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AN ENHANCED SECURED AND ROBUST MOBILE PAYMENT SYSTEM USING QR CODE AND HYBRID CLOUD COMPUTING MECHANISM

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Abstract
The recent redesign policy for the Nigerian Naira currency notes by the Central Bank of Nigeria caused significant inconveniences and distress to peoples, as some of the old naira notes were illegal and unacceptable. As a result of this, peoples faced so much inconveniences and challenges which include limited access to the POS or ATM terminals, no or insufficient cash to customer for purchase and financial losses due to poor network connectivity. This research presents an enhanced secured and robust mobile payment system using QR Code and Google Firebase, a Hybrid-cloud computing mechanism. The system is designed and developed with the Object-Oriented Analysis and Design Methodology (OOADM). It is implemented with Flutter, a Dart Programming Language with Android Studio and XCode Integrated Development Environment (IDE). Google Firebase was also used in the implementation of the database that provided several benefits of secured cloud computing services such as real-time database updates, authentication and authorization services, cloud storage, and hosting. The result shows the new QR code mobile payment system developed represents a significant advancement in the field of digital payments, providing users with a fast, secure, and convenient way for instant transaction tracking. The system addresses the challenges associated with traditional payment methods such as long queues, delayed payments, and exorbitant charges. It incorporates user authentication and data encryption protocols to ensure security. The new QR code mobile payment system has the potential to revolutionize payment systems in markets where traditional payment methods have been the mainstay.
Keywords: *Mobile Payment, Security, QR Code, Google Firebase, Dart Programming and Hybrid Cloud Computing*

Introduction

As technology continues to advance, various new methods of payment have emerged in recent years, expanding beyond the traditional use of cash or credit/debit cards. One such method is mobile payment, or m-payment, which allows consumers to buy products and services using their smart-phones (Chawla & Joshi, 2019). One popular form of mobile payment is QR code payment, which utilizes a dot matrix or two-dimensional barcode that can be printed on paper or shown on a screen to provide payment information and can be recognized by special devices. QR stands for "Quick Response," indicating that the code contents should be decoded very 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 (Dong-Hee *et al*., 2012).

QR code payments are gaining popularity due to their low cost and convenience for both customers and businesses (Tu *et al*., 2022). For example, customers can use the camera on their mobile phone to scan a store's QR code at checkout or show a QR code on their phone's screen to a store employee, who can then scan the code using a scanner or their own mobile phone. QR code payments have seen significant growth in recent years, with a survey by the China Internet Network Information Center (CNNIC) in February 2021 finding that 8.74 million new mobile payment users were added between March and December 2020. Additionally, a survey by China UnionPay revealed that QR code payments made up 85% of all mobile payments in 2020. This trend towards QR code payments in physical stores is indicative of a shift towards a cashless future (Tu *et al*., 2022).

The COVID-19 pandemic has further accelerated the shift towards QR code mobile payments. The pandemic has pushed the adoption of mobile payments to the point that P2P systems now substantially threaten the usage of cards and cash for routine purchases. By the end of 2023,

P2P transactions in the USA are predicted to reach $1 trillion (Daniel *et al*., 2022). The adoption of mobile payments has also changed people's perceptions of mobile usage. It is no longer restricted to just communication, entertainment, and internet browsing. Direct contact and cash are no longer required to conduct transactions and exchange value. Mobile payments have made transactions simple, easy, and quick. Furthermore, they enable people to transact at any time and from any location. The recent redesign policy for the Nigerian Naira currency notes by the Central Bank of Nigeria has caused significant inconvenience and distress to both customers and merchants, as some of the old naira notes was illegal and unacceptable. This led to financial losses for small businesses and reduced customer satisfaction in Nigeria due to difficulties in completing transactions. These issues hinder the efficiency and effectiveness of financial transactions within small business settings, and imposed so many security challenges to the people.

As the Nigeria economy is tending to era of cashless, the introduction of mobile payments, specifically QR code mobile payments, is a clear indication of a shift towards a cashless future. The convenience and security provided by these methods make them an attractive option for both consumers and merchants. These hinder the efficiency and effectiveness of financial transactions within small business settings together with its security threats. This research performed studies on the existing mobile payment system and developed an enhanced secured system for the mobile payment using QR Code and Hybrid cloud computing mechanism to address the aforementioned challenges as a result of Nigeria currency redesign policy. The system integrates easily with existing merchant platforms with minimal disruption to their operations. Its success depends on the willingness of users to adopt the technology, which can be achieved through appropriate marketing and sensitization campaigns. It opens up for further research and serves as a valuable reference for other researchers, developers, and businesses looking to create similar systems.

Review of Related Works

Some papers related to the work were studied and discussed below:

Tu *et al*., (2022) discovered that QR code technology has experienced a sharp increase in popularity because it is simple and quick for notifying customers about their goods or services. It is widely employed in marketing. The authors also mentioned QR codes offer a number of benefits, including affordability and speedy, accurate reading. As a result, more businesses, including those in retail, finance, and healthcare, are using QR codes. Hence, there is need for researchers to work on the system for improvement.

Berrin, (2022) conducted a survey in Turkey involving 207 adults who had used the QR code m-payment method and predicted behavioral intentions of users in future by bringing together the concepts of Information System Success Model (ISSM) and marketing, examining the QR code m-payment customer experience in the pandemic period with an integrative approach. Partial least squares structural equation modeling (PLS-SEM) was used to investigate the relations between the variables. Research results showed that information quality, system quality, perceived transaction speed, and optimism significantly affected customer experience.

