MAKERERE UNIVERSITY
COLLEGE OF COMPUTING AND INFORMATION TECHNOLOGY

Ubiquitous Computing for Mobile Based Payments in Localised Intelligent Transportation Systems

By
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DEPARTMENT OF COMPUTER SCIENCE

A Project Proposal 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

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Abstract

Traffic congestion is a major issue in many developing world cities, including Kampala, due to limited infrastructure and traffic management resources. Governments in these regions have attempted to address this issue by constructing toll express highways as part of embracing intelligent transportation systems. However, this approach has led to challenges,such as long queues and delays at tollgates.One proposed solution is the use of RFID technology,but this approach is cost-prohibitive.

This research proposes a low-cost solution tailored to the local context of Uganda. The proposed solution leverages techniques from the field of ubiquitous computing where a secure, reliable mobile application for prepaid payment of toll fees. These payments are recorded and in a cloud server and can be verified using a linked embedded QR code scanner. The proposed system can serve as an example of how intelligent transportation systems can be implemented in a developing city like Kampala, utilizing techniques from the field of ubiquitous computing. In the long run, such a project could help Kampala evolve into a smart city that is clean and self-sustaining.

Keywords: Intelligent Transportation Systems, Ubiquitous Computing, Mobile Commerce, Smart Cities

Chapter 1

Introduction

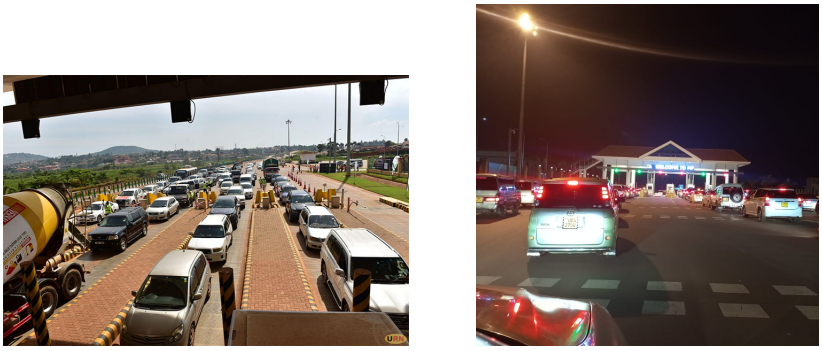
1.1 Background and motivation

Traffic systems in developing-world cities such as Kampala tend to have issues such as limited infrastructure, as well as traffic management resources. Increase in vehicle ownership for both private and personal use among residents in these regions has also played a part in this[1]. These factors have an aggregate effect and result in traffic congestion in most of these cities[2].

One solution that has been put in place in efforts to improve the existing infrastructure is the construction of express highways that use a toll system, and studies have shown that such projects are of great significance spurring economic growth in the region[3]. The highways are less congested and are constructed as alternatives to any already existing routes.Motorists arrive at the tollgates found at the entrance to these roads,pay the toll fees, charged on a vehicle size basis in some cases and are then granted access to the highway.

Challenges have however risen with this solution, a major one being congestion and queues as motorists wait to pay their toll fees, thus defeating the road's intended purpose. These challenges can be attributed to issues such as finding cash change as well as limited manpower to attend to the various vehicles accessing the gates[4].

This research therefore explores how techniques from the field of ubiquitous computing can be used along with mobile commerce tools to create a localised low-cost solution to streamline this payment process. Such a system



(a) (b)

Figure 1.1: Queues at the Entebbe Express Highway

can serve as a demonstration of how intelligent transportation systems can be implemented in Uganda, and in the long run, ultimately aiding in the development of cities like Kampala into smart cities.

According to Jonathan Reichental, smart cities are a form of Urbanization that leverages technology from a variety of domains such as Internet of Things and cloud computing to improve infrastructure and service delivery, while lowering costs of resource consumption[5]. One key feature of such cities is the use of intelligent transportation systems.

Intelligent Transportation Systems use various technologies to optimise urban mobility guaranteeing safety of drivers[6]. They use data and communication of various devices, such as sensors embedded inside cars or road side cameras to improve transportation problems in cities.One such technology used in these systems is ubiquitous computing

Originally coined by Mark Weiser[7], the term ubiquitous computing at its core is concerned with embedding microprocessors into other objects of daily use, connecting them to a given network such as the internet and enabling perform similar tasks for users as normal computers[8]. Today, it has a number of applications such as self-driving vehicles, smart devices such like smartwatches and electronic tollgates. With regard to intelligent transportation systems these electronic tollgates can be implemented through the use of ubiquitous computing applications such as use of RFID scanners and tags.These can also be coupled with mobile payment tools to make the entire flow seamless

Mobile Commerce, on the other hand is a branch of E-Commerce concerned

with cashless initiation and verification of payments for goods or services[9]. In SubSaharan Africa, its commonest implementation has been through the mobile money platforms such as Airtel Money and MTN mobile money. These allow users to easily create accounts using their personal SIM cards and carry out financial transactions such as sending, receiving money or making payments for goods and services[10].

