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Automated E-Tolling System using RFID Technology, Steganography & Cloud Computing A Zimbabwean Perspective

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***Abstract*:- Automated e-tolling system will help collect road tax automatically and efficiently in Zimbabwe. In this paper RFID technology is used for vehicle identification, steganography is used to preserve privacy on the communication between RFID tag and reader to put an end to tag tracking problem. The tag information is hidden in another text using zero width Unicode characters steganography at the point of vehicle registration. Cloud computing is used for authentication of RFID tags and hosting of the database and the system. When a vehicle approaches the toll gate, sensors will detect the presence of a vehicle, the RFID reader mounted on the tollgate reads the information that is on the RFID tag mounted on the windscreen of the vehicle and sends the information to a cloud server for tag authentication. This tag is given by Central Vehicle Registry department upon vehicle registration which links it to details stored on the cloud database. During vehicle registration an account is assigned to the vehicle owner that he/she has to maintain a healthy balance. After authentication the vehicle is classified using its weight recorded upon registration. If account balance is adequate the gate opens for the vehicle to pass. In case of inadequate account balance or no tag, the vehicle is directed to the tollbooth that does manual transactions.**

Keywords- RFID, cloud computing, steganography, privacy, authentication.

I. INTRODUCTION

Toll collection is a method used in many countries to collect money for road usage which will help in repairing, modified text steganography technique to hide actual data that is communicated between RFID reader and RFID tag such that tracking of tags will be extremely difficult if nearly not impossible. Currently Zimbabwe uses manual toll collection systems where a vehicle has to stop at the toll plaza and make payment either electronically or manually so that it can pass through. The current manual system though uses weight of the vehicle to classify the vehicle in order to determine the correct fee that a vehicle has to pay and this is done when the car is registered and the information will be stored in the database. This manual system causes congestion at the toll plaza which is sometimes unbearable during festive seasons and other public holidays. The current system also enables revenue leakages and environmental pollution, wastage of fuel while waiting in the queue. According to A. Chilunjika,2018[3] revenue from Zimbabwean tollgates rose by 80% when electronic payment systems were introduced at tollgates as compared maintenance and construction of new roads. The first automated e-tolling system was introduced and implemented in Trondheim in Norway in 1991[1]. Techniques that enable efficient collection of this revenue without negatively affecting the road users, the road administrators and the environment are implemented. RFID vehicle identification technology has proved very efficient and cheap as compared to various vehicle identification technologies such as Automatic Number Plate Recognition(ANPR) usually known as Video tolling, Dedicated Short Range Communications(DSRC) technology, Global Navigation Satellite Systems (GNSS) technology and Tachograph-based technology. RFID is widely used in various sectors in the world, manufacturing, medicine, agriculture, security, warehouses etc.[2]. The proposed automated e-tolling system will help reduce time taken by each vehicle to pass through the toll plaza and clear vehicle congestion at Zimbabwean toll gates as vehicles will not need to stop at tollgates in order to manually pay toll fees. This will also reduce pollution and fuel wastage as is the case with available manual tolling systems in Zimbabwe. This proposed e-tolling system will automatically collect toll on moving vehicles that pass through the toll gate. The problem of RFID tag tracking used by criminals to track cars that pass through different toll gates for purposes of either stealing them or stealing the cargo that they will be carrying. This paper proposes a

to manual methods were only cash was the accepted mode of payment. The proposed solution will significantly improve revenue collection as it will minimise the costs of revenue collection by significantly reducing manpower at tollgates and also minimising revenue leakages.

II. RELATED WORK

B. Kommey et al,2020[4] proposed an electronic tollbooth collection and management system suitable for developing countries, especially for Ghana in this context. The proposed system uses Radio Frequency Identification (RFID) tags and uses them to identify a particular user's account that has been registered in the system[4]. Uses gsm (gsm shield) to connect to the internet, uses TDMA for tag anti-collision, uses a database hosted on the cloud (Hiroku) the researcher implements anti tag collision which makes his proposed system more efficient because in times of heavy traffic there will be very minimum tag misses for the reader.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 11 Issue 03, March-2022

K. Devi Priyanka et al, 2020 [5] proposed system uses RFID for identification. It also uses near field communication such that the user has to bring the card nearest to the reader which causes the vehicle to somehow stop and bring the card near the reader to be read. The solution will not totally eliminate congestion.

Md.Armanul Hague et al,2020 [6]proposed an automated toll collection system that uses RFID technology and a GSM module. They key aspect being automatic deduction of money from vehicle owners maintained account without the vehicle stopping. Their proposed model being formulated by RFID and GSM modules that are controlled by a microcontroller based database control module. Their proposed system also uses IR sensor to determine when to open or close the gate. The authors use experimentation Methodology to test and prove their hypothesis.

M A Berlin et al, 2020 proposed a system that has roadside units stationed 250m before and away from the toll plaza[7]. These roadside units query the vehicle whether it is registered or has enough balance in its account for payment. If not an alert message is sent to warn the vehicle owner to recharge his account before entering the toll plaza. The system is gateless and also has a violation module that detects and reports payment violates to responsible authorities to take action against such violations. Their system uses RFID technology for vehicle identification. The authors ideas are good but not applicable in the Zimbabwe because in Zimbabwe it will not be good idea to have a gateless toll plaza.

