (NFC) technology can transmit data at a maximum rate of 424 kilobits per second (kbps) and operates within the frequency range of 13.56 megahertz (MHz).

We carefully picked NTAG213 NFC tags as the best fit for application in our system. The NTAG213 tags offer exceptional functionality by effectively integrating a substantial memory capacity with efficient data transfer at high speeds. The device's memory capacity is 144 bytes, which is adequate for storing vital data while maintaining a small physical size. The rewritable nature of these tags enables the ability to make updates and modifications to the recorded information, hence preserving the system's flexibility in terms of functioning. In addition, the NTAG213 tags provide security features such as password protection and data encryption, which are of utmost importance in safeguarding confidential data within our specific context. The seamless communication between our system and consumers' smartphones or other NFC readers, facilitated by their interoperability with a wide range of NFC-enabled devices, positions them as the optimal alternative.

2. *Arduino Uno*

The Arduino Uno was selected as the primary microcontroller platform for our research project due to its versatility and user-friendly nature. The experimental setup utilized the Arduino Uno, the fundamental component, incorporating the ATmega328P microprocessor. This selection facilitated the accurate manipulation and acquisition of data tailored to our particular application. The primary advantage of utilizing the Arduino Uno in our research was its comprehensive array of input and output pins, facilitating seamless integration with a diverse range of sensors and actuators. The capacity for adaptation facilitated the acquisition of data from various sources and the implementation of precise actions following the received information. Utilizing a 5-volt working voltage and its compatibility with USB and external power sources served as a reliable foundation for our research endeavors.

Table 1. The Arduino Uno Specification

Feature	Specification
Microcontroller	ATmega328P
Operating voltage	5V
Input voltage	7-12V
Digital I/O pins	14
Analog input pins	6
DC Current per I/O pin	20 mA
DC Current for 3.3V pin	50 mA
Flash memory	32 KB
SRAM	2 KB
EEPROM	1 KB
Clock speed	16 MHz
USB interface	Type B

Using the Arduino Integrated Development Environment (IDE) proved advantageous in terms of programming and configuring the Arduino Uno for our project. The programming language under consideration is a more streamlined kind, akin to C/C++, which expedited the progression of development and facilitated our focus on the fundamental functionality of our research. In addition, the extensive library support and online resources provided by the Arduino community proved to be of great value in addressing technical challenges encountered throughout the project. Table 1 displays the specifications of the Arduino Uno utilized in the project.

3. *Ethernet Shield*

The Ethernet shield is a crucial element within the Arduino ecosystem as it facilitates network and internet connectivity, fulfilling a fundamental requirement for various applications. The Ethernet shield played a crucial role in establishing a connection between our Arduino-based system and the broader digital network environment within the scope of our research project. The aforementioned supplementary board, which can be seamlessly integrated with the Arduino Uno and Mega boards, facilitates the integration of our system with local area networks (LANs) and broadband internet.

The Ethernet shield, which utilizes the Wiznet W5100 chip, offers a reliable and consistent data-transmitting foundation. Our system's comprehensive TCP/IP stack facilitates the effective transmission and reception of data, ensuring uninterrupted connection. The utilization of the Serial Peripheral Interface (SPI) bus for establishing a connection between the Ethernet shield and the Arduino board simplifies the process of integrating hardware components, enabling a more concentrated approach toward the primary functionality of the research. In addition, the Ethernet shield's compatibility with the Arduino ecosystem enables it to leverage the extensive library support and online resources the Arduino community provides. Establishing this support network has played a pivotal role in effectively resolving technological challenges, enhancing system efficiency, and expediting the progress of our research endeavor.

Methods

In general, the research was conducted in the steps depicted in Fig. 1.

1. *System Design*

A block diagram in this part gives a general overview of the system design. The figure describes the function of each system component, from the buyer picking the product to reading the UID of the product to giving the consumer the information they require about the particular product.

