MAKERERE UNIVERSITY
COLLEGE OF COMPUTING AND INFORMATION TECHNOLOGY

Ubiquitous Computing for Mobile Based Payments in Localised Intelligent Transportation Systems

By
CS23-4

DEPARTMENT OF COMPUTER SCIENCE

A Draft Project Report submitted to the School of Computing and Informatics Technology For the Study Leading to a Project Proposal in Partial Fulfillment of the Requirements for the Award of the Degree of Bachelor of Science in Computer Science Of Makerere University

Supervisor

Mr. Ggaliwango Marvin: .....

Date: .....

School of Computing and Informatics Technology, Makerere University
ggaliwango.marvin@mak.ac.ug, +256-754-655-524
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NAME	STUDENT NO.	REG. NO	SIGNATURE
MUTABAZI NOBLE	2000705746	20/U/5746/PS	
SSEMPALA BENJAMIN	2000701199	20/U/1199	
NTSINGA ELIJAH MUKUMBI	2000700052	20/U/0052	
WANDERA EMMANUEL	2000705793	20/U/5793/PS	

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Abstract

The current system of ticketing and payment for parking at Makerere University in Kampala, Uganda, faces several challenges, such as frequent malfunction of the ticketing machines, fraud by the system employees, difficulty in locating a payment point for motorists, and hefty fines of 50000 Ugandan shillings for lost tickets. These challenges result in inconvenience, inefficiency, as well as revenue loss for both the system's managers as well as motorists using it. To overcome these challenges, we propose a low-cost system that consists of a mobile app that enables cashless digital prepayment of the parking fees using local popular payment platforms such as MTN mobile money. The app interacts with an embedded microcontroller at the gate that scans the QR codes and grants access. We describe the design and implementation of the app and the microcontrollerr. We also examine the benefits and shortcomings of our system. We argue that our system offers a more convenient, efficient, and transparent way of managing toll payments in the university context.

Keywords: Intelligent Transportation Systems, Ubiquitous Computing, Mobile Based Payments, Smart Cities

Chapter 1

Introduction

1.1 Background and motivation

Access to parking places is a common challenge in many ueban areas such as universities, shopping malls, hospitals, where there is a high demand for parking spaces and a limited supply. Makerere University in collaboratio with KSA in 2014 put in a place an utomated palrking system that wllows motorists to purchase tickets and make payemtns at any of the payment points wihtin the university premise for purposes of ensuring the smooth flow of traffic, reducing congestion, and generating revenue for the university. However, the current system of ticketing and payment for parking at Makerere University in Kampala, Uganda, suffers from several problems, such as frequent malfunction of the ticketing machines, fraud by the system employees, difficulty in locating a payment point for motorists, and hefty fines for lost tickets. These problems result in inconvenience, inefficiency, and revenue loss for both the system's managers and motorists.

To address these problems, we propose a novel system that consists of a mobile app that enables cashless digital prepayment of the parking fees using local popular payment platforms such as MTN mobile money, Airtel Money, etc. The proposed app interacts with an embedded microcontroller at the gate that scans the QR codes and grants access. Our system aims to provide a more convenient, efficient, and transparent way of managing toll payments in the university context.

Our work is also motivated by a growing trend of using mobile apps for parking payment in some cities around the world. Mobile apps offer several

advantages over traditional methods of parking payment, such as convenience, flexibility, security, and cost-effectiveness, amongst others. A report by Grand View Research indicates that the global mobile parking app market size was valued at USD 6.4 billion in 2020 and is expected to grow at a compound annual growth rate (CAGR) of 22.1% from 2021 to 2028. Some examples of mobile parking apps include ParkMobile developed and used in the United States and Flowbird developed in France . Most of these apps are designed for developed countries with advanced infrastructure and technology. There is a need for developing context-specific solutions that cater to the needs and challenges of developing countries like Uganda.

1.2 Problem Statement

Access to parking is a common challenge in many urban areas, especially in universities where there is a high demand for parking spaces and a limited supply. Managing parking efficiently and effectively is crucial for ensuring the smooth flow of traffic, reducing congestion and pollution, and generating revenue for the university. However, the current system of ticketing and payment for parking at Makerere University in Kampala, Uganda, suffers from several problems, such as frequent malfunction of the ticketing machines, fraud by the system employees, difficulty in locating a payment point for motorists, and hefty fines for lost tickets.