Kavyashree et al,2021[8] proposed a system that uses RFID for identification and all the vehicle details will be stored on the tag. This is not a secure way of implementing because anyone with a reader that uses that frequency can easily view all the details of the car and be able to track it. A sensor is used to detect the presence of a vehicle. A prototype is also build to test the concept.

Piyush Sinhal et al,2021[9] proposed a system that uses RFID for vehicle identification classification of the vehicle is done by camera first taking photo of the number plate and comparing the details with what is in the database. This system uses relays for opening and closing the toll barrier. This shows a big flaw in design since relays are not reliable as drivers of gates.

Md Namzul et al,2021[10] proposed a solution that uses RFID for vehicle identification and reading data. A prototype is constructed to test functionality of the concept. This proposed solution only reduces congestion but does not completely eliminate it since the vehicle has to first stop because near field communication is being used.

Nimritee Sirsalewala et al, 2021[11] proposed a barrier less e-tolling system that also keeps record of every vehicle that passes through the toll plaza. This system that has no barrier cannot be implemented in Zimbabwe due to the lawlessness of road users in Zimbabwe.

All of the proposed solutions done by the above mentioned authors all do not address security issues that affect RFID systems.

III RELATED WORK ON SECURING RFID SYSTEMS

Hanguang Luo et al,2016[12] proposed an authentication protocol that makes use of bitwise XOR conversion . Its advantages being less computation requirements and ease of implementation on passive tags. However, its main disadvantage is for XOR encryption long runs for the same characters easily exposes the hidden message.

Han Shen et al,2017[13] proposed a solution that uses elliptic curve cryptography. Works well on expensive active tags. Heavy computation involved so not suitable for low cost passive tags.

Hamidreza Damghani et al 2019[14] proposed a solution that uses the security bit method(a logical bit embedded in RFID tag) It is mostly suitable for inventory systems and not suitable for use on vehicle identification.

Janakiraman, et al 2019[15] proposed an indicator based lightweight LSB(least significant bit) steganography technique suitable for resource constrained RFID components but it has a very low embedding capacity

Hafsat Muhammad Bashir et al ,2020[16] proposed a security solution that uses Unicode zero –width characters. Its advantages being, less computation is involved, high imbedding capacity and robustness and high invisibility against visual attacks. however, its disadvantage being the use of one-time pad cryptography.

All of the above mentioned security solutions fail to adequately secure RFID systems that use cheap(affordable) passive RFID tags especially securing the communication between RFID reader and tag.

IV. PROPOSED SYSTEM

The proposed system will use RFID technology for vehicle identification, steganography for hiding tag information in text, that is securing the communication between RFID reader and RFID tag. Cloud computing will be used to host both the web app and the database. A miniature prototype was produced to test the hypothesis using Arduino mega with on-board integrated Wi-Fi module.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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Block diagram of the proposed system