Hewawasam *et al*., (2023) presented a conceptual model to discover the major elements affecting user purpose, perceived fulfillment, and approval to utilize QR code payments as a means for payments when purchasing and using services in retail. 484 results from an online survey conducted in Sri Lanka were used in the study model. The model was developed using the UTAUT2 (Unified Theory of Acceptance and Use of Technology 2) model. The study found that ease of use, perceived usefulness, and attitude all had a substantial impact on users' intentions to use QR Code payment methods, which in turn affected users' perceptions of their delight with the technology and recommendations to utilize the technology.

Iviane *et al*., (2019) emphasized that lack of standardization of QR code technology across different countries and regions is a major issue that needs to be addressed to ensure interoperability and ease of use for consumers and merchants. Addressing this challenge requires standardization efforts, and secure QR code technology development, including encryption and authentication features.

Dewan & Rubina (2023) presented valuable insights for marketing managers and policy makers in accepting digital natives' perceptions towards taking up QR codes with regard to making payments and press forward the hypothetical strength by contributing to the literature connected to the embracing QR codes while making payments.

Ali, *et al*. (2019) considered the behavioral attitude of consumers over fear of acceptance or rejection of QR code as a payment method and recommended a conceptual model that examines consumer's behavioral intention for implementing QR code for Mobile Payment System (QR code MPS) which is aided by Unified Theory on Acceptance and Use of Technology (UTAUT2) model.

Geetha, *et al*. (2022) designed and implemented payment system based on QR code. The security of the proposed QR-based system is provided using visual cryptography. The proposed system consists of an application and a payment gateway server that implements visual cryptography.

Romi, *et al*. (2021) analyzed the problems in using QR Codes such as security, infrastructure, education, and transparency problems faced by users in Indonesia and used a Mobile Technology Acceptance Model (M-TAM) based research model with quantitative methods in their analysis. Their result indicates that the perception of transaction convenience, perception of transaction speed, mobile usability, ease of use of mobile, personal innovativeness, perceived security, and behavioral intentions affect actual usage of QR Code on digital wallet applications in Indonesia.

In summary, the future of QR code payment systems relies on the standardization of QR code technology and the development of secured payment systems. Most of the reviewed related works adopted security measures but not cloud-based, adopted in this research, which is much more reliable and authentic. Some consumers may lack trust and have security concerns regarding the transmission of sensitive financial information. This is considered by the researchers by adopting a secured mechanism for safeguarding the user's data.

Materials and Methods

System Methodology

The methodology adopted for this research is the Object-Oriented Analysis and Design Methodology (OOADM). OOADM is used because it is a popular and widely used software engineering approach that has become a standard in the industry. It is based on the principles of object-oriented programming. The methodology is based on the idea of encapsulating data and behavior into objects and using these objects to model real-world systems. This is aimed at viewing, modeling and implementing the proposed system as a collection of interacting classes and objects.

One of the key advantages of OOADM is that it promotes the use of reusable code and modular design, which can improve the efficiency and maintainability of software systems. It also provides a standardized way of designing and implementing systems, which can reduce the risk of errors and improve the overall quality of the software.

Dart Programming and Flutter Framework

Dart programming language together with the Flutter framework is adopted in the development of this system. Dart is a powerful, object-oriented programming language that is optimized for client-side development. It offers features such as static typing, asynchronous programming, and a modern syntax that makes it easy to write clean, concise code. Dart is a fast and efficient language that allows for rapid development and testing of code. This means that developers can build and deploy features quickly, reducing the time-to-market for the product.

Flutter, on the other hand, is a mobile app SDK that is built on top of Dart. It provides a rich set of pre-built widgets and tools that enable developers to create beautiful, high-performance mobile apps for both iOS and Android. Flutter's pre-built widgets and tools make it easy to create visually appealing and responsive user interfaces. This is particularly important for the system, as the user interface needs to be intuitive and easy to use.

Dart and Flutter are both open-source technologies with a vibrant community of developers. This means that there are many resources available online, including documentation, code samples, and tutorials, that can help developers to learn and improve their skills.

Class Diagram of the Proposed System

The class diagram (figure 1) represents the static view of an application. The class diagram describes the attributes and operations of a class as well as the constraints imposed on a system. The class diagram shape consists of a rectangle with rows. The top row contains the name of the class, the middle row contains the attribute of the class, and the bottom section expresses the methods or operations that the class may use. All classes have different access levels depending on the access modifier (visibility). The access level use in our classes for the fields are private (-) while the methods are public (+) other access level that can be use in a class are protected (#), package (~), derived (/), and static (underlined).

Firebase Firestore, Cloud-based NoSQL

The database development tool employed for the design of this system is Firebase Firestore.

Firebase Firestore is a cloud-based NoSQL document database that is designed to store and manage large amounts of data for web and mobile applications. It enables the organization of data into tables, rows, columns, and indexes, facilitating efficient storage and quick retrieval of relevant information. Firestore provides real-time data synchronization and offline data access, making it an ideal tool for building highly responsive and scalable applications. It is a document-oriented database, meaning that data is stored as JSON-like documents that can be easily retrieved and manipulated using a simple API.

The key benefits of using Firestore as a database development tool are its scalability and security. Firestore is built on a distributed architecture that allows it to scale horizontally, automatically handling increases in traffic and data volume. It also offers robust security features, including access control rules that allow developers to define who can read and write data to the database. Additionally, Firestore provides real-time data synchronization, enabling changes to be instantly propagated across all connected clients.