These problems result in inconvenience, inefficiency, and revenue loss for both the system's managers and motorists. There is a need for developing a novel system that can provide a more convenient, efficient, and transparent way of managing these payments in the university context.

1.3 Objectives

1.3.1 Main Objective

To design and implement a novel system that consists of a mobile app and an embedded microcontroller for cashless parking payment at Makerere University using QR code technology and local popular payment platforms such as MTN Mobile Money. The system aims to provide a more convenient, efficient, and transparent way of managing toll payments in the university context, and to overcome the problems and limitations of the current system of ticketing and payme

1.3.2 Specific Objectives

The project's specific objectives include:

- To understand the existing payment approach used at Makerere University toll gates.
- To collect requirements for the digital parking payment system for motorists trying to access Makerere University.
- To design a system prototype for the proposed solution.
- To implement the proposed mobile application and confirm whether it solves the highlighted problems within the current payment system.

Figure 1.1: Makerere University main gate where the projected will be implemented

1.4 Scope of the project

The challenges mentioned in the problem statement above affect various parking payment points in the country and even beyond Uganda's borders. However, for this project we will be focusing on Makerere University's main gates. .

Implementation of the project was done at Makerere University.

1.5 Significance of the project

Our main project significance is digitising the payment of parking tickets of motorists trying to access Makerere University. The project also addresses a number of issues prevailing in the current system such as difficulty in accessing payment points. Fraud by the gate attendants and the issue of hefty fines for ticket loss.

Chapter 2

Literature Review

2.1 Introduction

In this chapter we consider similar projects that have been done and how they relate to the project development and execution in relation to our project. We also look at their short coming so that we can improve those areas in our project

2.1.1 Makerere University Automated Payment System

This is the existing system in place in our area of study. The project was commenced in 2014 by Makerere University in collaboration with Kenya Airport Parking Services . From our interviews with the owners of the system, we learned that he system costs approximately 1.5 billion shillings to set up, and consists of a ticketing machine that issues tickets to motorists that they are then required to present at one of the various payment points within the university. Some of the chellenges in this system include:

- Frequent malfunction of the ticketing machines
- Fraud by the system employees
- Difficulty in locating a payment point for motorists
- Hefty fines for lost tickets as motorists who misplace their tickets are required to pay a fine of 50,000 Uganda Shillings
- Inconvenience, inefficiency, and revenue loss for both the system's managers and motorists.

Figure 2.1: Gen. Katumba Wamala showing an UPESI payment card on the launch of the Entebbe Express Highway

2.1.2 Uganda National Roads Authority Express Highway

The Uganda National Roads Authority in 2022 launched the Kampala Entebbe Express Highway, a Ugandan government project worth approximately 450 million dollars developed to help ease transport flow in Kampala city. Access to the highway is via the toll gates where motorists can make both cash and digital cashless payments. For cashless payments, motorists use an UPESI card.[1]. A motorist purchases an UPESI card that they then load a given amount of money and upon arrival at the toll gate, they swipe the card. The fee is then deducted from the card and the motorist is then granted access.

The main gap with the approach is motorists often resort to only using the cash payments that result in delays and other issues because they find it easier than purchasing an UPESI card. Additionally the process of loading money onto the card is unnecessarily long. Fine for losing card.

2.1.3 ParkMobile

Parkmobile is a leading mobile application launched in 2009 in the United States of America that allows motorists to find and pay for parking on their phone, and is currently used in approximately used in three thousand lcoations in North America. It also has over 43 million users and processed over 113 million parking transactions in 2022. Parkmobile offers various features and benefits for its users, such as making prepayments and reserving parking points at any given location. It also offers a rewards program

that allows users to earn points for every parking transaction and redeem them for discounts or free parking. Parkmobile also supports Google and Apple Pay for a faster and more secure payment process. [**?**] The projeect has had good traction since it was launched and in 2022 it generated $9.1 million in revenue, with an average revenue per employee of 52{,}906$. Parkmobile was acquired by EasyPark Group, a Swedish company that provides smart parking and mobility solutions, in June 2021.