The system architecture is displayed in the accompanying diagram in Fig. 2. The customer chooses the item they want to buy, then brings the NFC tag on it up close to the NFC reader to begin the transaction. The NFC reader then reads the ID and data stored in the NFC tag. The Arduino Uno, which

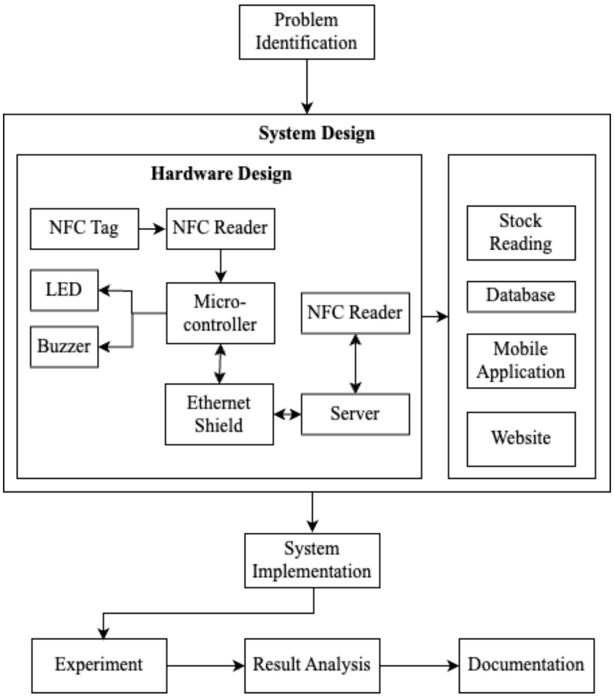


Fig. 1. Research Design

houses the logic and program instructions, acts as the system's command center. Data from the microcontroller is transmitted to the network and then transferred to the server by the Ethernet shield. The LED is an indicator with two colors: green to indicate smooth operation and red to indicate disruption or issues. The buzzer provides audio feedback on the validity of the NFC tag used. The Android application displays stock information and allows users to select the product details they wish to purchase. Lastly, the server stores the product stock database.

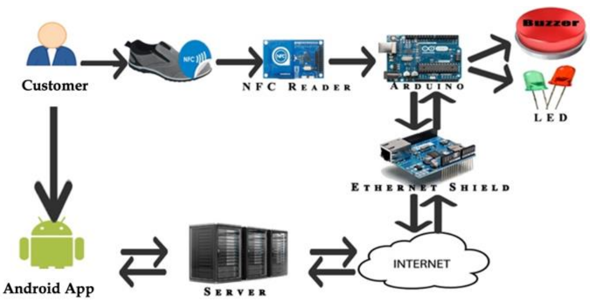


Fig. 2. System design

Overall, this system is designed to provide a seamless process for buyers to select and purchase products using NFC technology and an Android application. The various components work together to ensure the buyer is provided with accurate and up-to-date information about the product stock.

2. *Interface design*

The application's user interface is designed to be simple so that users can easily and comfortably use the application. There are four pages in this application. The first page is the primary menu users use to view the details of the item they want to buy, as shown in Fig. 3(a). The second page is the size selection menu for the item to be purchased (Fig. 3(b)). After selecting the item's size, the user will be directed to the next page, which is the color selection page of the item to be purchased. On this page, as shown in Fig. 3(c), the user only needs to select the item's color to be purchased. After the user selects the color, the item stock information will be displayed based on the size and color the user selects, as shown in Fig. 3(d). Fig. 4 shows flowchart of the process design. Particularly, the figure depicts how the customer would interact with the system.