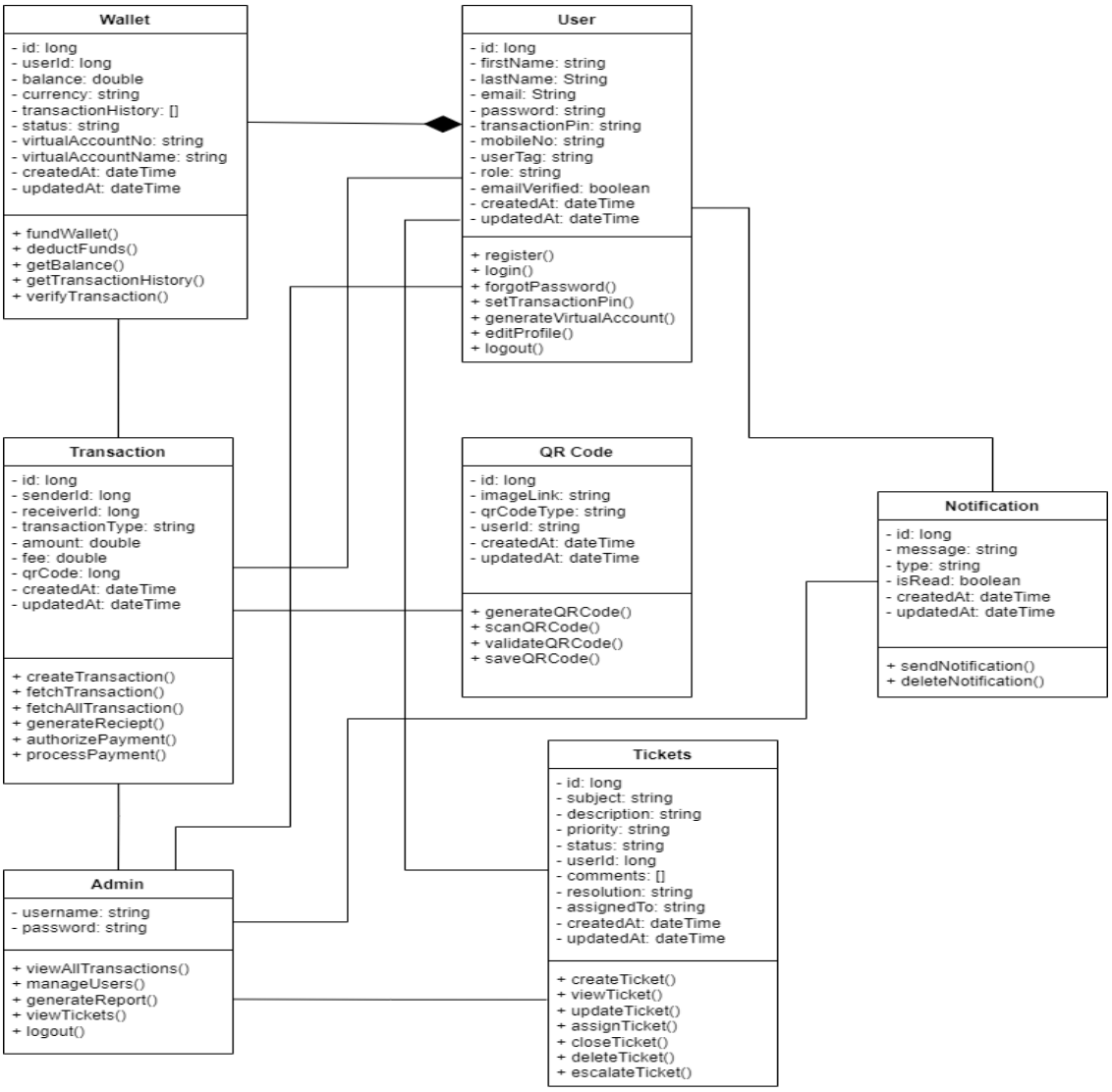

Figure 1: Class Diagram of the Proposed System

Results and Discussion

This section involves the practical method of putting into work all the theoretical design of the proposed secured and robust QR Code Mobile Payment system.

An enhanced secured and robust mobile payment system using QR code and hybrid cloud computing mechanism is designed with Object-Oriented methodology and implemented with with the Dart Programming Language. Google Firebase was also used in the implementation of the database which provided several benefits of secured cloud computing services such as real-time database updates, authentication and authorization services, cloud storage, and hosting. The New QR Code Mobile Payment System has one main menu and three sub menus.

High Level Model of the New QR Code Mobile Payment System

A high level model allows you to test and evolve your design incrementally against a model specification. The figure 2 depicts a specific High Level Model (HLM) that is envisioned and believed to be capable of resolving the weaknesses identified in the current system.