Unfortunately to the best of our knowledge, ParkMobile or any other application of this nature are not available in Uganda thus the need for a local contextualised solution

2.1.4 Use of GPS Software and Cell Towers

Research on how this can be leveraged in easing toll fee payment has been done by others. In 2020, Danang Dismantoro, Istas Pratomo and Surya Sumpeno also proposed a mobile application that allowed payment of these fees via GPS software[2, 3]. The system was tested through simulations in Vissim software [4], which they believe was able to simulate the real world condition at tollgates. Cell phone towers and GPS technology are used to identify the motorist' s location and if the motorist happens to be within the toll's gate vicinity, the money is automatically deducted from their personal account.

Research Gaps

- No physical implementation of this system was realised
- The researchers acknowledge the need for a deeper feasibility study and the fact as it has some shortcomings.
- Some scenarios are unaccounted for such as if one is near a cell tower but does not necessarily intend to access the tollgate,they'll have their money deducted even without actually using the gate.

2.1.5 Use of RFID sensors

An RFID system has two main components:

- A transponder: This is the tag that holds information, found on the object to be identified

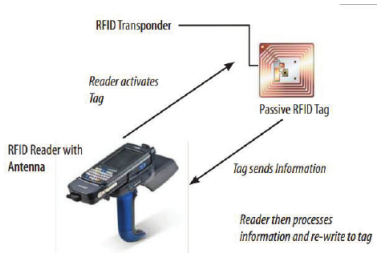


Figure 2.2: Components of an RFID system

- A reader/interrogator: This device is able to capture data from the tag.It has a radio frequency module, control unit and coupling element for linking to the transponder. Additionally, an interface is added to pass on data captured from the transponder to a different system

Sabbir Ahmed et al in 2019 also proposed a similar solution.Their proposed system would simplify toll payment through use of RFID tags placed on digitised license plates of all vehicles.Once the tag is scanned, and the motorist has a sufficient balance on their account, the vehicle is granted access[5].

Another study by Etqad Khan et al. in 2018 proposed a system similar to ours that would ease payment of toll fees using RFID tag that would be linked to motorists' personal accounts where would have a mobile e-wallet on which a given amount would be saved.The system also provides a mobile application to view their past payments[6].

Research Gap

These two identified studies are constrained in our project scope's context, because:

- It would first off require digitisation of all vehicle license plate, an endeavour that has not yet been taken on by the government of Uganda.
- Long range RFID tags and scanners are costly to purchase which would be needed in this use case are costly ,and would thus the need for a low-cost solution that's accessible to majority of the motorists.

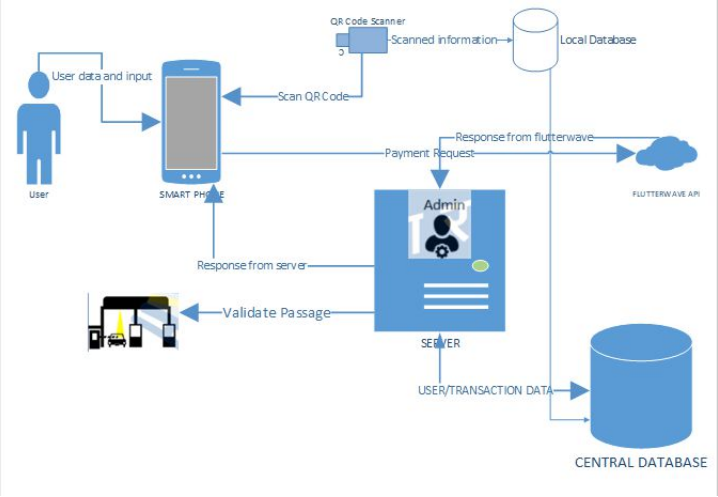


Figure 2.3: System Architecture Diagram for the proposed solution

2.2 Our Contribution

Alot of work has been done by other researchers to address the issue of tollgate queues. Many of these solutions leverage RFID technology as an alternative to the physical cash payments. This would however require purchasing costly scanners and tags, thus the need for a similar but cheaper solution. The biggest benefits to our proposed system:

- Developing a low-cost and context-specific solution for cashless parking payment using local popular payment platforms such as MTN mobile money
- Designing and implementing a mobile app and an embedded microcontroller that interact using QR codes to facilitate parking access and payment
- Evaluating the performance and usability of the system and comparing it with the current system of ticketing and payment
- Examining the benefits and challenges of the system, such as security, scalability, and user acceptance
- Providing insights and recommendations for improving parking management in the university context and in developing countries in general

Chapter 3

Methodology

3.1 Introduction

This chapter discusses the techniques that were used to achieve the objective of the proposal. It covers the approaches as well as techniques used for data collection, design, final implementation, and system testing.