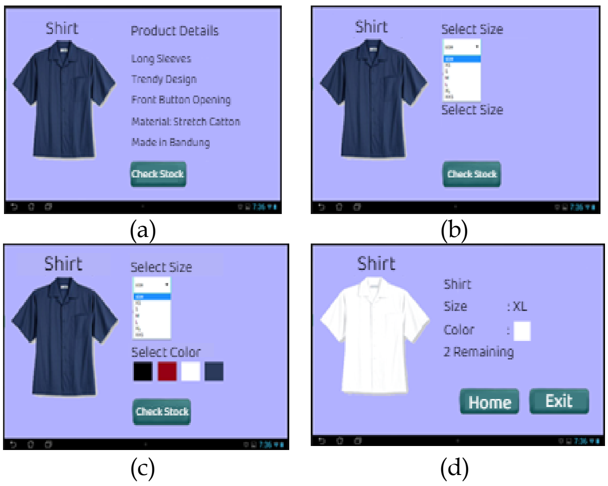


Fig. 3. Interface design

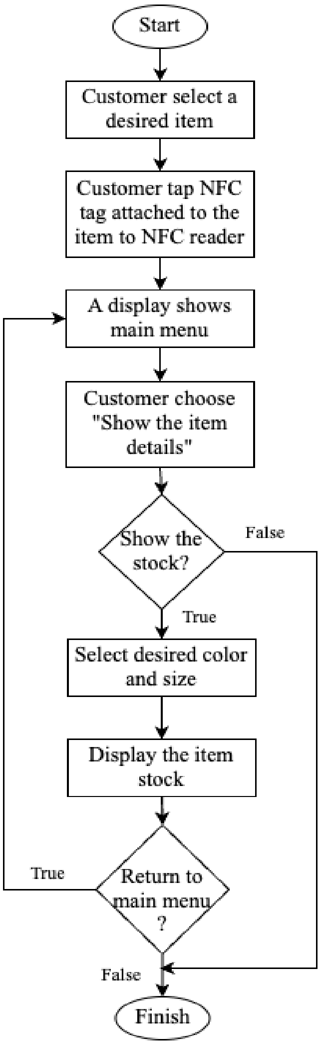


Fig. 4. Process Design

3. *Hardware Implementation*

Implementing the passive NFC tag for product availability tracking is carried out based on the system design, as mentioned earlier. The system implementation aimed to verify whether the system can function properly and achieve the research objectives.

The components described in the system design section were assembled and connected to implement the hardware, as depicted in Fig. 5. The NFC reader was connected to the Arduino Uno, and the Ethernet shield was used to connect the system to the network. The LED indicators and buzzer were also connected to the Arduino Uno to provide visual and auditory feedback to the user. This system uses NFC tags attached to the product label as the unique identifier (UID) for each product type. The obtained UID is sent to the server, and then the information about the stock of that product is displayed in the mobile application. The logic of the program implemented in the microcontroller is shown in Fig. 6.

Fig. 5. Hardware implementation

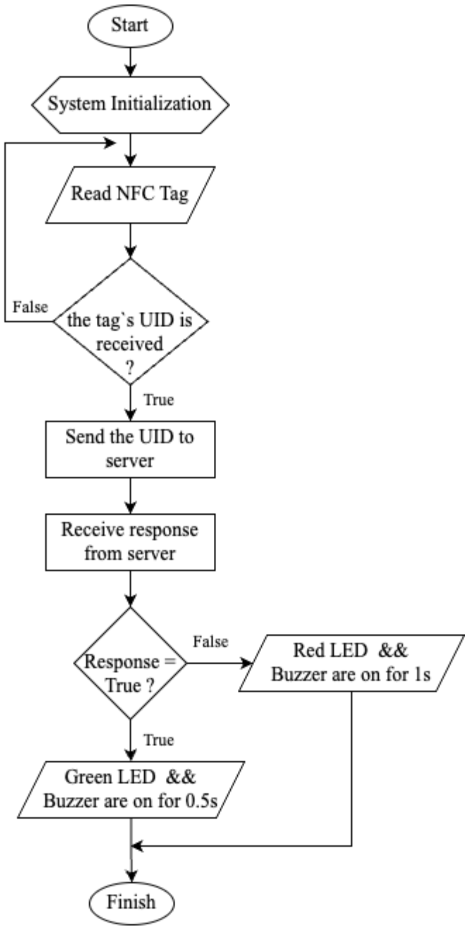


Fig. 6. Flowchart program of the microcontroller

4. *Software Implementation*

The software implementation begins with initializing all the components of the system. The software implementation of the stock checking system includes coding the embedded system, PHP programming on the server side, and Android programming using Android Studio for the user interface to display stock information.