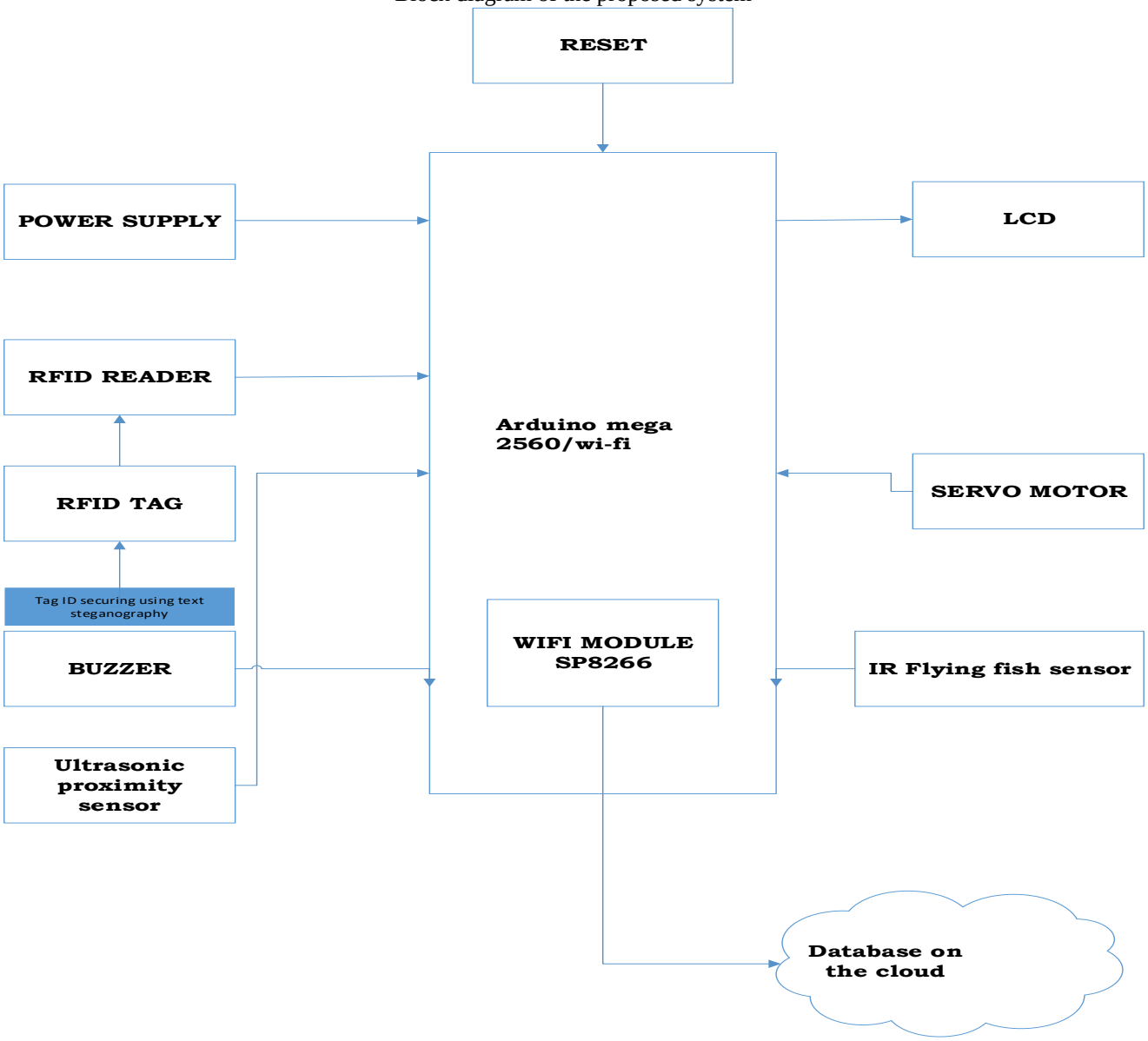

Fig 1. Block diagram of the proposed system

The following are the tools used to build the prototype:

1.Microcontroller
Arduino Mega 2560/ Wi-Fi microcontroller is used. It based on ATMEGA 2560 chip. It is a fully integrated Atmel ATmega2560 microcontroller and ESP8266 Wi-Fi IC, with 32 Mb of flash memory, and CH340G USB-TTL converter on a single board. All components can be set up to work together or independently by toggling on board switches. It has 256kb of usable memory of which 8kb is used by bootloader.

International Journal of Engineering Research & Technology (IJERT)
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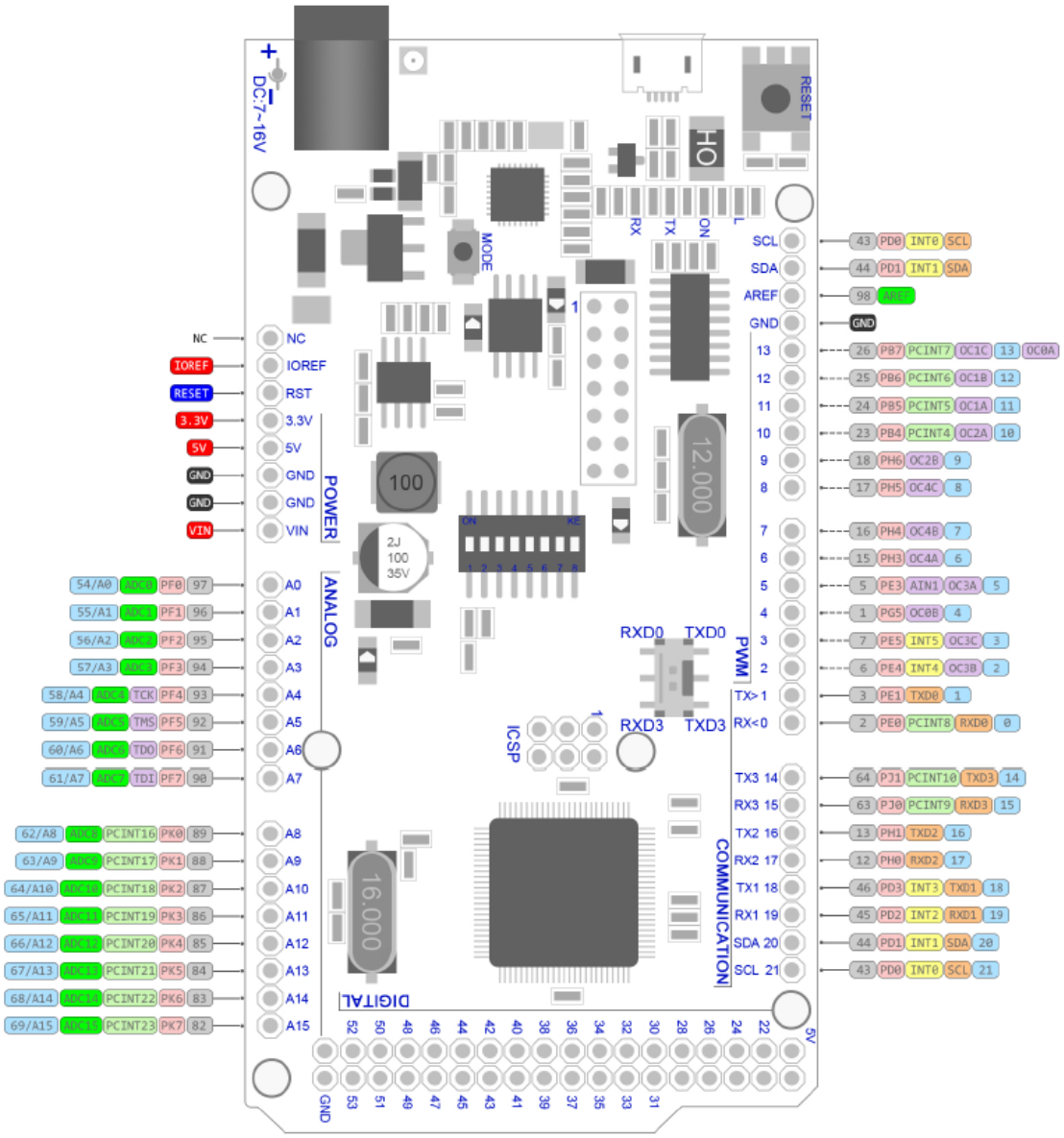
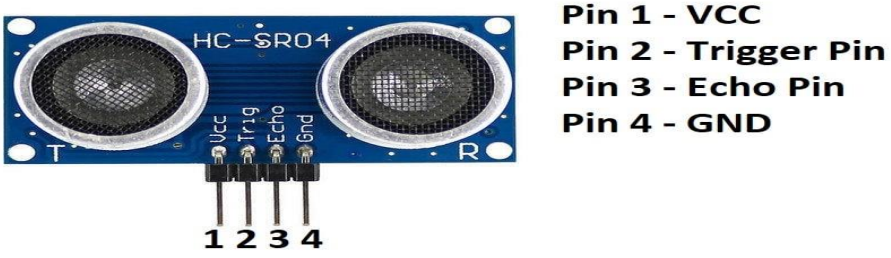