3.2 Data Gathering and Elicitation

The team collected relevant and appropriate data to determine the requirements of the proposed system. This was done through questionnaires, interviews and physical observation[7].

3.2.1 Questionnaires

Questionnaires contain open or closed ended questions given to a selection respondents to solicit information on a selected research topic[8]. Google forms were be used to create online questionnaires that will be shared through social media and emails to targeted stakeholders. Advantages of online questionnaires are that they are relatively easy and quick to distribute. It is also quicker to receive responses and the data can be collected directly into the database for analysis.

3.2.2 Interviews

An interview is a one on one planned conversation with a person with an aim of attaining information. Researchers had interactions with owners of the system currently in place as well as a selection of the motorists in order to get firsthand information on issues faced. This helped us in better defining the system requirements of the project. The interviews also enable the researchers to establish relationship with potential respondents as well as owners of the current system and therefore gain their corporation, yielding highest response rates in the survey research.

3.2.3 Observation

Observation involve spending time with stakeholders and keenly monitoring their activities. This will provide unbiased information that will benefit the study. Researchers will take a physically closer look at what takes place during the daily activities of motorists trying to access the university and the challenges they face and will entail systematic noting and monitoring of events, behaviors of the motorists as they go on with their activities

3.3 Data Analysis

This will be done to remove inconsistencies in the data collected, as well as sieve out useful data that will be used to improve the system requirements.

3.4 System Design

For the system design, context diagrams will be created and used to define the scope of the project and its environment as well as the entities who will interact with it.Additionally, there will be detailed processes and data modelling[9].

3.4.1 Process Modelling

Here, data flow diagrams will be used to demonstrate the processes and entities that interact with the system.

3.4.2 Data Modelling

Entity relationship modelling will also be carried out to identify the entities as well as their relationship how they interact with each other This will be

achieved by use modelling entity relationships. The researchers will use this top down approach to identify the entities interacting with the system and relationship between the data that must be represented in the model.

3.5 System Implementation

At this stage the team will of the E-Tolls application.A number of tools and technologies will be used and these are defined below:

3.5.1 Software tools

- Android Studio.
- Arduino IDE: This will be used to write the code for the microcontroller.
- Flutter mobile framework: This will be used to write the cross-platform code for the application
- DigitalOcean: This will be used to host the remote server.

3.5.2 Hardware tools

- Microcontroller
- Camera to be used to scan QR codes
- Wi-FI GSM module to enable internet connection of the microcontroller

3.6 System Testing and Validation

Here, the system is tested with the intention of evaluating its functionality. [10]

Prototype builds for user testing and validation will be created. These will be shared using Firebase App Distribution[11]. This will be done to verify certain aspects of the application such as exception handling, security as the application involves connecting to users' mobile money accounts.

Chapter 4

System Analysis and Design

4.1 Overview of the System

This chapter consists of the general introduction, the study of the existing system, requirement specification and system design. The study of the existing system includes findings from existing systems, requirements specifications include functional, non-functional requirements, software and hardware requirements. System design includes modelling the solution from the findings.

4.2 System study

The data gathered using the selected data collection techniques enabled the system developers to get information which was studied to realise the weaknesses of the existing systems and how the new system would be designed in a better way.

4.3 Study of the existing system

Our case study as previously mentioned was the Makerere University Parking System used at Makerere University. We conducted two interviews with the project manager who informed us all the details of the current system and its shortcomings. Some details however such as average revenue garnered by the system,etc were not shared with us for confidentiality purposes.

4.4 System Analysis

4.4.1 Data Analysis

This is to be added soon, as we're still collecting responses from the survey.

4.4.2 Requirements Specification

In order to come up with the end user requirements for the new system, data was collected through interviews with both the project manager of the current system at Makerere University as well as a survey shared with motorists who use the gates.

The collected data was then analysed in order to come up with the requirements of the new system. This section included the requirements of the new system divided into user requirements and system requirements.

User Requirements

This encompasses the requirements of the system from the user's point of view.

The users identified are gate attendants who can also double as administrators of the system as well as motorists who use the gates. The motorists are split into two further categories: regular users and occasional users.