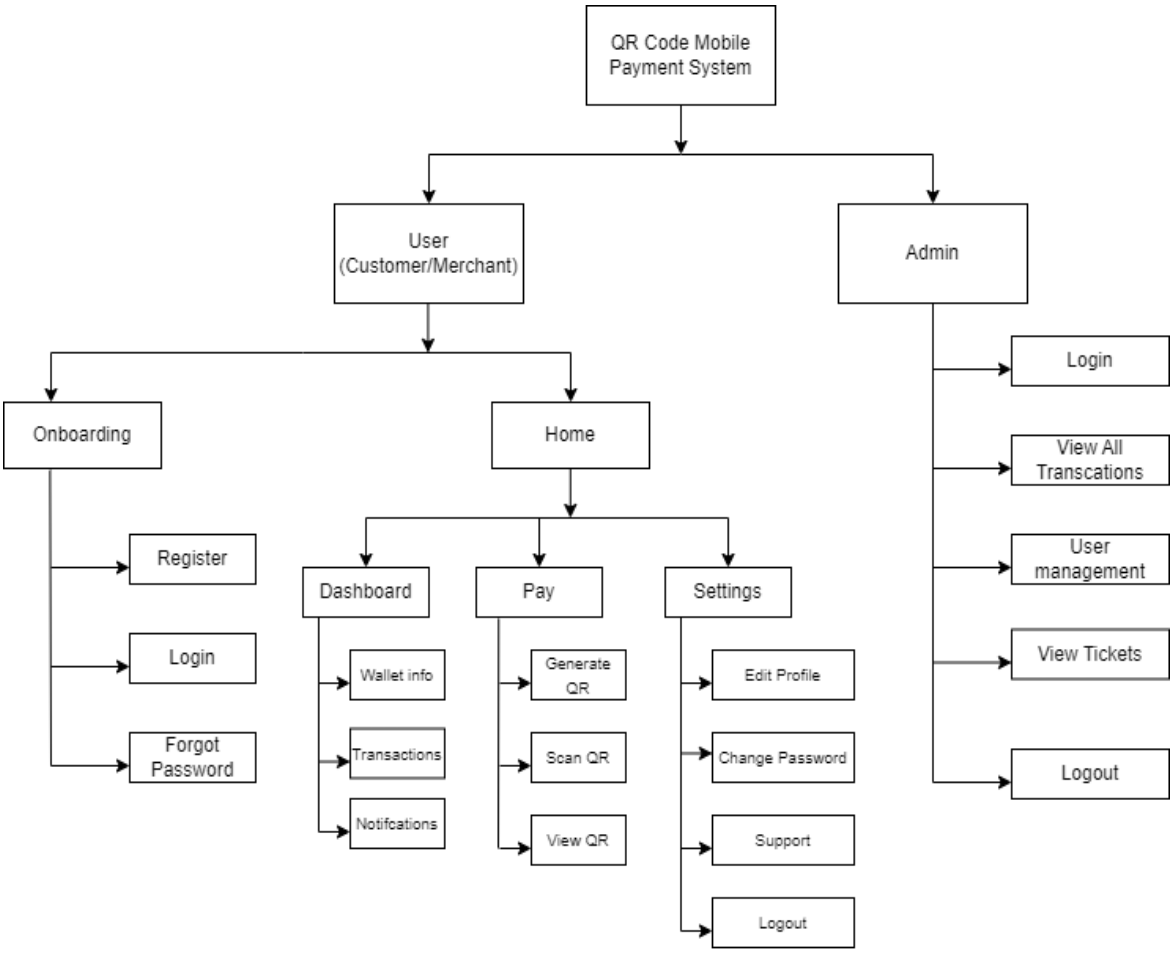

Figure 2: High Level Model of the New QR Code Mobile Payment System

Data Flow Diagrams (DFD) of the New QR Code Mobile Payment System

Data Flow Diagrams (figure 3 and figure 4) graphically represent the functions, or processes, which capture, manipulate, store, and distribute data between the new system and its environment and between components of the system.

Data Flow Diagram Level 0 (Context Diagram)

A level zero diagram (figure 3) is a simplified view of a system that shows its interactions with external entities. It consists of a single box that represents the entire system and other boxes or circles that represent external entities. Figure 3 provides an overview of the system's relationships with external entities without going into detail about internal processes.