1.2 Problem Statement

Toll payment checkpoints at the toll gates often experience queues and delays as motorists try to pay their toll fees. These queues occur due to issues such as:

- Limited manpower to handle the number of vehicles using the station causing congestion especially during moments such as peak hours of morning and evening, but there is limited labour to service them.
- Delays as tollgate employees try to find change for motorists since current payment system employs cash payments

Another issue arises when employees managing the systems collude with some motorists who are granted access even without paying the required fees. Implementation of a similar checkpoint system is not limited to tollgates, and is also used in places such as parking ticket systems for public places such as malls, universities[11], which also suffer similar shortcomings.In this context, there is also an issue of breakdown of the ticketing machines due to low maintenance works

The above issues have their own attached negative effects. One study found that the present state of traffic flow in Uganda, particularly Kampala city causes Uganda losses of approximately 6.7% of its GDP to traffic congestion annually. Another study by Thomas Munzel found that frequent congestion of vehicles increases the risk of heart failure and other health conditions in motorists.This is caused by the high level of stress during congestion[12].

From an environmental point of view, the current approach is also unfeasible.This is because the congestion from the delays results in increased carbon emissions from the vehicles, which also puts pedestrians and other road users at risk[13]. The checkpoint systems used in the parking management context use tickets, assigned to each motorist, which is also not only costly, as a lot of paper is required for printing, yet the paper is needed for a brief time, but it is also a bad practice as trees are cut down to get paper[14].

The payment approach currently used at these checkpoints is also an issue as these payments are mainly done through physical cash. In light of the recent global CoVID-19 pandemic, there is need to adopt cashless payments leveraging platforms such as mobile money [9], as physical cash is known to be a vector for viruses,[15, 16] and this would be an opportunity for countries to better future-proof themselves in case of another pandemic or disease outbreak.

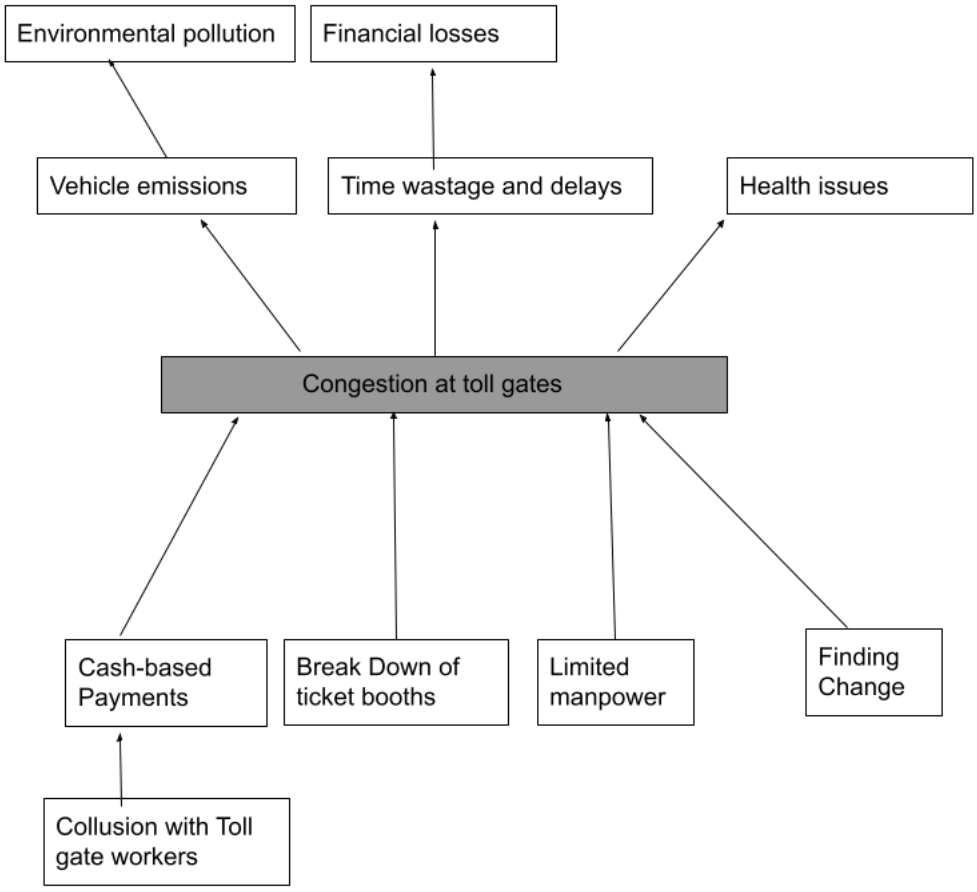


Figure 1.2: Problem Tree for the research project

Altogether, these factors impede on the establishment of intelligent transportation systems as well as utilisation of techniques like ubiquitous computing for cities like Kampala, and their gradual evolution into smart cities.