- **Gate attendants / Administrators**: Manages the ETolls System
- **Motorists**: Uses the ETolls System to make their payment

Function Requirements

This is to with the services that the system will provide to the users. The system will be able to:

- Allow new users(motorists) to register for the system
- Allow registered users to login to the system
- Allow users to make payments for parking
- Allow users to view their payment history
- Allow users to view their parking history
- Allow the system administrator to add or delete users

Non-Functional Requirements

These are requirements that are not directly related to the functionality of the system but are important for the system to work properly. These include:

- The system should allow for easy registration of users
- The system should support various payment platforms such as MTN Mobile Money, Airtel Money
- The system should be secure
- The system verifies all user inputs and users must be notified in case of error

4.4.3 System Design

This section defines the physical architectural design and the logical design (showing processes, sub processes and data flows to/from external entities) and database design of the system required to satisfy the specified requirements.

Architectural Design

The system will comprise a mobile application as well as remote server hosted on the cloud. The mobile application will be used by the motorists to make payments and view their payment history. The remote server will be used to store the data of the users and their payment history. The final component is the microcontroller which will be used to control the gates and communicate with the remote server.

Logical Design

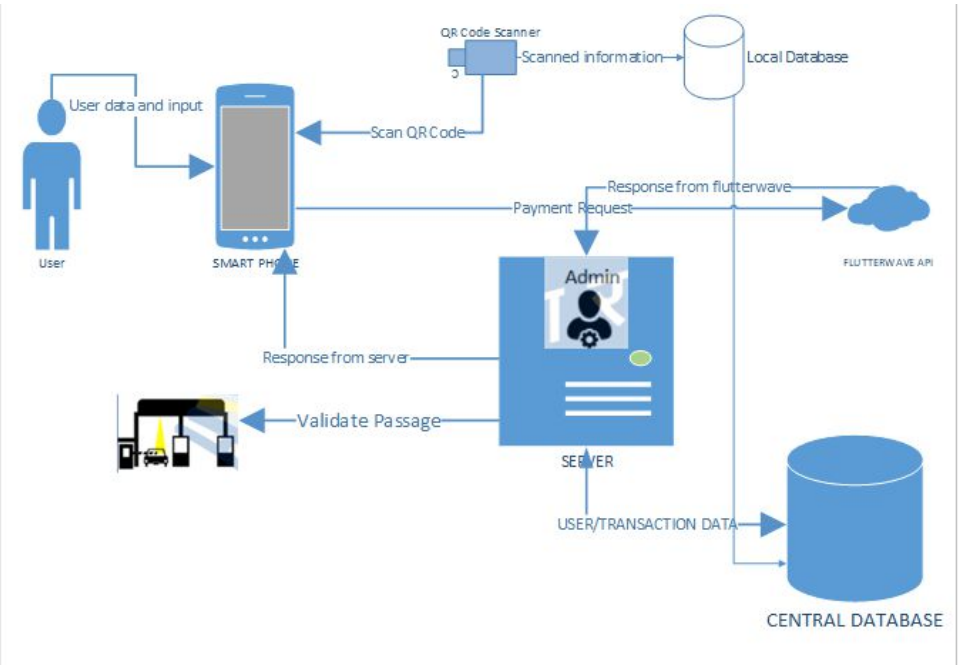


Figure 4.1: System Architecture diagram for E-Tolls System

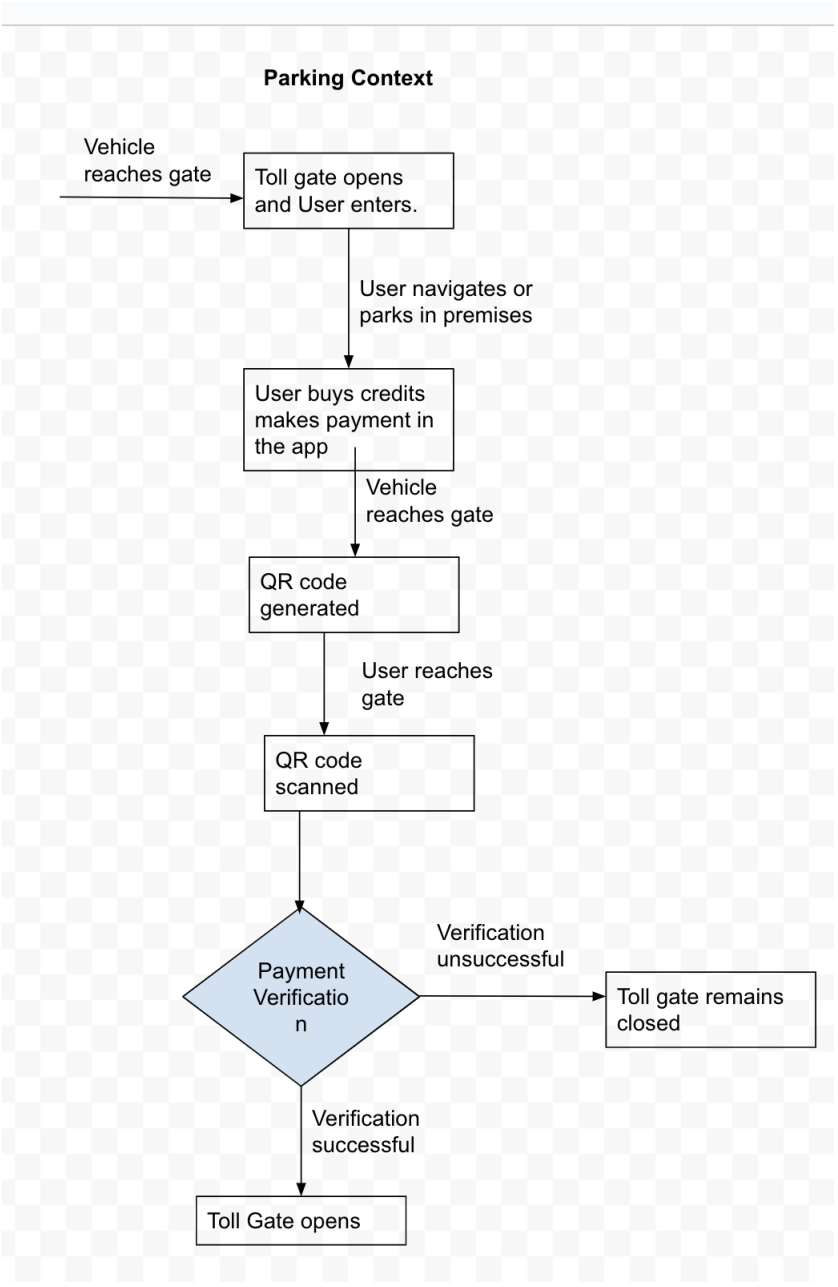


Figure 4.2: System Architecture diagram for E-Tolls System

Chapter 5

Presentation of Results

5.1 Introduction

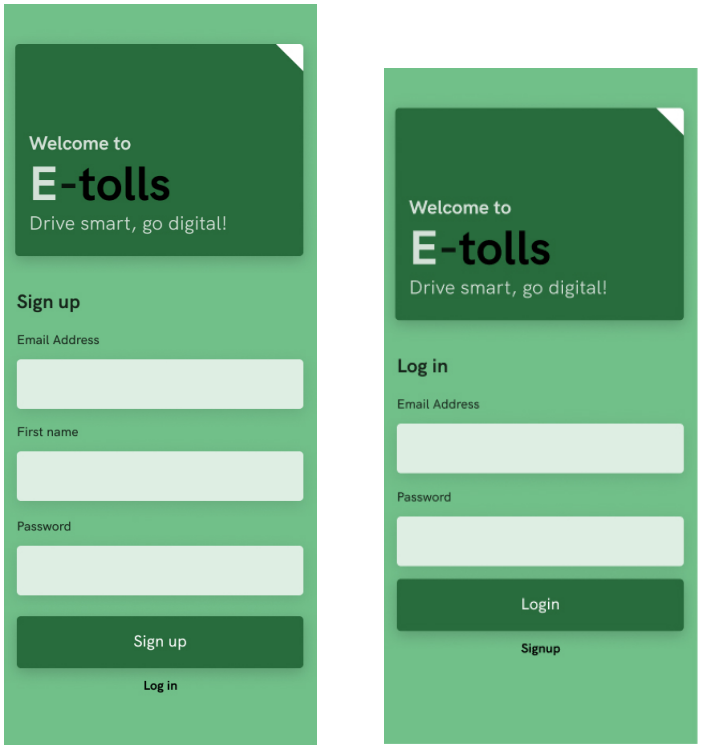
This chapter shows screenshots of the system interface and details the programming environment , data manipulation and programming languages used in the development of the system.