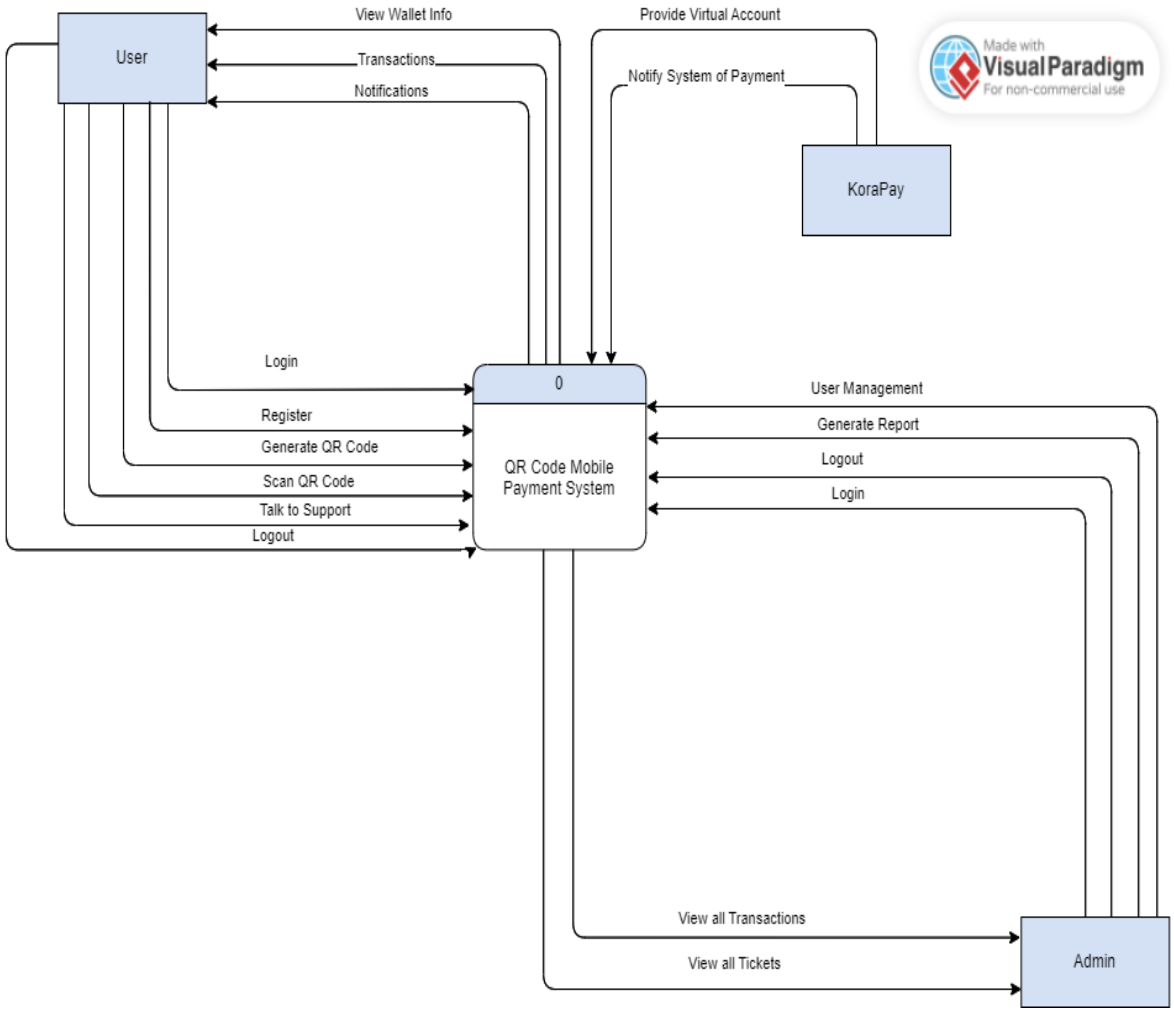

Figure 3: Context Diagram of the New System

Data Flow Diagram Level 1

The level 1 DFD of the new system (figure 4) provides a broad overview of the system and went into greater depth than the context diagram. The single process node from the context diagram of QR Code Mobile Payment System (figure 3) is broken down into sub processes in this data flow diagram, each process handling a unique task. In addition to that, this may also serve as reference on how the inputs or data is fed on the system and also outputs information of the system.

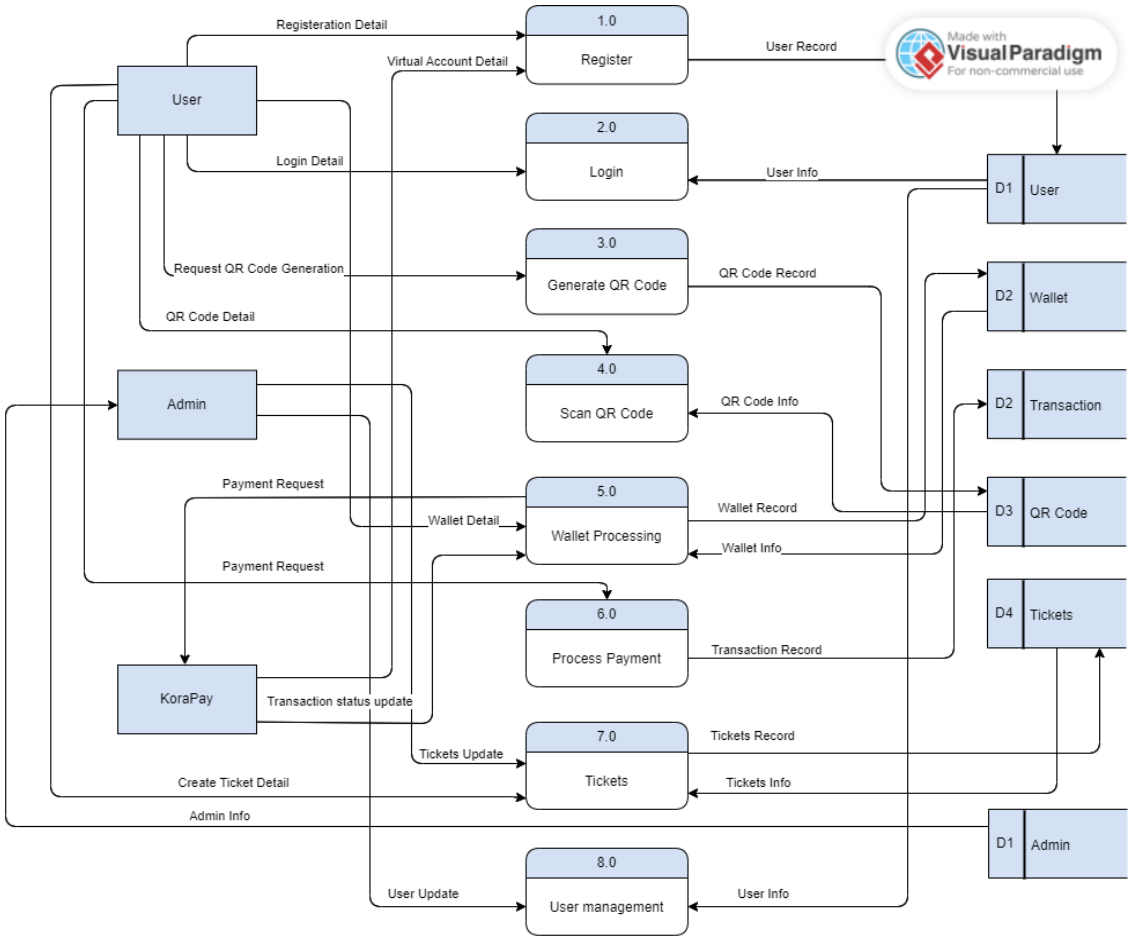

Figure 4: Level 1 Data Flow Diagram of the New System

Control Center/ Main Menu

The main menu (figure 5) is a critical part of the system; it serves as the gateway to all other functionalities within the application. In the developed system, the main menu provides a clear and intuitive user experience. There are four sub menus within the system.

