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RFID Ticketing Solution for Improved Railway System in Nigeria

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Abstract

The Design and Implementation of a model contactless smart card railway ticketing solution is presented in this paper. An appropriate ticketing system is one of the necessary means to ensure optimal revenue collection as a rail station operator. In Nigeria, manual ticketing involving plain paper tickets are still in use as at the time of this research. This system has many disadvantages which include the difficulty in tracking sales, very poor access control, difficulty in offering benefits to customers and the high cost of providing security for the trains. The system proposed is easy to use and manage. It makes use of the Contactless Smart MIFARE S50 card which has a three – step authentication method and also has 15 sectors to allow for use in multiple applications apart from rail transport ticketing. A model to show how the system will work was implemented using the Intel Galileo Generation 1 Board as the controller.

Keywords: *contactless smart card, RFID, e-tickets, railway ticketing, Nigeria*

1. Introduction

The importance of Rail Transport cannot be overemphasized in Nigeria especially given the country's population. A well-organized Rail Transport System in Nigeria can go a long way in providing an efficient means of transporting large numbers of people and goods between and within cities. Therefore, it is very important that there is a robust ticketing system in place.

There are many Transport ticketing solutions available these days due to new ICT technologies. Researchers and transport operators alike are interested in these new technologies because of their numerous advantages. The major issue faced by Transport operators is in reducing congestion at both the entrance and exit of their vehicles. The choice of new technology now hinges on how fast a technology can process payments and grant access to the passengers. In this paper, a contactless smart card is proposed for an access control and micropayment facility to reduce the cost of operations and increase revenue generation for business sustainability. Contactless Smart Card/Device is an RF (Radio Frequency) based tag that normally operates at a frequency of 13.56MHz. This device can only be read by an appropriate reader at a distance that is less than 10cm. It normally has a microcontroller or microprocessor for processing and storing information, and an antenna for transmitting and receiving information from a suitable reader. It can be found in a card, inside a watch, a key fob, documents or inside bracelets. The contactless smart cards support a lot of security structures for guarding payment, identity and access control applications. Contactless Smart Card technology is being used all around the world for applications that need to protect personal information and supply fast secure

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transactions such as access control, documentation, toll collection, micropayments and automatic transport collection.

The allure of using contactless smart cards in automatic transit collection resides in the fact that for customers, it offers appropriate and fast service (*i.e.*, how they pay and access the trains), while for the rail operators, it enables them to provide high level of proficient service delivery to their clients, and a robust ticketing system without fraud.

2. Literature Review

Rail Ticketing Scheme adopted by Operators determine to a large extent the amount of income generated. In Nigeria, the rail ticketing scheme is manual and makes use of plain paper for tickets. Passengers purchase tickets for each single journey from the rail station then board the train. The disadvantages that arise from this setup include but are not limited to the following:

- Paper tickets are easily damaged;
- Paper tickets cost more to produce and they are not easily recyclable;
- There is the risk of losing such a ticket without ease of reimbursement from the transport operator;
- There is the possibility of waiting in long queues in order to purchase a ticket;
- There is difficulty in proper access control and this leads to high operational cost;
- There is difficulty in collating passenger data for planning.

All over the world, in order to combat these disadvantages, Rail and Transit Operators started automating their rail ticketing services. They have used technologies such as Bar Codes, Magnetic Stripe Cards and RFID (Radio Frequency Identification) Tags. They are easier to use, cheaper to maintain and similarly their use have made it easier to retain customers. Bar codes and Magnetic Stripe Card do have disadvantages that are not encountered when using the contactless smart cards. The contactless smart card can be used in access control and micropayments hence can be used in automating the rail ticketing scheme in Nigeria.

A contactless smart device contains a microcontroller, an RF interface, internal memory, can perform complex functions (encryption and security functions) and provide access [1]. This technology is based on an international standard that limits its reading range to approximately 10cm. The RFID reader sends out radio frequency electromagnetic waves; when a contactless smart card passes within its range, the antenna of the card already tuned to receive these waves, activates the chip in the smart card and a wireless communication channel is created between the reader and the smart card. The smart card validates the reader and allows the reader to validate the smart card. Then there is an exchange of information. All of these can take place in less than 0.5 seconds.

The following characteristics of contactless smart cards make them desirable for applications that require security and privacy of information stored and transmitted [1]:

- Mutual Authentication: Certain contactless smart card can verify that the reader is authentic and also prove its authenticity to reader before transaction occurs.
- Strong Information Security: Contactless smart cards can be encrypted for eavesdropping prevention.
- Strong Device Security: They have a variety of software and hardware capabilities to detect tampering.