5.1.1 Implementing the system

Programming Tools

The system was implemented using the following programming tools:

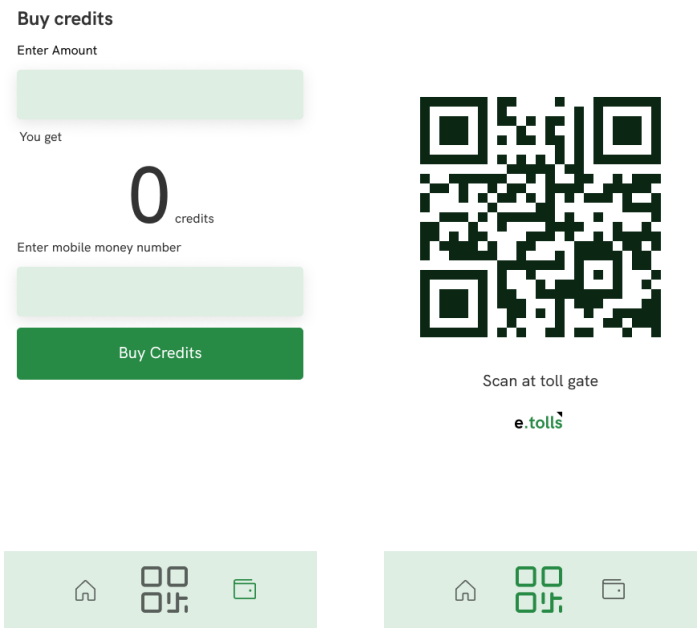
- **Android Studio**: This is the official IDE for Android development. It is used in the development of the mobile application.
- **Arduino IDE**: This is the official IDE for Arduino development. It is used in the development of the microcontroller code.
- **Digital Ocean**: This is a cloud hosting service. It is used to host the remote server.
- **Flutter**: This is a cross-platform UI toolkit developed by Google. It is used to develop the mobile application.
- **ESP32 Microcontroller**: This is a microcontroller developed by Espressif Systems. It is used to receive data from the mobile application and send it to the remote server.



(a) (b)

Figure 5.1: Login and Sign Up Screens of the mobile application

5.1.2 Sample Screenshots



(a) (b)