i. Onboarding: It welcomes the users into the system (Mobile App). Allows them to either register or login.
ii. Dashboard: It shows the current user information such as wallet balance, transaction history and notifications
iii. Pay: This allows the user to either generate, scan or view QR codes
iv. Settings**:** This allows the user to make modifications to their profile, change their password, raise tickets and logout

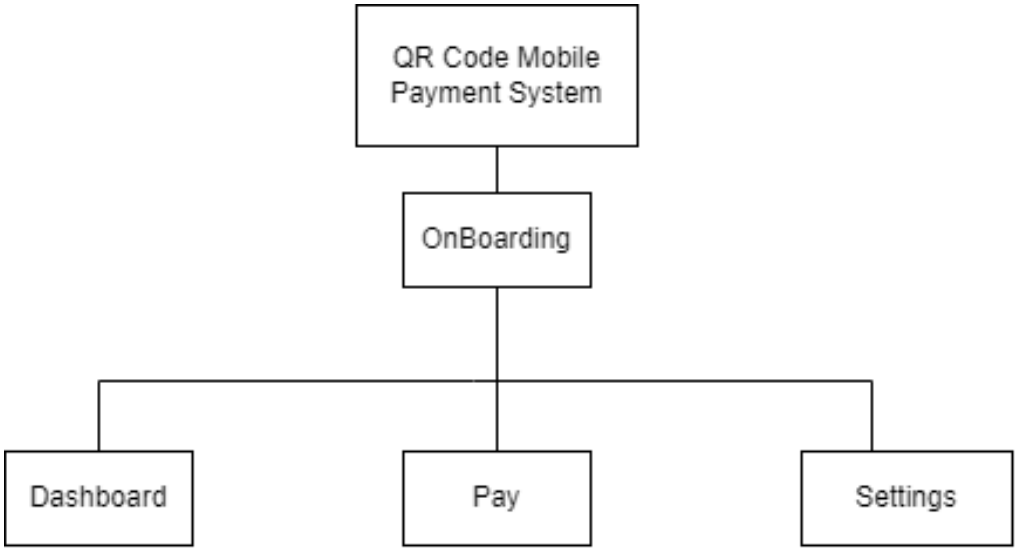

Figure 5: Main menu of the New System

On Boarding Menu

The On Boarding menu (figure 6) is the first set of screens the user is introduced to when they launch the app. The components of this menu are:

i. Register screen: This shows the user a registration form so they can create their profile.
ii. Login screen: It allows the user to login to the app.
iii. Forgot Password screen: It allows the user to recover their forgotten password.
iv. Validate BVN screen: It allows the user to validate their BVN.
v. Take a Selfie screen: It allows the user to take a picture of themselves.

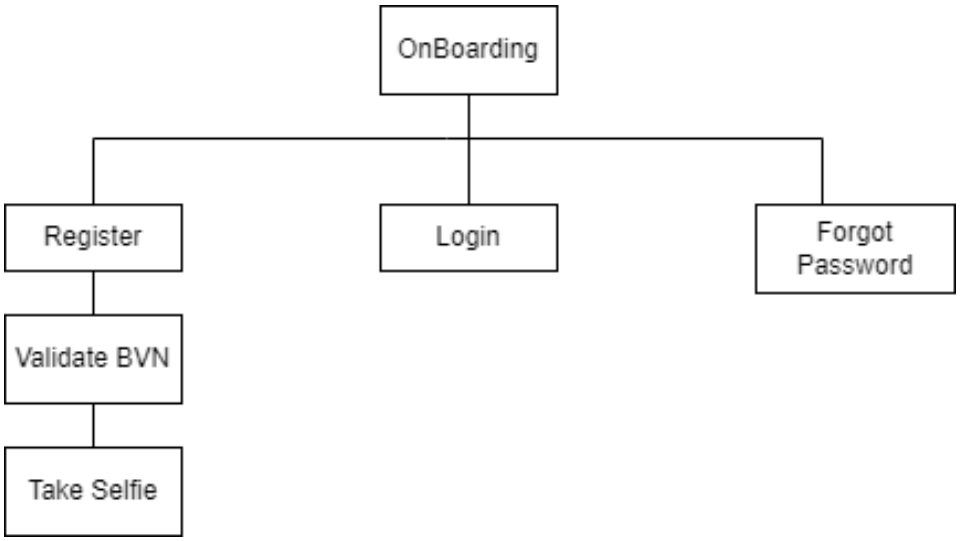

Figure 6: The OnBoarding Menu

The Dashboard Menu

This dashboard menu (figure 7) shows the latest information about the user, information such as the current wallet balance, the transaction history and the notifications. The components of this menu are:

i. Home Screen: This shows the user wallet balance, last ten transactions.
ii. Transaction Screen: This shows the full list of transactions done by the user.
iii. Notification Screen: This shows a list of all the notifications received by the user.