[17]

Fig 1 Arduino Mega 2560/ Wi-Fi microcontroller pinout diagram

2. Ultrasonic Proximity sensor

It is a type of proximity sensors usually used in automation applications. They use frequencies in the range 25kHz to 50kHz which is higher than human audible frequencies. They are used for object detection and distance which the object is.



[18]

Fig 2 ultrasonic HC-SR04 proximity sensor

International Journal of Engineering Research & Technology (IJERT)
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Vol. 11 Issue 03, March-2022

3.Servo motor SG90

[19]

Fig3 micro servo motor

5. Breadboard

It is a rectangular plastic board with tiny holes in it. These holes are used easily insert electronic components to prototype. It is a solderless board used to emulate a printed circuit board(PCB).

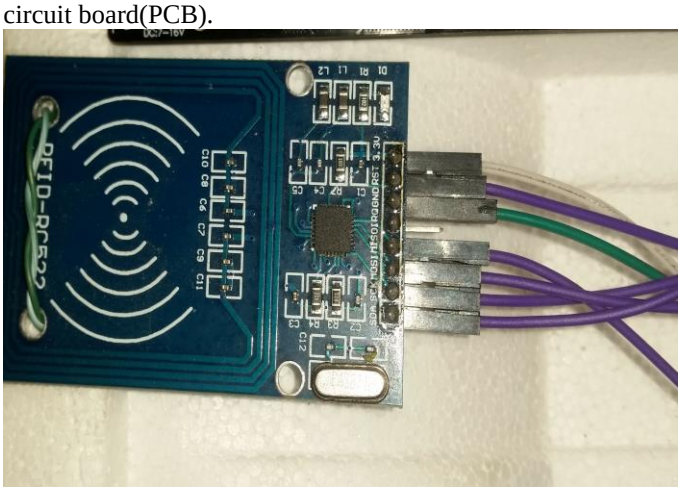

Fig5 RC522 RFID reader

7.RFID tags

They are sometimes called transponders. They are small which utilises low power radio waves to store, receive and transmit data to readers that are within range. They are made up of a microchip(IC), an antennae and protective material that holds the components together. They can either be passive, semi-passive and active tag. In this instance passive tags were used.

8. Arduino power supply

Used to power up the microcontroller board and all components connected to the microcontroller unit(MCU) for example sensors, RFID readers, servo motor etc.

4.IR flying fish MH8 sensor

It is used for object detection in this instance to detect the presence of a vehicle at the toll plaza

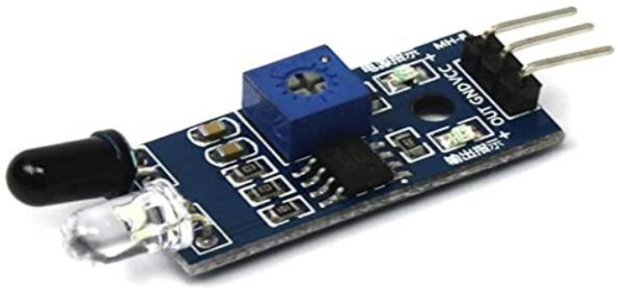

Fig 4 IR flying fish MH8 sensor

6. RFID Reader RC522

It is an RFID reader/writer. It operates in the 13.56Mhz frequency band. Operating voltage is 2.5v to 3.3v. Its read distance is 5cm. It is used to read information from the RFID tag.