The software used for implementing the embedded software is the Arduino IDE. This software is used to send and process the received data to control other connected devices, starting from a network connection, reading NFC tags, processing the UID information read by the NFC reader, and then sending the UID data to check information from the server and getting a response back from the server with the LED and buzzer indicators activated by the microcontroller. Fig. 7 shows the response from the server after the UID is sent to the server. The response is in the form of 1 and 0, where 1 is the response for the UID registered in the database, while 0 is the response for the UID sent but not in the database. The logic how program implemented to search the UID in the server is depicted in Fig. 8.

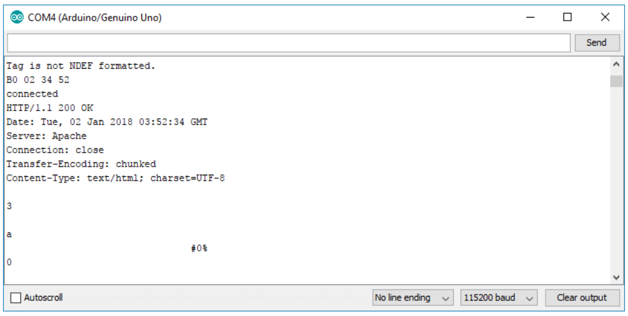


Fig. 7. Server response when receiving UID

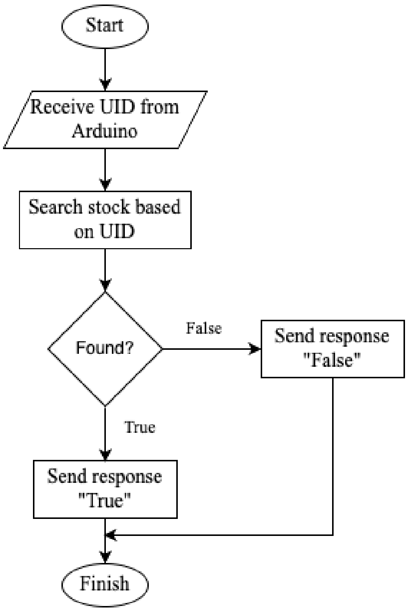
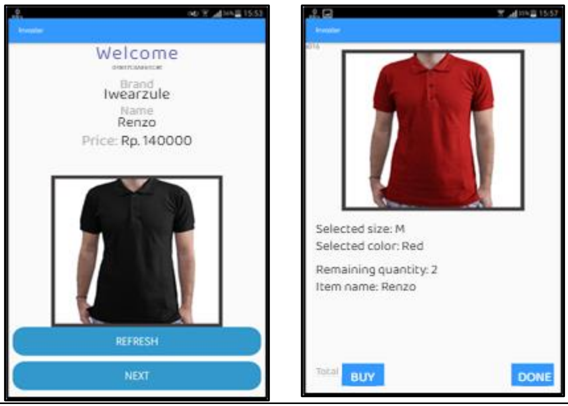


Fig. 8. Flowchart program of UID search in the server

The development of the mobile application with Android Studio software serves as the user interface. General stock information will be displayed, starting from the product's price, brand, and UID. The displayed product information on the application depends on the NFC tag UID used as the product identifier. Users can select the product size and choose the desired color to search and display the product quantity. The user can enter the desired quantity on this application to buy the product. The mobile application interface is depicted in Fig. 9.

The website implementation, as shown in Fig. 10 of the stock checking system facilitates the admin to enter product information into the database. The admin can also update the data of each product in the database. To do that, the admin will be prompted to input the admin's username and password. When the Sign-in button is selected, the system will send and search for admin data in the database. If the admin data is available, the information page of all products in the database will be displayed. If not, a notification will appear that the username and password are incorrect. The implementation of the product stock information page can be seen in the following figure. All product stock information in the database will be displayed on this page. The information displayed is the product UID, stock ID, brand, product name, size, color, and quantity. The admin can update the product quantity information by pressing the edit button on the right side of the table.