1.3 Objectives

1.3.1 Main Objective

To develop a low-cost secure reliable system, based on ubiquitous computing and mobile commerce techniques, as a component of a larger intelligent transportation system mainly used to simplify and quicken payment of toll fees.

1.3.2 Specific Objectives

The project's specific objectives include:

- To understand the existing payment approach used at Makerere University toll gates.
- 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.
- To demonstrate how embedded QR code scanners can be used in the toll payment context as an alternative to long range RFID scanners in low-resource settings

1.4 Scope of the project

This project is limited to building a cross-platform mobile application to enable motorists to pay their toll and parking fees.This application will be used with an embedded microcontroller with QR code reading capabilities.

Implementation of the project will be limited to Makerere University premises where there exists a system similar to that described in the project's problem statement

Figure 1.3: Makerere University main gate where the projected will be implemented

1.5 Significance of the project

The biggest significance of this research project is demonstrating how intelligent transportation systems can be applied in Uganda.This project will also quicken the toll payment process for motorists eliminating the congestion from the queues and delays that arise from the current system.

Additionally, the project is a step in the right direction towards achieving one of the UN Sustainable Development Goals, SDG13, that is concerned with climate action[17] as paper wastage in printing tickets, and vehicle emissions as they wait in queues are both reduced significantly by the proposed solution.In the long run, such a system can be scaled to various parts of the country paving the way for development of smart cities in Uganda

Chapter 2

Literature Review

In this chapter we discuss 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 shortcomings and how they are addressed in our project.

2.1 Intelligent Transportation Systems

Intelligent Transportation Systems are technologies that work with applications and are built with the intention of improving safety in the transport sector, and raising productivity for people

Initially proposed in the United States in the twentieth century, a great deal of research is currently going on in this domain as these systems not only improve traffic conditions but are also likely to improve safety, and sustainability in the transportation sector by limiting the inconveniences caused by traffic congestion[6].

These systems leverage information and communication technologies, such as embedded sensors, IOT devices[18]. They're used in efforts like real-time data collection from sensors placed in vehicles or infrastructure,and are able to aggregate this data that can then be used to gain insights in information concerning a given city or region. This information can then be used for services and applications aimed at improving the management, plus impproving traffic flow in cities by reducing traffic congestion, which helps lower consumption of fuel and carbon emissions[6].

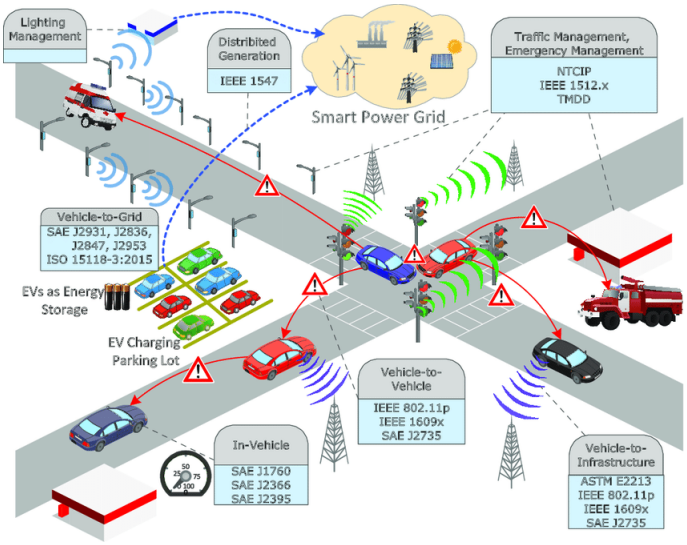


Figure 2.1: A sketch of an intelligent transportation system

2.1.1 Uganda National Roads Authority Express Highway and Makerere University Kampala

Attempts to put in place a project of this nature in the Ugandan setting have been made though limited by the resources and technology available in the region by the Uganda National Roads Authority through the construction of the Entebbe Express Highway. This implementation is however limited as cashless payments on this road are made electronically through an UPESI RFID card that's scanned as one tries to access the road[19]. At Makerere University, individuals who are exempted from paying the parking fee are also given a RFID tag that they place inside their vehicles.This is then scanned by a long-range RFID camera and they're instantly granted access thereafter[20].