3. Related Work

A lot of research has been done in the use of contactless smart cards for transit ticketing and access control. RFID has been used in Access Control and security systems as documented in [2] for an RFID based security system for industries, companies among others. It consists of an RFID tag, reader, Liquid Crystal Display (LCD) and a buzzer. If the data contained in the card is the same as that in the database then the buzzer alerts the personnel that he/she has been granted access as the door opens. In [3] an RFID based security and access control system for a University Hostel is presented. The system designed made use of both RFID and biometrics to authenticate a student. RFID readers were installed at the entrance of the hostels with cameras; the reader detects the number stored in the RFID card while the camera takes a picture. These two data are then crosschecked with the information stored in the database and if they match then access is granted.

In [4] an RFID based ticketing system for the Bus transport for Dhaka, Bangladesh is presented. This system has 2 parts. The first part is used for bus identification; for this purpose, 2 tags are placed at the front and rear of the bus. These two would be used for indication of arrival and departure times of the bus. The second part of the system is for the ticketing, here a reader is placed inside the bus where the passenger can display his/her authorized RFID tag and then board the bus. The system proposed by [5] makes use of both RFID and cyclometer to provide a ticketing system for a user based on distance travelled on a bus. This design is an improvement on previous designs that required passengers to input their destination before boarding the bus. With this system, a passenger only needs to display their RFID tag at the beginning and at the end of their journey. An automatic gate machine based on the RFID technology is reported in [6]. The design consisted of RFID tags and readers, database system and a door controlled by the system. However, the card used in this design is an RFID tag and not a contactless smart card.

[7] Discusses the shortfalls of existing security protocols and then proposes solutions for using known cryptographic techniques to preserve privacy on e – tickets. They noted that there are 3 major attacks on an RFID based e – ticketing system and they are *impersonation* (which involves an attacker simulating a token issued to a customer); *tracing* (this involves obtaining movement information on passengers in transit); and *Denial of Service attacks* (Here attackers can sabotage transit operators by denying an authorized passengers access to the service). They proposed a solution to prevent cloning by using physically Un-clone able Functions (PUFs).

In [8]researchers proposed a secure RFID system that supports security properties such as secure authentication, correct billing and privacy and can prevent attacks. This system consists of two protocols. In Protocol 1, an RFID card doesn't perform any computation; it needs the vendor's machine (reader) to be trusted. In Protocol 2, RFID cards need to perform computation so there is no need for trust here.

While considerable research has been done on using contactless smart cards for transit in the developed nations, some of the factors that were not considered there can affect the success of such systems in Nigeria. Such factors include the lack of steady Internet facility nationwide and the largely unbanked populace. Also the system were just designed for transit purposes only, meaning that a customer would be required to have multiple cards to access other services that make use of contactless smart card. Then the cards used in the research above don't have adequate security features, they also have small memory making it near impossible to use them for multiple purpose.

4. RFID Ticketing Solution

The RFID Ticketing solution proposed in this research allows passengers without bank accounts to use the system. The system designed has the following features:

- It will be used for both railway transit, other modes of transit, and for minor retail outlets;
- It will use both offline and online card authentication methods to allow for card usage even when the Internet service is not available;
- The card used will be cheap to purchase and also use strong authentication for security purposes;
- The card is to be optimised for railway transport loyalty points of 1 free journey for every 10 journeys paid for using the card;
- A maximum daily amount to be loaded on the card is ₦10,000 in order to mitigate risks.

5. System Description

The System has a Contactless Smart Card-based Gate Machine located at a Railway Station. The Gate Machine is to be located before the platform and is an access control machine that either allows a passenger to get on to the platform or not.

The passenger approaches the Gate Machine and taps the Machine with his/her contactless smart card, the gate machine checks for the money balance on the card and then if it has the minimum balance allowed. If it has, then access is allowed, if not then access is denied. When the passenger comes down at his/her destination and taps the gate machine at that rail station, the gate machine deducts the appropriate fare and saves the new balance on the contactless smart card.

The System designed consists of 3 rail stations – Enugu, Port Harcourt and Aba.
Three card readers are used to represent 3 stations, Enugu, Aba and Port Harcourt Stations. The cost for a ride between Enugu and Aba is 500 naira while a ride between Aba and Port Harcourt is 150 naira. Enugu to Port Harcourt is 650 naira. The System also has a **Loyalty Point Feature**. For every 10 trips a customer takes, the system offers him/her 1 free one in return. The minimum amount a customer can have on his/her contactless card before being allowed access to the train platform is ₦1000.