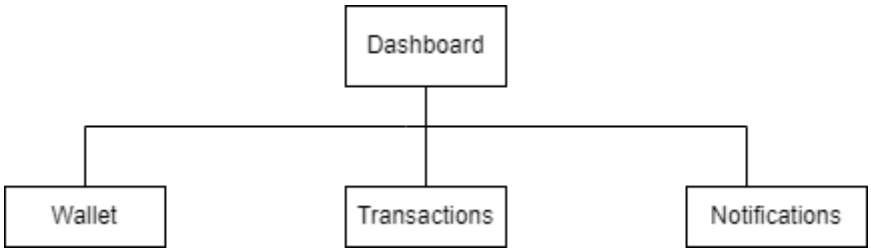

Figure 7: The Dashboard Menu

The Pay Menu

This pay menu (figure 8) allows the user to carry out the core functionality of the application which is generating and scanning QR code plus also viewing all previously scanned codes.
The components of this menu are:

i. Generate QR code Screen: The user is prompted to create a QR code while also entering the required information.
ii. Scan QR code Screen: It allows the user to scan any available QR code in other to fetch necessary payment information.
iii. View All QR code Screen: It shows a list of all generated QR codes.

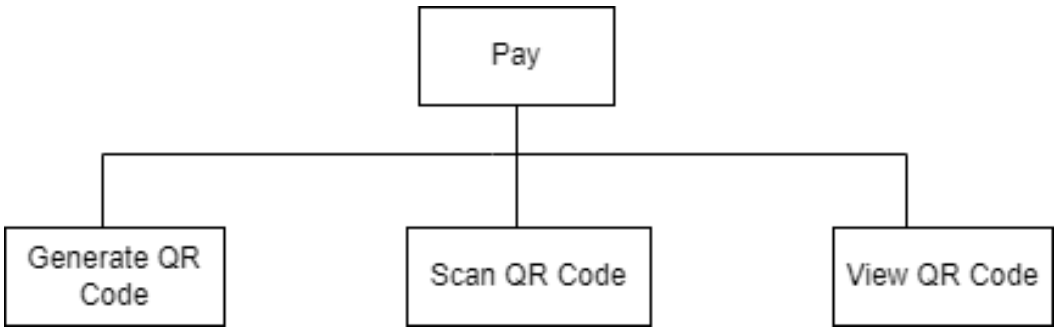

Figure 8: The Pay Menu

The Settings Menu

The settings menu (figure 9) is a section of a mobile app that allows users to customize and control their app experience. The settings menu is an important aspect of user experience as it allows users to personalize the app to their individual needs and preferences. The components of this menu are:

i. Edit Profile Screen: Allows the user to update their profile information on the app.
ii. Change Password Screen: Allows the user to change their password.
iii. Support Screen: Allows the user to create and view tickets.
iv. Logout Screen: Allows the user to logout.

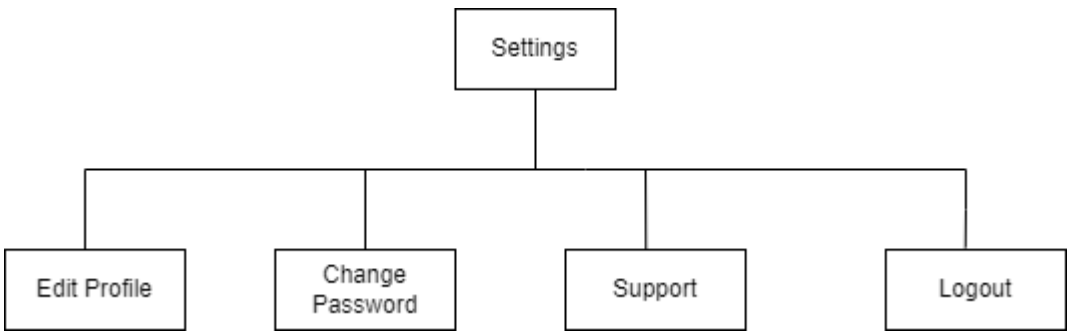

Figure 9: The Settings Menu

The Admin Menu

The admin menu (figure 10) is a section of a system or application that allows authorized users to perform administrative tasks and manage system settings. The admin menu is an important aspect of system or application management as it allows administrators to monitor and control system functions and ensure proper operation.

The main components of this menu are:

i. View All Transaction page: This page allows the admin to view all transactions on the system.
ii. Manage Users Page: This page allows the admin to manage users in the system.
iii. View All Tickets Page: This page allows the admin to view all tickets raised by users.
iv. Logout: This allows the admin to logout of the system

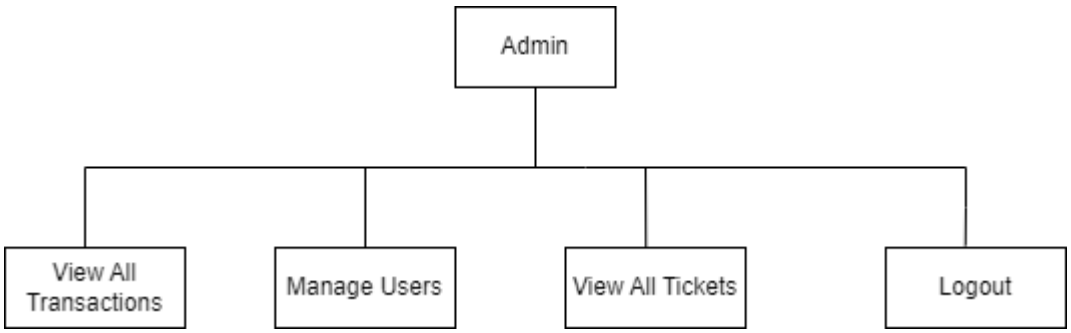

Figure 10: The Admin Menu

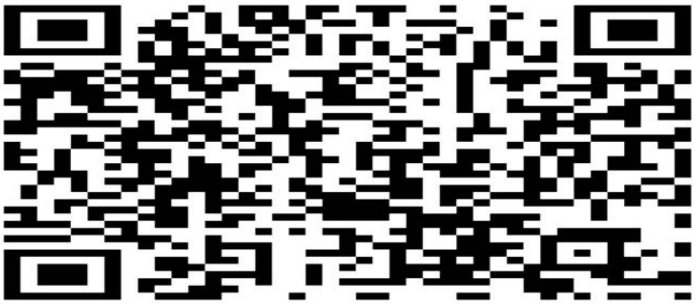

Figure 11: New System Generated QR Code

Figure 11 shows the QR code generated by the proposed system. It encodes information that can be read by the scanning application.