Project Gap

The systems mentioned above are not as feasible because:

- Cash payments are the commonest way to pay , and these take up time in terms of trying to find change
- The alternative payment is an UPESI card, and the process of getting out of the vehicle to scan it is time consuming.

Figure 2.2: Gen. Katumba Wamala showing an UPESI payment card on the launch of the Entebbe Express Highway

- The implementation at Makerere University only accounts for vehicles with RFID tags and the rest have pay with tickets.

2.1.2 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[21, 22]. The system was tested through simulations in Vissim software [23], 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.

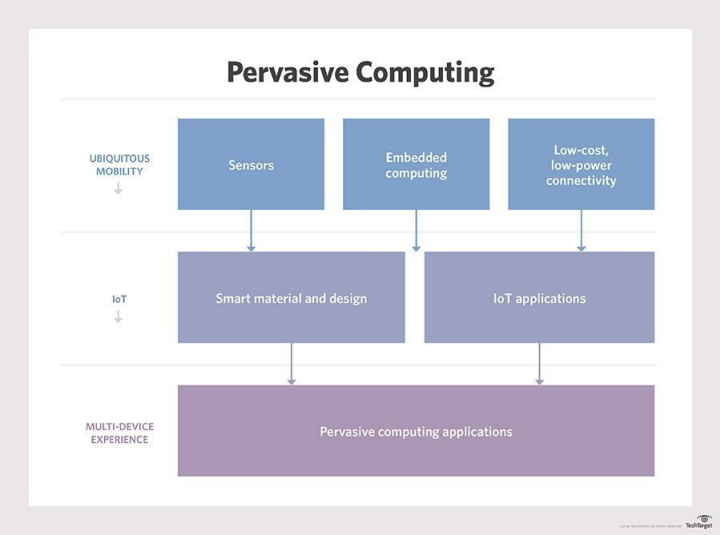


Figure 2.3: A sketch of a ubiquitous computing application

2.2 Ubiquitous Computing

The domain of ubiquitous computing also known as pervasive computing according to Michael Friedewalda and Oliver Raabe is concerned with countless small, wirelessly intercommunicating microprocessors, embedded into objects. Such techniques are applied in similar concepts, such as "the Internet of things".The main motive in these domains is assisting people and optimizing economic and social processes through the use of microprocessors and sensors

These microprocessors are equipped with sensors enabling them to capture information about their current environment or process information and communicate over a network with other similar devices[24].

Ubiquitous computing systems consist of features such as:[24]

- The system is decentralised
- Computers are embedded in other devices
- Real-time information is readily available for users
- The system is able to adapt basing on current information.

This concept has a number of real world applications in domains such as

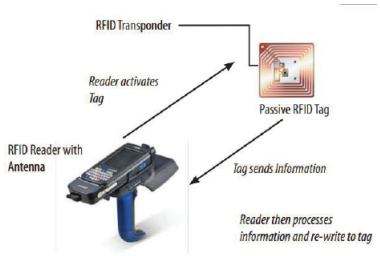


Figure 2.4: Components of an RFID system

retail, industrial production, health care and this is achieved through implementations such as tracking applications, wearable devices like smartwatches.

2.2.1 Use of RFID sensors

In the context of toll payment, ubiquitous computing has been put in use in a number of developed countries, and this has been mostly done through the use of RFID technology.

An RFID system has two main components:

- A transponder: This is the tag that holds information, found on the object to be identified
- 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[25].

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[26].

2.2.2 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 2.5: A mobile money kiosk in Kampala. These are a common sight in the city with agents to handle mobile money transactions as bank tellers would in normal banks

2.3 Mobile Commerce

The term E-commerce is used to refer to the buying and selling of goods over the internet. A subset of this is mobile commerce, which is strictly concerned with the same task, but conducted over mobile devices, [27] especially applications on smartphones. This can be attributed to the increased ubiquity of smartphones as well as other handheld devices such as tablets, allowing phone users to do shopping, make bank related transactions. This study is mostly concerned with the process of mobile payments.

Mobile payments refer to using a mobile device, such as a smartphone or tablet, to make financial transactions.This can include making purchases at a store, transferring money to another person, or paying bills.

In Uganda, the commonest implementation of this is through the mobile money systems[9]. In Sub-Saharan Africa, the use of mobile money platforms is promoting financial inclusion, with 548 million registered mobile money accounts in the region. These platforms have seen a 23% growth in transaction value, reaching 490 billion dollars.

In countries like Uganda, mobile money accounts are held by 43% of the population, compared to just 11% who have bank accounts.This demonstrates the significant impact that mobile money platforms are having on financial inclusion in the region[10].