[20]

Fig 6 Arduino power supply 12v- 3A

9.LCD

Liquid crystal display is an electronic device used to display data and messages. In this scenario a 16 by 2 is used which has 16 columns and two row and is capable of displaying only a maximum of 32 characters at any given time.

10. 330 ohms Resistors

These are used in this prototype to step down the voltage that is being supplied to the LEDs which will blow if the voltage is passed direct to them.

11. Visio 2016

It has been used to draw diagrams in this dissertation, system flowchart, system block diagram.

12. Fritzing software

It was used to draw circuit diagrams for the prototype.

14. Arduino IDE

Was used to write code for the embedded system using C programming language and was also used to upload the code to the MCU (Arduino mega 2560/Wi-Fi).

15. LARAVEL

It is a php framework which I used to create the system interface which is shown in fig that is used by CVR for registering vehicles. It is also the one that was used to code

International Journal of Engineering Research & Technology (IJERT)
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Vol. 11 Issue 03, March-2022

the text steganography utility for securing the communication between the reader and the tag.

16. MySQL

It is the database engine which I used to create the system database that is being hosted on the cloud.

Proposed system sketch breadboard view

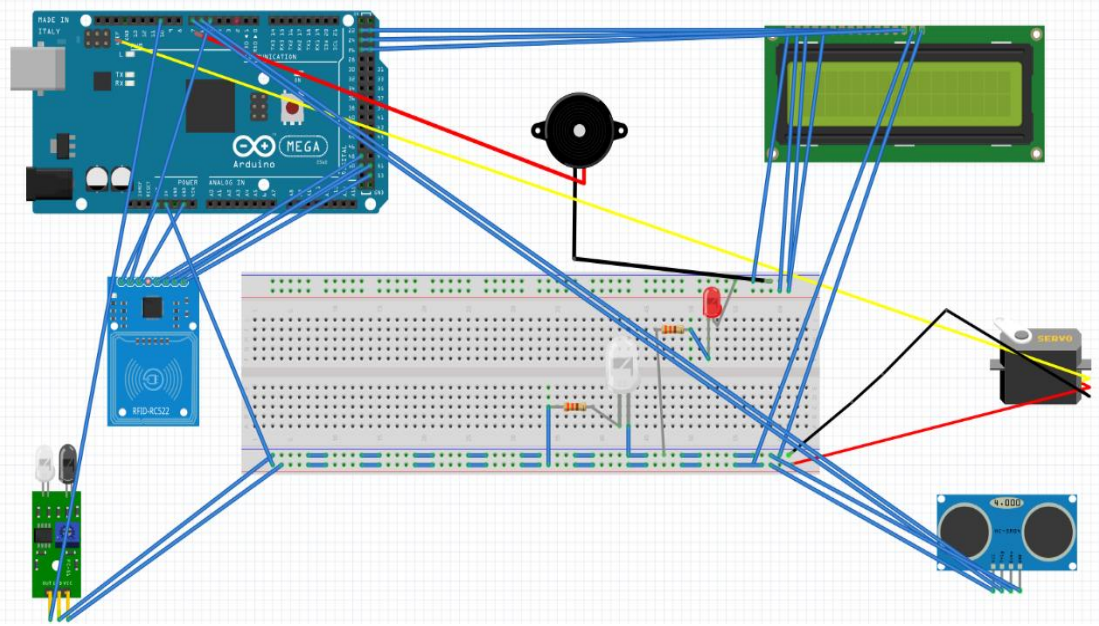

Fig 7. system sketch breadboard view diagram

Proposed system sketch schematic view

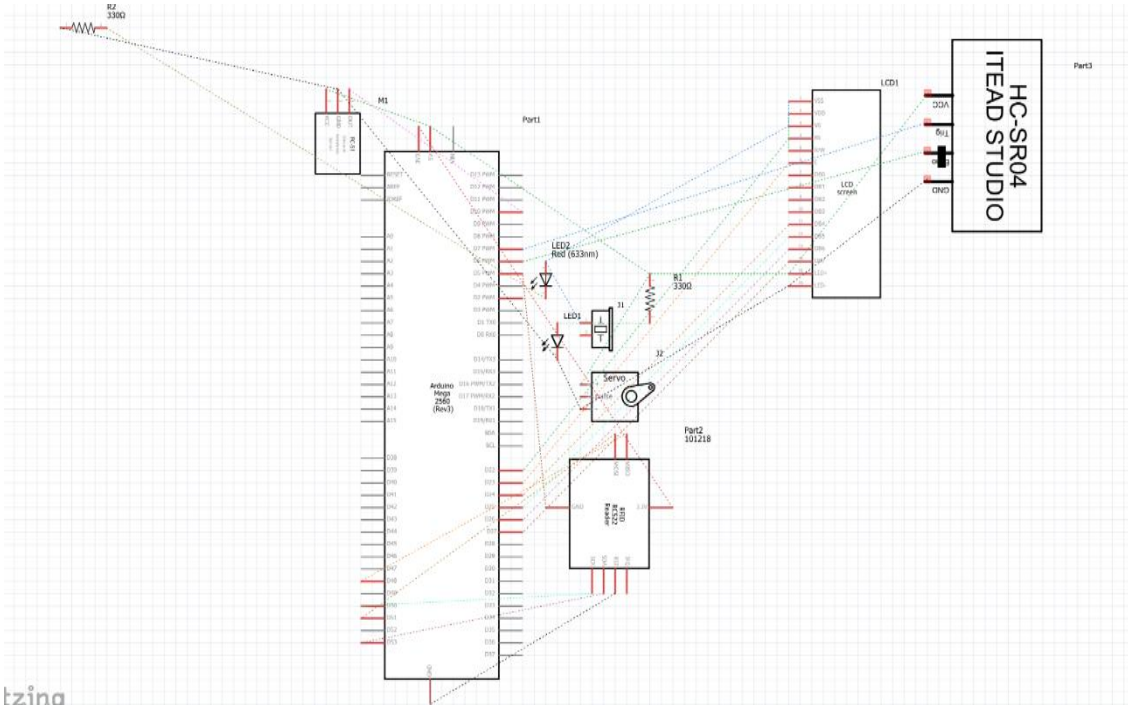

Fig 8 system sketch schematic diagram

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022

System flowchart

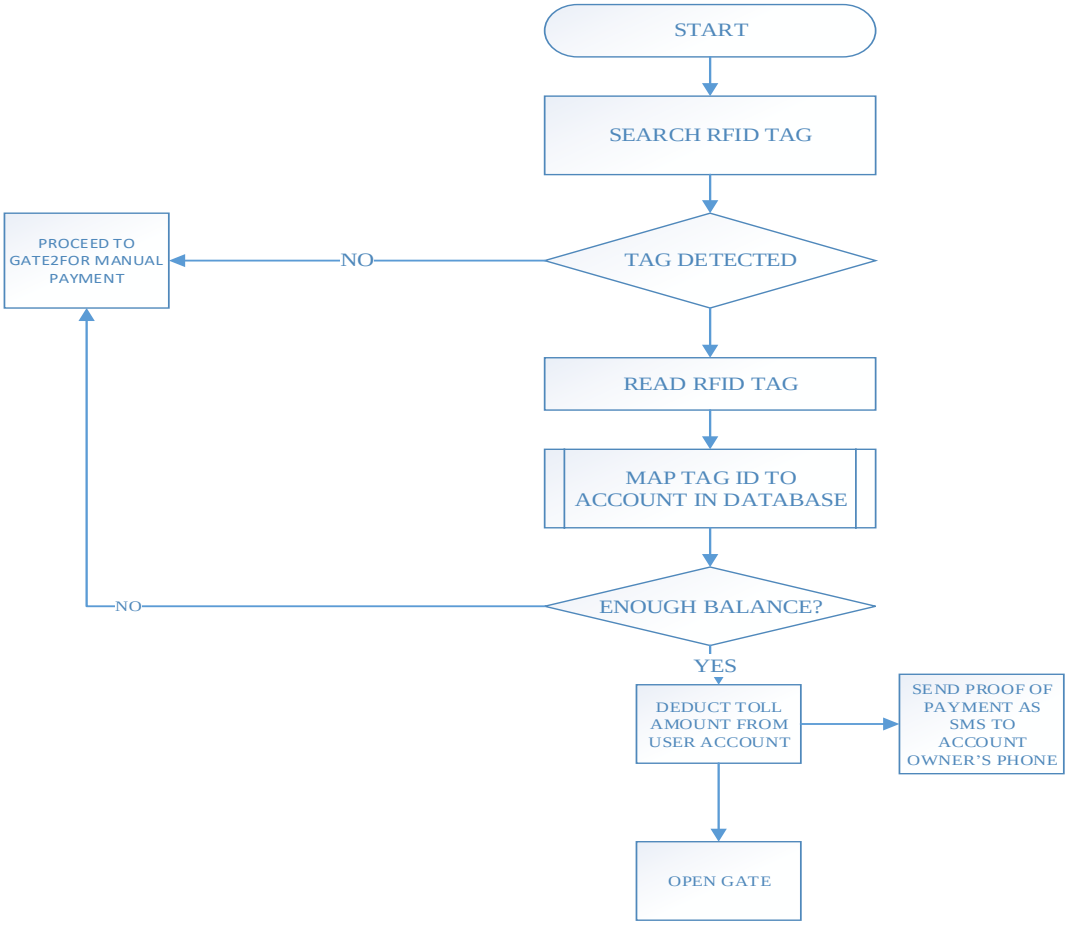

Fig 9 system flowchart

Assuming that the tag has already been secured using text steganography at the point of registration, as shown in fig 11 when a vehicle enters the toll gate area it is detected by sensors and scanned by the RFID reader for a valid tag. If there is no valid or no tag at all the vehicle driver is directed to a booth that does manual payments. the message is displayed on the LCD mounted on the toll plaza. If the tag is valid and the account has insufficient balance, one will again be directed to a gate that does manual payments. If the tag is valid and his/her account has sufficient balance, the required amount is deducted from the account and an sms is send to the vehicle owner's mobile number with details of the transaction and the gate opens and closes after the vehicle has passed. All user details are stored on the database that is hosted on the cloud and this database is used to verify the authenticity of the tag.