5.1. Sample Use Cases

Location 1: This represents Enugu as a take-off location. When a passenger swipes his/her card at the Enugu Station, the system saves the location on the card. The passenger can travel to Aba so the System either offers free journey or deducts 500 naira from the card; or to Port Harcourt and the System either offers free journey or deducts 650 naira. If the passenger goes across the Gate at Enugu Station and decides not to continue the Journey, he/she can go back without paying any amount.

Location 2: This represents Aba as a take – off location. When a passenger swipes his/her card at Aba Station, the system saves the location on the Card. The passenger can travel to either Enugu so the system either offers free journey or deducts 500 naira or to Port Harcourt Station and the system either offers free journey or debits 150 naira. If the passenger goes across the Gate at the Aba Station and decides not to continue the Journey, he/she can go back without paying any amount.

Location 3: This represents Port Harcourt as a take – off location. When a passenger swipes his/her card at the Port Harcourt Station, the system saves the Location on the Card. The passenger can either travel to either Enugu; so the system either offers free journey or deducts 650 naira, or to Aba and the system either offers free journey or debits 150 naira. If the passenger goes across the Gate at the Port Harcourt Station and decides not to continue with the Journey, he/she can go back without paying any money. Figure 1 shows the Block diagram of the system.

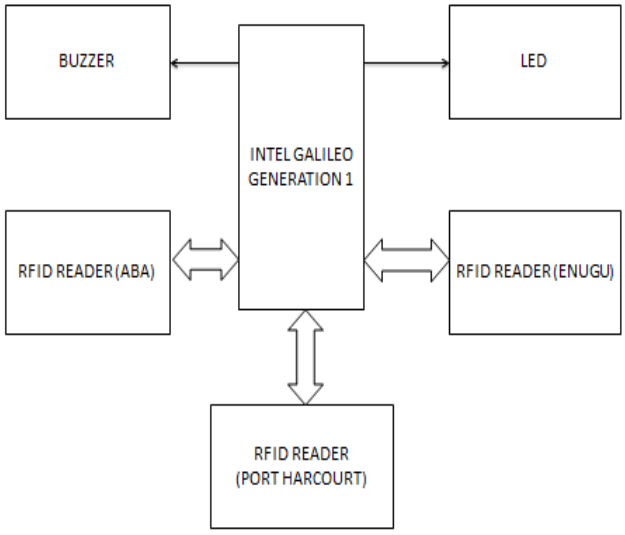

Figure 1. Block Diagram of the Railway System Ticketing Prototype

6. Results and Discussion

The prototype circuit is shown in Figure 2. The Arduino IDE has a Serial Monitor. This Serial Monitor can be used to view the changes in the Information stored in the MIFARE S50 card as it is being used as rail ticket.

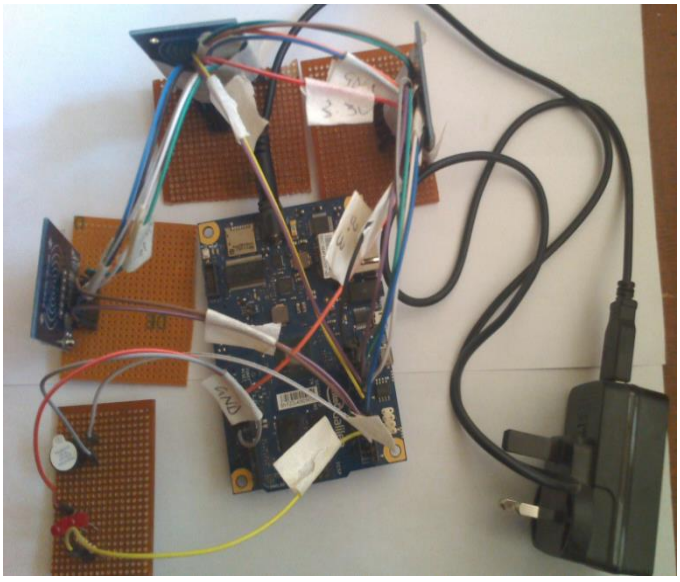

Figure 2. Railway System Ticketing Prototype

6.1. Passenger at Enugu Station

The Serial Monitor display of the various actions the Passenger at Enugu station can take as discussed earlier is shown in Figure 3 and Figure 4.

```
Location is at:
0
Passenger is at Enugu Station ready to board
Loyalty is:
1
1
Naira Amount is:
10001
10001
Card Reader 1 was identified
blockLocation was written
Card has been written with Location 1
```