One of the main advantages of mobile payments is convenience. With mobile

payments, there is no need to carry around a physical wallets. Transactions can be completed quickly and easily with just a few taps on your mobile device. This is especially useful in situations where carrying cash is inconvenient or unsafe, such as when traveling or when making a purchase online.

Another advantage of mobile payments is speed. Since mobile payments do not require the physical exchange of cash or the processing of a credit card, transactions can be completed quickly and efficiently. This can save time and effort for both the consumer and the merchant. In addition, mobile payments can enable real-time tracking of transactions, allowing both parties to have immediate access to information about the transaction, such as the amount, the date and time, and the location.

Enhanced security compared to cash payments.Mobile payment systems often use advanced security measures, such as encryption and authentication, to protect against fraud and unauthorized access. This can give consumers peace of mind when making financial transactions, knowing that their personal and financial information is protected.

Payments for these mobile transactions can be completed in a number of ways such as credit cards, debit cards and mobile money platforms such as MTN mobile money, Flutterwave. Our project will rely on the mobile money systems which are ubiquitous in Uganda[10]. It would therefore be advantageous to leverage these platforms

2.3.1 Uganda National Roads Authority

With regards to toll-fee payment, in Uganda, the Entebbe express highway is currently the only existing toll road.Mobile money platforms are leveraged here, but only for loading money onto the UPESI card,[19] that is then used by motorists to pay their fee. This process is quite long, as motorists have to first purchase the card, and repititively load money onto it.A more simplified approach would be to automatically pay directly from the mobile phone

Project Gaps

One major shortcoming on the use of mobile commerce with regards to this project, is the payments are only used to add money to the card, which is then later scanned and not directly for access to the road.

2.3.2 Use of NFC technology

Near field communication, or NFC, is a technology that allows two devices to communicate wirelessly when they are close together. This technology is based on radio frequency signals, and it operates over a very short range, typically within a few centimeters of the devices. To use NFC technology, a device must be equipped with an NFC chip, which contains the necessary hardware and software to transmit and receive NFC signals[28]. When two NFC-enabled devices are placed near each other, they can exchange information and perform various actions, such as making a payment or transferring data. NFC technology is commonly used in mobile phones, payment cards, and other devices, and it offers a convenient and secure way to conduct transactions and share information.

Rugnesh Rameshram Kanojia and Professor Sujata Pathak in 2018 also proposed a mobile application that would be used for payment of these fees that leverages NFC technology[29]. An NFC device such as an NFC tag is tapped at the tollgate's NFC tag reader, thereafter user data is verified and the toll charge is deducted

Research Gap

NFC payments are very useful as they offer convenience, speed, and security for consumers, and they are becoming increasingly popular as a way to make purchases. Many major banks and retailers now support NFC mobile payments, and the technology is expected to continue to grow in popularity in the coming years, however, as of this writing, they are not yet supported by many of the local payment merchants in Uganda.

2.4 Smart Cities

According to Jonathan Reichental smart cities are a form of Urbanization that leverages technology from a variety of domains such as Internet of Things, cloud computing, mobile applications to improve infrastructure and service delivery, while lowering costs of resource consumption [5]. This can include using sensors, data analytics, and other technologies to manage traffic and transportation, reduce pollution, improve public services, and create more efficient and sustainable urban environments.In developing countries like Uganda, implementing smart city technologies can have many benefits, including improving the quality of life for residents.

One of the key ways that smart city technologies can be implemented in Uganda is through the use of sensors and data analytics. For example, sensors can be placed throughout the city to collect data on traffic flow, air quality, and other factors. This data can then be analyzed to identify patterns and trends, and to develop solutions to improve urban services and infrastructure. For example, data on traffic flow could be used to develop more efficient and sustainable transportation systems, such as intelligent traffic management systems or public transportation networks[30].

Implementing smart city technologies in Uganda has the potential to bring many benefits, including improving the quality of life for residents, and promoting economic growth. By using sensors, data analytics, and digital platforms and services, cities like Kampala can become more sustainable, and a better place to live and work.

Digital toll payment systems can play a key role in a smart city, by improving the efficiency and convenience of toll payment, and providing valuable data and insights for urban planners and policymakers. By using technology and data to improve urban services and infrastructure, a smart city can create a better quality of life for its residents and attract investment and economic growth.

2.4.1 South Korea

In South Korea, motorists are able to clear toll fees using a Hi-Pass card. The Hi-Pass system allows drivers to pay tolls without cash and no interaction with the tollbooth is necessary. They are required to have both an OBU (on-board unit) installed on their vehicle's windscreen, and a Hi-Pass card. The OBU is produced by various manufacturers and can be purchased at stores that sell automotive electronics. The Hi-Pass card can be pre-loaded

with cash for the toll payment. These cards can often be found at the same stores that sell the OBU[31].