Figure 5.2: Payment Screens of the mobile application

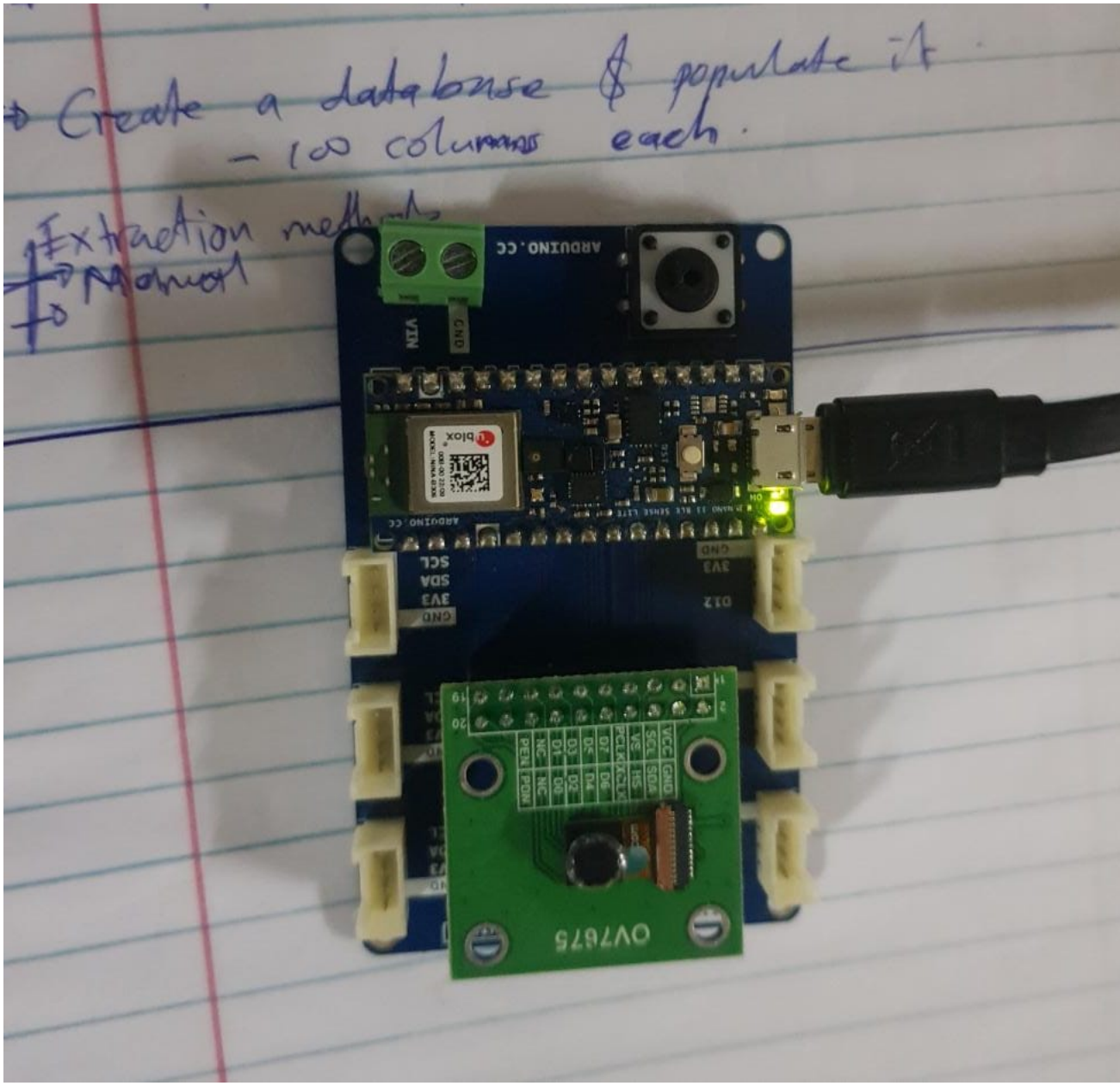


Figure 5.3: ESP32 Microcontroller

Chapter 6

Outcomes

The project achieve the following outcomes:

- Informative results on testing and evaluating the current payment system used at toll gates in comparison to the new proposed system
- A well developed and operational cross-platform mobile application to enable payment of toll fees as well as verification of the payments. This application is available for both iOS and Android mobile platforms
- A functional embedded QR Code scanner that's able to capture QR code values and verify payments that have been made.

6.1 Project Gaps and Future Works

Currently, implementation of the project is limited to the university scope and only accounts for users with smartphones with iOS and Android Operating Systems.

This project can easily be scaled to various places such as malls and hospitals, and extended to account for non-smartphone users.

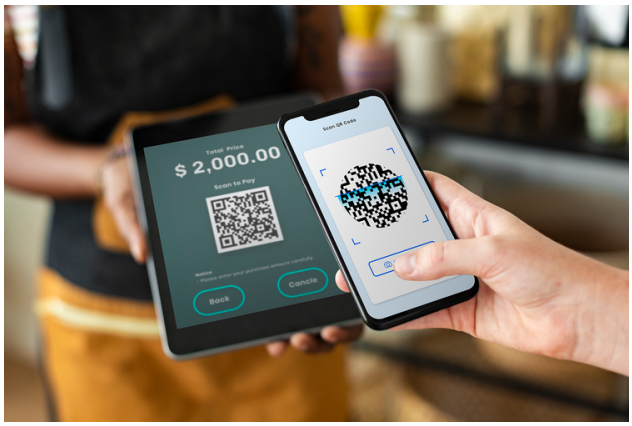


Figure 6.1: The system payment is currently limited to smartphones. In future, the project could be improved to support other phones

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Appendices

Interview Questions: Motorist

- What are some of the challenges you have faced using Makerere's toll gates?
- Describe the process of payment for toll fee at the ticket stations.
- How many times do you use the toll gate in a day?
- How much do you typically spend on toll gates?
- Do you often find queues at the toll gates?
- If you do, how often does this happen and at what times of the day?

Interview Questions: Toll Operator

- How many vehicles use this gate?
- What challenges do you normally face when using these gates?
- Do you believe cashless payments would ease your organisation's work?

Figure 2: The team members of the project conducting in person interviews with motorists and the project manager at the toll gate