Figure 3. Passenger at Enugu Station for Take-off with Naira Account

```
                Location is at:
0
Passenger is at Enugu Station ready to board
Loyalty is:
10
10
Naira Amount is:
10001
10001
Card Reader 1 was identified
blockLocation was written
Block written with Location 1 info
```

Figure 4. Passenger at Enugu Station for Take-off with required Loyalty Points

6.2. Passenger at Aba Station

For a passenger who gets to Aba from Enugu and doesn't have enough loyalty points, but has 9351 Naira on the card; the gate machine deducts 650 naira from the card and saves it. Loyalty points are increased as well. Then the customer can leave the station. The Serial Monitor display for this action is shown in Figure 5 and Figure 6.


```
Location is at:
1
Passenger is at the Aba Station
The Naira Amount is:
9351
9351
Loyalty is:
2
2
The Naira Amount is:
8701
8701
blockLocation was written
```

Figure 5. Passenger at Aba Station from Enugu Station paying from Naira Account

If on the other hand, the passenger has up to 10 Loyalty points; the gate machine does not deduct a fare but grants access while reducing the loyalty point back to 0.

```
                Location is at:
1
Passenger is at the Aba Station
The Naira Amount is:
10001
10001
Loyalty is:
10
10
blockLocation was written
blockLoyalty was written
```

Figure 6. Passenger at Aba Station from Enugu Station using the Loyalty Point for Payment

6.3. Passenger at Port Harcourt Station

For a passenger who boards the train at the Aba Station and travels to Port Harcourt and does not have enough loyalty points, then the gate machine will deduct the 500 naira from the card. Access to leave the Port Harcourt Station is then granted. The Serial Monitor display for this action is shown in Figure 7 and Figure 8.

```
Location is at:
2
Passenger is at Port Harcourt Station
Loyalty is:
2
2
Naira Amount is:
9501
9501
Naira Amount is:
9001
9001
blockLocation was written
```

Figure 7. Passenger at Port Harcourt Station from Aba Station paying from Naira Account

If the customer has enough Loyalty Point, He/she gets access to leave the station while the Loyalty Point gets cleared back to zero. There is no change to the Naira Account Balance.

```
Location is at:
2
Passenger is at Port Harcourt Station
Loyalty is:
10
10
Naira Amount is:
10001
10001
blockLocation was written
blockLoyalty was written
```

Figure 8. Passenger at the Port Harcourt Station from Aba Station paying with Loyalty Points

6.4. Processing Timing: The time of processing a single passenger is also of utmost importance in using a contactless smart card. It is necessary that Automatic gate machine processes a single transaction accurately in less than a second in order to be handle rush hour traffic. The average processing time measured at the automatic gate machine from presentation of card to beeping of the buzzer was 2.64 seconds.

7. Conclusion

Contactless Smart card can be used to replace the use of smaller denominations of cash and eliminate the need to have these denominations in your wallet and also the time wasted in searching for change/balance by small scale retailers and transit operators. Contactless Smart Technology has been implemented in many developed countries all

over the world since 1997. However, in Nigeria, the technology is still at its infancy. This technology has the capability to solve a lot of problems encountered not only in transit operation but also in the small scale retailing business.

The aim of the project to design and implement an alternative way to provide ticketing for the Nigerian Railway Corporation was achieved. This System is made up of contactless smart cards, contactless smart readers, Intel Galileo Generation Board 1, buzzers and LEDs. The system worked as specified when tested.

The use of a contactless based rail ticketing system if implemented will eliminate many of challenges faced by the Nigerian Railway Corporation presently. It will enable the Corporation to automate its ticketing processes, thereby saving money and improving its services. With the contactless smart card, the corporation can then offer up loyalty points to its customers, rewarding them and encouraging them to use the service.

8. Recommendation for Further Work

The following items are recommended for implementation in order to improve upon the work:

Near Field Communication integrated in Mobile Devices can be used in addition to the contactless smart card. This will enable customers to use their mobile phones for payment.

There are still security issues with contactless smart cards. Research can be conducted to develop better cryptographic systems. The system produced in this work while making use of a contactless smart card that supports multi-application, did not make use of all the functionalities that the contactless smart card has to offer. Improvements can include adding a retail market payment application to the system.

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