Summary of the proposed system

The proposed system will use in production, RFID technology for vehicle identification but will use RFID readers and tags that are fully anti-collision compliant. They should operate in ultra-high frequency range(UHF) thereby offering a higher bandwidth and faster data transfer rates between reader and tag. We will adopt the current vehicle classification systems already available at toll gates in Zimbabwe that uses pre-recorded weight of vehicle that is done at CVR upon vehicle registration. well as the Optical character reader cameras that are currently at the toll gates for violation enforcement. The system and its database are hosted on the cloud. As for privacy preservation between reader and tag steganography techniques will be used. Text steganography will be the best option considering the limitation in processing capabilities of the tag and also the limitation in the tag's memory

The components of the proposed automated solution will be as follows:

1.Automatic Vehicle Identification(AVI) –vehicles are automatically identified using RFID technology to determine who owns the vehicle, so that the toll amount is charged and deducted from the rightful owner's account.

2. Automatic Vehicle Classification- vehicles will be automatically classified using their weight recorded during registration and also type of vehicle. Different classes will have different toll fees that are supposed to be paid. The vehicle type may include light vehicles like the passenger car or heavy vehicles like recreational vehicles. A vehicle's class can be determined by the physical attributes of the vehicle. In this instance we will stick to what is currently used at manual toll plazas in Zimbabwe, which is a vehicle is classified according to its mass. Classification is done when the vehicle is registered at CVR and not at the toll plaza and the details entered into the cloud hosted database together with all the required vehicle details.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022

3. Payment – after the vehicle has been identified and classified an amount has to be deducted from the vehicle owner's account.
4. Video Enforcement system(VES)- the system (VES) captures images of the license plates of vehicles that pass through an electronic tollbooth without a valid RFID tag or insufficient balance. This system already exists at ZINARA toll plazas, it just needs to be adopted and integrated to the proposed automated toll collection system. Securing the communication between reader and tag will be done using text steganography using Unicode zero width characters. Information hiding is done at the time of vehicle registration that is in this instance at CVR.

V. EXPERIMENTAL SETUP

In this case our test subject is the automated toll collection prototype that was built to test how effective the proposed solution is in meeting the stated objectives.
The Arduino mega 2560 /Wi-Fi microcontroller is the heart that controls all operations to be carried out by the system. All components are connected to this microcontroller.
1.RFID RC522 reader/writer:
In this prototype it is used to read information (unique ID) from the RFID tag and pass it to the Arduino Mega 2560 MCU which is then send to the cloud using an on-board ESP8266 Wi-Fi module for authentication and checking if the account linked to the unique ID on the tag has the required balance to pay the toll fees. It's reading distance is 5cm. It uses the frequency range 13.56 MHz ISM band. The reader(RC522) is connected to the MCU.
2. Flying fish sensor MH8 series:
In this prototype it is being deployed as an object detection sensor.in this scenario it detects the presence of a vehicle and I calibrated it using C code to detect an object in the range of 10cm.
3. Buzzer
It is used in the prototype to produce an audible sound when a tag has been read. It will produce a shot beep when a tag read has enough balance to effect toll payment and a long beep when the tag read has insufficient balance.
4. Ultrasonic Proximity Sensor HC-SR04:
In this prototype it is deployed as a proximity sensor to detect that an object has completely crossed the tollgate barrier and message is sent to MCU so that an interrupt signal is sent to the servo motor to now close the barrier(gate).
5. Micro Servo motor SG90:
It is used to open and close the barrier on the gate in this prototype, thereby controlling what should pass through and what should not.

6. LCD 1602
In this prototype the liquid crystal display is used to display messages for the user such as "insufficient balance", ''tag not found "and "authorised". It is a 16*2 LCD that means it can only display a maximum of 32 characters from the system.

7. Inbuilt ESP8266 Wi-Fi module:
In this prototype it is used as a gateway from MCU to the cloud database and system, and from database to MCU. It is also being used to send sms messages to vehicle owners 'numbers in this instance I used Blue Dot sms gateway to send messages about transactions to vehicle owners numbers.
8. Power supply 12v-3A
This is used to supply power to the MCU using UART port that is on the MCU and also supplying power to different components that are connected to the MCU.
9. LEDs
These are special type of diodes that glow when current passes through them. In this prototype they are used to indicate whether a vehicle can pass through or not. The red led is on by default, while the green only turns on when the tag scanned on the vehicle is valid and the account linked to it has sufficient balance giving greenlight to the vehicle to pass through.
10. Breadboard
It is used in this scenario to build the circuits for the prototype instead of using printed circuit boards that requires soldering components to the printed circuit board. Being used to connect different components to the MCU.
11. 330 ohms Resistors
These are used in this prototype to step down the voltage that is being supplied to the LEDs which will blow if the voltage is passed direct to them.