(a) (b)

Fig. 9. Mobile application display

3. Result and Discussions

System testing was conducted to determine whether the components of the designed system could function effectively. The testing comprised NFC tag reading distance, ethernet shield, buzzer circuit, and LED circuit testing.

The NFC tag testing aims to determine the minimum and maximum distance the NFC reader could detect against the NFC tag. The result is shown in Table 2. The testing was performed by bringing the NFC tag close to the NFC reader. The indicators used were the sound of the buzzer and the green LED light, which indicated that the NFC tag had been detected. The NFC tags used were stickers, cards, and keychains with a maximum reading distance of 3.5 cm, 2 cm, and 1.5 cm, respectively.

The Ethernet Shield testing was performed by measuring the time required for the Ethernet Shield

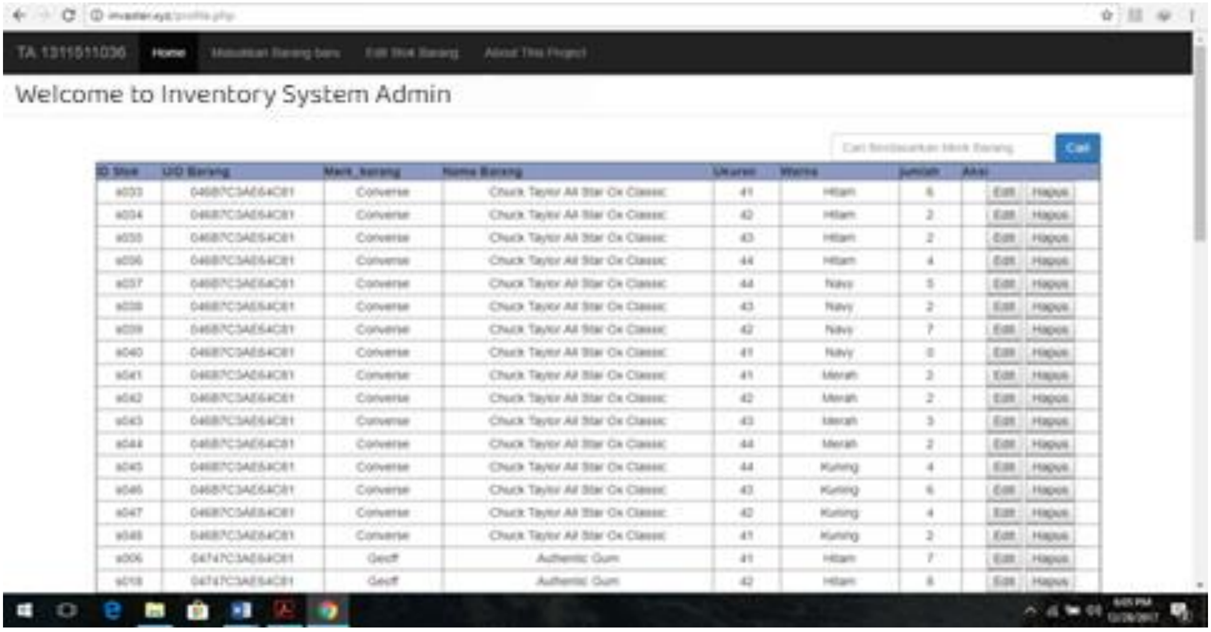


Fig. 10. Product availability information in the website

to send data to the server and receive a response from the server. Two data samples were used in the testing; each was tested ten times. The average time required to send data and receive a response from the server with the Ethernet Shield was not significantly different. The testing was performed ten times for each sample. The average time obtained was 4.38 seconds for data sample 1 and 4.4 seconds for data sample 2. It can be concluded that the internet network speed affects the Ethernet Shield response time; the faster the network, the faster the Ethernet Shield response time.