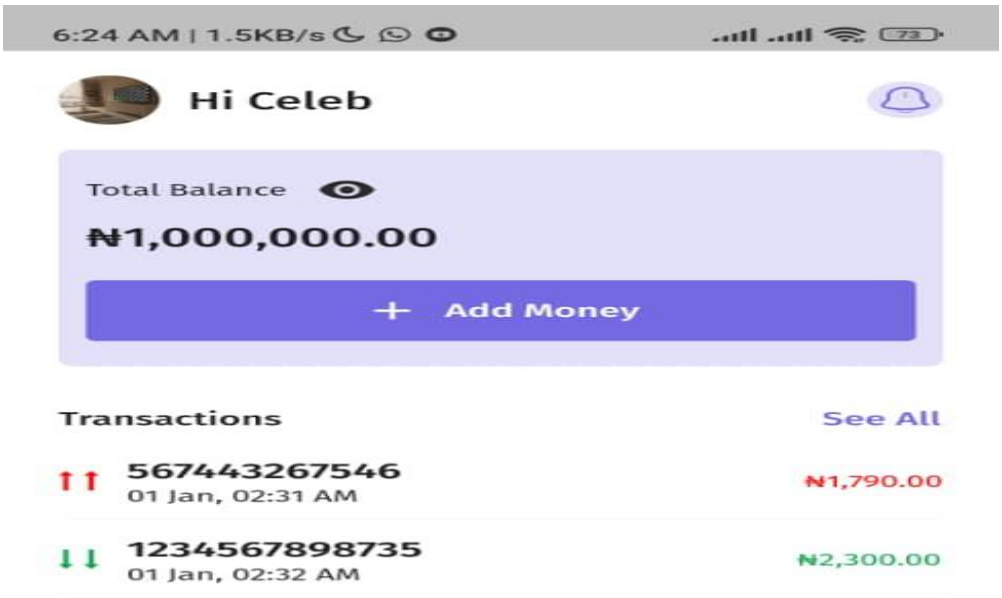

Figure12: New System User Dashboard

Figure 12 shows the user wallet balance, the full list of transactions done by the user showing the date and time of the transactions. If the user clicks on the "Add Money" button, it will navigate to the "Add Money" screen where they can fund their wallet. The user wallet is an application in the developed system that stores confidential financial information about the user. The system is developed with a strong security measure to ensure the safety and authenticity of the stored data.

In summary, the development of the new QR code mobile payment system represents a significant advancement in the field of digital payments, providing users with a fast, secure, and convenient way to make transactions. With the integration of Firebase as the backend infrastructure, the system allows real-time transaction tracking and enhanced security features, providing users with confidence in the reliability and safety of their transactions.

Conclusion

The processes for the analysis, design and implementation of an Enhanced Secured and Robust Mobile Payment System Using QR Code and Hybrid Cloud Computing Mechanism is carried out. The project began with a comprehensive analysis of the current system to identify the specific issues at hand and suggest potential solutions. To further improve the system's development, a thorough literature review was conducted to explore the work of other experts in the field.

The developed system will definitely offer numerous benefits to the users. The system access speed is fast, high security, and easy to use, making it an attractive alternative to traditional payment methods. The adoption of Firebase as the backend infrastructure allows real-time transaction tracking and enhanced security features, providing users with confidence in the reliability and safety of their transactions. The system's seamless integration with existing merchant platforms and parallel changeover procedures makes adoption and implementation of the system a smooth and easy process for merchants and customers alike. With these advantages, the implementation of a QR code mobile payment system has the potential to revolutionize payment systems in markets where traditional payment methods have been the mainstay.

Recommendation

The QR code mobile payment system has a wide range of potential application areas, including:

i. Retail and e-commerce: QR code mobile payments can be used to facilitate transactions in physical retail stores or online, providing customers with a convenient and secure payment option.

ii. Transportation and ticketing: QR code mobile payments can be used for transportation fares and ticketing, allowing commuters to quickly and easily pay for bus, train, or subway rides without the need for physical tickets or cards.

iii. Hospitality and food service: QR code mobile payments can be used in restaurants, cafes, and bars to pay for food and drinks, reducing wait times and improving the overall dining experience.

iv. Event ticketing: QR code mobile payments can be used for ticketing at events such as concerts, sports games, and conferences, allowing attendees to easily purchase and access their tickets.

v. P2P payments: QR code mobile payments can be used for person-to-person payments, allowing users to easily transfer money to friends and family members.

Suggestion for Further Research

While QR code mobile payment systems have diverse and valuable application areas, there is always room for improvement. One potential area for improvement is the addition functionalities for order management and shopping carts, particularly to enhance retail and e-commerce transactions.

It is important to note that this project is just one step in a larger journey toward improving QR code mobile payment systems. Due to time constraints, not all possible modules could be implemented, and this research should be viewed as a starting point for further research and development. By continuing to explore new ways to improve QR code mobile payment systems, we can unlock even more potential for this innovative technology to transform how we make payments and conduct transactions.

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