VI. A SUMMARY OF HOW THE PROTOTYPE FUNCTIONS

when a vehicle(object) approaches the toll plaza an IR Flying fish sensor detects that an object is approaching and the reader scans the object for the availability of tag, if available the unique tag id is sent to the cloud database to check for validity, if valid its account balance is checked. If the account balance is healthy, the required amount is deducted from the account depending on the vehicle class and an interrupt is send by the microcontroller to both the servo motor to open the gate and the integrated Wi-Fi module to send an sms to the mobile phone of the account holder with the details of the transaction done. In this case the sms gateway that we are using with the Wi-Fi module is Blue Dot sms. If insufficient balance is detected the user is directed to go to another gate to make manual payment. Also if no tag is detected after 5 seconds the user is directed to go to a certain gate that does manual payments and the gate does not open.

VII RESULTS AND DISCUSSION

Environment:
1.Econet 4G network was used using a Samsung S5 phone as a hotspot and network signal strength was excellent was used to connect to the cloud database
2. Dandemutande Wi-Fi using a Wi-Fi router was used to connect to the cloud database.
* note that, overally almost the same results were obtained using the different environments stated above.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 11 Issue 03, March-2022

In this scenario a set of experiments were done on the prototype to evaluate the proposed system. In the proposed system when a vehicle(object) approaches the toll plaza an IR Flying fish sensor detects that an object is approaching and the reader scans the object for the availability of tag, if available the unique tag id is sent to the cloud database to check for validity, if valid its account balance is checked. If the account balance is healthy, the required amount is deducted from the account depending on the vehicle class and an interrupt is send by the microcontroller to both the servo motor to open the gate and the integrated Wi-Fi module to send an sms to the mobile phone of the account holder with the details of the transaction done. In this case the sms gateway that we are using with the Wi-Fi module is Blue Dot sms. If insufficient balance is detected the user is directed to go to another gate to make manual payment. Also if no tag is detected after 2 seconds the user is directed to go to a certain gate that does manual payments and the gate does not open.

The experiments done were categorised as follows:

i. Experiments for registered vehicles with sufficient balances.
ii. Experiments for registered vehicles with insufficient balances
iii. Experiments with vehicles that have no tags

1.Observation for registered vehicles with sufficient balances

It has been observed that when a registered vehicle approaches the toll plaza area a sensor senses the presence of a vehicle and the RFID reader scans for the tag and the scanned tag unique id is sent to the cloud database to check for validity and adequacy of account balance. the amount is deducted from the account and the servo motor opens the gate for vehicle to pass and an sms is sent to the account holder's mobile number and an ultrasonic proximity sensor is used to detect that the vehicle has passed and the gate can close. When the network connection is good this whole process takes only 5 seconds to complete.

2. Observation of registered vehicle with insufficient balance

It has been observed that when a registered vehicle with insufficient balance approaches the toll plaza area, it is detected by the object detection sensor and the reader scans the tag and send the unique code to the database on the cloud to check whether it is a valid tag and the state of the balance in its account. In this scenario it has insufficient balance, the LCD screen displays and instructs the user to go to a specified gate to make payment manually. The gate does not open and after one second the system waits for another vehicle. This takes about 4 seconds to complete.

3. Observation of a vehicle without a tag

It has been observed that when a vehicle that does not have a tag approaches the plaza area, the object detection sensor detects the presence of a vehicle and the reader begin a scan for a tag. After one second if tag not found the user is directed to go to a specified gate to manually make the payment. This process only takes two seconds as shown by results of the test.

VIII. DISCUSSION

With the current system it takes a minimum of 45 seconds to make the actual payment only (Skyline Tollgate) without taking into consideration waiting time in the queue, which can range from a minimum of 300seconds (5 minutes) depending on the time of the day. In reference to the results produced by tests from the prototype it takes only 5 seconds to complete the whole process of identifying a vehicle, reading the unique Id on the tag, authenticating, verifying the balance, deducting correct amount from the account, sending an sms to the account holder and opening of the gate for the vehicle to pass and finally closing the gate when the vehicle has passed.This shows a significant reduction in time spent and the toll plaza from 345 seconds to 5 seconds.

So the percentage reduction in time is (345-5)/345 *100=98.6%, which is very significant.

So when travelling at 60km/hr and assuming the reading distance of the RFID reader is 40m it will take you approximately 2.5 seconds to reach the barrier so it is highly possible that the vehicle will not stop to make payment but payment will be made while the vehicle is in motion.

IX. CONCLUSION

In this report the automated Toll system provides a method to significantly reduce congestion around the toll plaza and efficiently collect revenue without polluting the environment. With this system, vehicles do not need to first stop and make payment but all the necessary processes that are currently being done manually with the current system are automated. It will take a minimum of 5 seconds to complete all the necessary processes for the vehicle to pass through. This system provides security for communication between tag and reader using text steganography that uses zero width characters. Overally the system will solve the problem of congestion that that has an effect of causing environmental pollution, leakages in revenue, delay travelling people and loss of fuel. Instead of waiting for a minimum of 5 minutes at toll plazas vehicles no longer need to wait at any toll plaza but payment will automatically be done while the vehicle is moving.

RECOMMENDATIONS

We recommend that when the system is put into production every toll plaza should be linked to the internet using fibre optic cables and also a vxlan should be created for the 26 toll plazas in Zimbabwe. The already existing OCR system being currently implemented by ZINARA should be integrated to the proposed system to cater for Violation Enforcement where vehicles without tags are captured and given time to acquire RFID Tags from central vehicle registry(CVR).

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