Table 2. The NFC reading distance testing

Number	Distance (cm)	NFC Tag type		
		Sticker	Card	Keychain
1	0	√	√	√
2	0.5	√	√	√
3	1.0	√	√	√
4	1.5	√	√	√
5	2.0	√	√	√
6	2.5	√	√	√
7	3.0	√	√	√
8	3.5	√	√	√
9	4.0	√	√	√
10	4.5	√	χ	χ

Note: √ = detected, χ = not detected

Software testing involves testing mobile applications on smartphones and websites. The testing is done by verifying whether the UID of the product read by the NFC reader matches the data in the database. Doing so helps us evaluate the mobile application's ability to provide accurate information to users. Based on the testing, it can be concluded that the application displays product information correctly, with a success rate of 100%. Additionally, we conduct testing on the inventory of products based on color and size. This activity verifies whether the quantity of the products displayed matches the remaining amount in the database.

We also tested data updates in the database after a product was purchased through the mobile application. This testing involves verifying whether the data in the database is updated automatically after a product is purchased. A product can only be purchased if the quantity purchased is less than or equal to the available quantity. This testing helps determine the latest stock information of a product after a purchase has been made. The application can update the data in the database automatically, allowing it to display the latest information based on the database. The success rate achieved in this testing is 100%

We also conduct testing on accessing the mobile application simultaneously using two smartphones. This testing is done by observing the server's response when data is updated simultaneously. In this testing, each smartphone uses a different network. Smartphone 1 has an internet speed of 1093 Kb/s, while smartphone 2 has an internet speed of 734 Kb/s. We assume that two buyers will purchase the same product using two smartphones, with the quantity purchased less than the total quantity available. Based on the testing conducted, it can be concluded that internet speed affects the data update process in the database. Therefore, smartphone 1, with a faster internet speed, updates the data in the database before smartphone 2, resulting in smartphone 2 having a reduced stock of the product due to the purchase made by smartphone 1. This system prioritizes the purchase process that is first received by the server.

Testing is also conducted on the website to ensure that the displayed data matches the data in the database, as shown in Fig. 11. The administrator is assumed to update the quantity of a product on the database through the website. Based on the testing conducted, it can be concluded that the data on the website is updated in the database automatically. The success rate achieved in this testing is 100%. Testing is also done to verify data consistency between the website and the mobile application, including whether the mobile application updates the product inventory information on the database when the administrator updates the website data and vice versa. Overall, the testing conducted on the mobile application and website software components shows that the system can update and display data accurately and consistently.

a

048C7C3AE64C81	Nike	As Men NSW Tee TB AM90 Sw	XL	Hitam	4
048C7C3AE64C81	Nike	As Men NSW Tee TB AM90 Sw	XL	Putih	7
048C7C3AE64C81	Nike	As Men NSW Tee TB AM90 Sw	L	Putih	5
048C7C3AE64C81	Nike	As Men NSW Tee TB AM90 Sw	M	Putih	5
048C7C3AE64C81	Nike	As Men NSW Tee TB AM90 Sw	S	Putih	2

b

Fig. 11. (a) A particular data in mobile application, (b) Data in the web

4. Conclusion

After conducting design, observation, and testing, the following conclusions can be drawn: Firstly, the system can identify passive NFC tags with different NFC readers. The maximum reading distance for NFC tags with type card, keychain, and the sticker is 3.5 cm, 1.5 cm, and 2 cm, respectively. Secondly, the microcontroller and server can establish a connection to send and receive responses from the server with an average time of 3.39 seconds. Thirdly, the system can display product stock information that corresponds to the database based on the size and color selected in the mobile application, with a 100% success rate. Fourthly, the system can distinguish between NFC tags that are registered in the database and those that are not, with a 100% success rate. Finally, the speed of the internet network will affect the process of updating data in the database. Therefore, if multiple applications are opened simultaneously, the smartphone with a faster internet network will be processed first. In summary, the system has been tested and can identify different types of NFC tags, display accurate product stock information, and distinguish between registered and unregistered NFC tags. The connection between the microcontroller and server is also efficient, and the internet network's speed affects the database's updating data: the website data and vice versa.

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