2.4.2 Canada 407 toll Express Highway

The Canada 407 Express toll route is another demonstration of an futuristic highway that can be used in smart cities. Users create an account on the official website, and purchase a personal transponder, that's attached to the windshield of the vehicles. Cameras on the highway then scan the transponder to identify the vehicle, and make the necessary financial deductions[32].

Project Gaps

The systems mentioned above and all similar projects help eliminate the tollgate delays and allow the regions they've been implemented evolve into advanced smart cities, however for the scope of our research which is Uganda, taking into account the limited resources such as capital, such projects would be costly to implement thus the need for low-cost solutions

2.5 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:

- Use of the local preferred payment platforms such as MTN mobile money, increasing the system's accessibility to individuals in Uganda.
- Use of embedded QR code readers as an alternative to RFID tags and scanners which are costly. The QR codes that motorists will use to access the gates will be generated on their mobile phones, thus no need for tickets or such that would be wasteful
- Prepaid payments that would eliminate the delays and queues: Our proposed system would eliminate the queues that commonly arise as motorists make their payments.

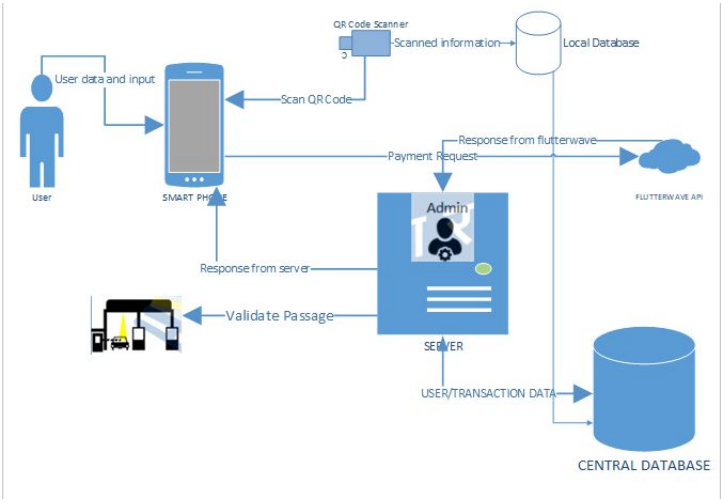


Figure 2.6: System Architecture Diagram for the proposed solution

Chapter 3

Methodology

3.1 Introduction

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

3.2 Data Gathering and Elicitation

The team intends to collect relevant and appropriate data to determine the requirements of the proposed system. This will be done through questionnaires, interviews and physical observation[33].

3.2.1 Questionnaires

Questionnaires contain open or closed ended questions given to a selection respondents to solicit information on a selected research topic[34]. Google forms will 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 will have 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 will help in better defining the system requirements of the project. The interviews will also enable the researchers to establish relationship with potential respondents 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[35].

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.
- Xcode
- Flutter mobile framework: This will be used to write the cross-platform code for the application
- Google Firebase: This will be used for adding, accessing and processing of data.

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. [36]

Prototype builds for user testing and validation will be created. These will be shared using Firebase App Distribution[37]. 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

Outcomes

The project intends to 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 will be 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.

4.1 Project Gaps and Future Works

Currently, implementation of the project will be 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 4.1: The proposed system's payment will be limited to smartphones. In future, the project could be improved to support other phones

Bibliography

[1] J. A. Gómez-Gélvez and C. Obando, "Modeling car ownership in urban areas of developing countries: Case study of bogotá, colombia," vol. 2394, no. 1, pp. 111–118. [Online]. Available: http://journals.sagepub.com/doi/10.3141/2394-14

[2] N. Bashingi, M. Mostafa, and D. Kumar Das, "The state of congestion in the developing world; the case of gaborone, botswana," vol. 45, pp. 434–442. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2352146520301988

[3] J. Muvawala, H. Sebukeera, and K. Ssebulime, "Socio-economic impacts of transport infrastructure investment in uganda: Insight from frontloading expenditure on uganda's urban roads and highways," vol. 88, p. 100971. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0739885920301694

[4] C. S. Bari, Y. V. Navandar, and A. Dhamaniya, "Delay modelling at manually operated toll plazas under mixed traffic conditions," vol. 11, no. 1, pp. 17–31. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2046043020300629

[5] J. Reichental, "STRATEGIC PLANNING FOR SMARTER CITIES," in *Internet of Things and Data Analytics Handbook*, H. Geng, Ed. John Wiley & Sons, Inc., pp. 83–93. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1002/9781119173601.ch4

[6] R. I. Meneguette, R. E. De Grande, and A. A. F. Loureiro, *Intelligent Transport System in Smart Cities: Aspects and Challenges of Vehicular Networks and Cloud*, ser. Urban Computing. Springer International Publishing. [Online]. Available: http://link.springer.com/10.1007/978-3-319-93332-0

[7] M. Weiser, "Hot topics-ubiquitous computing," vol. 26, no. 10, pp. 71–72, conference Name: Computer.

[8] S. Judith, *Ubiquitous and Pervasive Computing: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications*. IGI Global, google-Books-ID: VqPgO7J2fUUC.

[9] S. Centellegher, G. Miritello, D. Villatoro, D. Parameshwar, B. Lepri, and N. Oliver, "Mobile money: Understanding and predicting its adoption and use in a developing economy," vol. 2, no. 4, pp. 157:1–157:18. [Online]. Available: https://doi.org/10.1145/3287035

[10] B. Baah, K. Kipkemboi, D. Lindsey, B. Muthiora, A. Nautiyal, V. Pathy, B.-J. Pors, D. Tricarico, and Z. White, "State of the industry report on mobile money 2021," p. 86.

[11] M. A. Bagadiong, L. A. De Leon, A. A. Dizon, and M. Young, "Car park reservation using QR system: Proposed flow," in *2020 IEEE 7th International Conference on Engineering Technologies and Applied Sciences (ICETAS)*, pp. 1–5.

[12] T. Münzel, F. P. Schmidt, S. Steven, J. Herzog, A. Daiber, and M. Sørensen, "Environmental noise and the cardiovascular system," vol. 71, no. 6, pp. 688–697. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0735109717419309

[13] K. Zhang and S. Batterman, "Air pollution and health risks due to vehicle traffic," vol. 0, pp. 307–316. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4243514/

[14] P. Bajpai, *Basic Overview of Pulp and Paper Manufacturing Process*. Springer International Publishing, pp. 1–29. [Online]. Available: http://link.springer.com/10.1007/978-3-319-18744-0_2

[15] E. Angelakis, E. I. Azhar, F. Bibi, M. Yasir, A. K. Al-Ghamdi, A. M. Ashshi, A. G. Elshemi, and D. Raoult, "Paper money and coins as potential vectors of transmissible disease," vol. 9, no. 2, pp. 249–261.

[16] J. M. Maritz, S. A. Sullivan, R. J. Prill, E. Aksoy, P. Scheid, and J. M. Carlton, "Filthy lucre: A metagenomic pilot study of microbes found on circulating currency in new york city," vol. 12, no. 4, p. e0175527, publisher: Public Library of Science. [Online]. Available: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0175527

[17] U. N. United Nations. Goal 13: Climate action. [Online]. Available: https://globalgoals.org/goals/13-climate-action/

[18] S. A. Shaheen and R. Finson, "Intelligent transportation systems," pp. 487–496.

[19] U. UNRA. News & updates - uganda national roads authority. [Online]. Available: https://www.unra.go.ug/news/update-on-tolling-operations-along-the-kampala-entebbe-expressway

[20] M. Wamai. Mak automated vehicle control system project kicks off. [Online]. Available: https://news.mak.ac.ug/2014/04/mak-automated-vehicle-control-system-project-kicks-off/

[21] A. El-Rabbany, *Introduction to GPS: The Global Positioning System*. Artech House, google-Books-ID: U2JmghrrB8cC.

[22] D. Dismantoro, I. Pratomo, and S. Sumpeno, "Minimizing toll payment queue using GPS-based mobile applications," in *2020 Fifth International Conference on Informatics and Computing (ICIC)*, pp. 1–7.

[23] P. V. PTV Vissim. Traffic simulation software | PTV vissim | PTV group. [Online]. Available: https://www.ptvgroup.com/en/solutionsproducts/ptv-vissim/

[24] M. Friedewald and O. Raabe, "Ubiquitous computing: An overview of technology impacts," vol. 28, no. 2, pp. 55–65. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0736585310000547

[25] S. Ahmed, T. M. Tan, A. M. Mondol, Z. Alam, N. Nawal, and J. Uddin, "Automated toll collection system based on RFID sensor," in *2019 International Carnahan Conference on Security Technology (ICCST)*, pp. 1–3, ISSN: 2153-0742.

[26] E. Khan, D. Garg, R. Tiwari, and S. Upadhyay, "Automated toll tax collection system using cloud database," in *2018 3rd International Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU)*, pp. 1–5.

[27] U. Varshney, R. Vetter, and R. Kalakota, "Mobile commerce: a new frontier," vol. 33, no. 10, pp. 32–38, conference Name: Computer.

[28] V. Coskun, B. Ozdenizci, and K. Ok, "The survey on near field communication," vol. 15, no. 6, pp. 13 348–13 405. [Online]. Available: http://www.mdpi.com/1424-8220/15/6/13348

[29] R. R. Kanojia and S. Pathak, "Secured vehicle toll payment system using NFC," in *2018 Fourth International Conference on Computing Communication Control and Automation (ICCUBEA)*, pp. 1–6.

[30] C. L. Stimmel, *Building Smart Cities: Analytics, ICT, and Design Thinking*, 0th ed. Auerbach Publications. [Online]. Available: https://www.taylorfrancis.com/books/9781498702775

[31] M.-S. Chang, Y.-T. Oh, K.-W. Kang, and H.-W. Jung, "EVALUATIONS AND IMPROVEMENTS OF THE KOREAN HIGHWAY ELECTRONIC TOLL SYSTEM," vol. 26, no. 1, pp. 37–44. [Online]. Available: https://linkinghub.elsevier.com/retrieve/pii/S0386111214600807

[32] W. E. Oliver, "Toronto's highway 407," in *The Handbook of Municipal Bonds*, S. G. Feldstein and F. J. Fabozzi, Eds. John Wiley & Sons, Inc., pp. 1185–1193. [Online]. Available: https://onlinelibrary.wiley.com/doi/10.1002/9781119198093.ch78

[33] C. R. Kothari, *Research Methodology: Methods and Techniques*, 2nd ed. New Age International, google-Books-ID: hZ9wSHysQDYC.

[34] B. Bartram, "Using questionnaires," in *Practical Research Methods in Education*. Routledge, num Pages: 11.

[35] J. Rumbaugh, J. Rumbaugh, S. Blaha, M. Blaha, W. Premerlani, M. R. Blaha, F. Eddy, B. Lorensen, J. R. Rumbaugh, and W. Lorensen, *Object-oriented Modeling and Design*. Prentice Hall, google-Books-ID: Q4ZQAAAAMAAJ.

[36] P. Klaus, *Requirements Engineering*, 1st ed. [Online]. Available: https://link.springer.com/book/9783642125775

[37] G. Google. Firebase app distribution. [Online]. Available: https://firebase.google.com/docs/app-distribution

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?

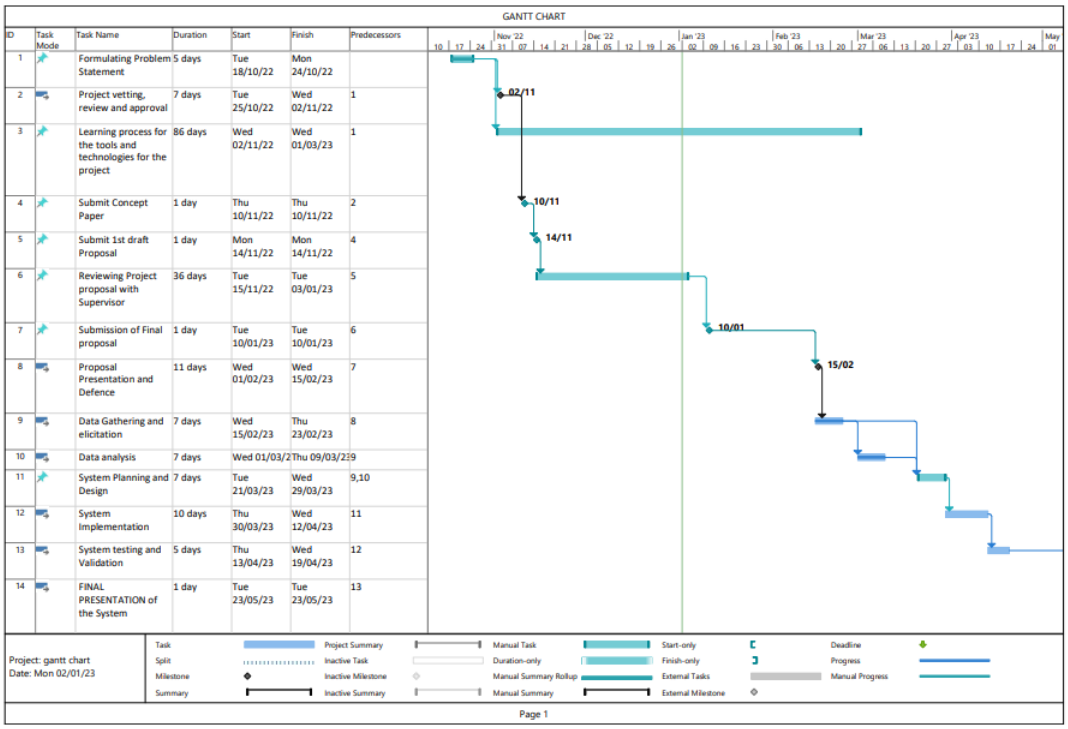


Figure 2: Gantt chart for execution of the project

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