Design and Implementation of a Radio Frequency Identification based Enhanced Electronic Voting Machine (EEVM) for Free and Fair Elections

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ABSTRACT
Critical in choosing credible candidates to govern a nation such as Nigeria, is the quality of voting method or system adopted in the voting process. Owing to the manual ballot system of voting being employed in Nigeria, the existing electoral process is characterized by various integrity impairments. Most of the electoral impairment issues can be prevented by the introduction of electronic voting (e-voting) system. To mitigate these challenges therefore, an enhanced electronic voting machine (EEVM), employing radio frequency identification with additional verification process, has been successfully designed and implemented. The results obtained show that this device is able to minimize the possibility of rigging in Nigerian elections. It also eliminates the need for much manual work. The cost of the device is relatively low and the system is very convenient to use. Moreover, this system is locally designed and manufactured. Some of the advantages recorded in this proposal include: denial of access to register and vote to non-citizens and the under-aged, improved security of equipment and personnel, lower risk of human and logistic errors, improved accessibility, greater accuracy as well as faster collation of results. The incorporated authentication mechanism affords additional and enhanced security by granting eligible voters the opportunity to vote only once. By assigning unique identification (UID) numbers to voters' cards and capturing the bank verification numbers (BVNs) or national identification numbers (NINs) of eligible voters, the integrity of future general elections in Nigeria is assured. We therefore, recommend that this device be deployed by the Independent National Electoral Commission (INEC) for the 2023 general elections in Nigeria.

General Terms
Enhanced electronic voting machine, free and fair elections, integrity impairments, verification process, authentication mechanism, unique identification number, electoral process

Keywords
Open ballot, secret ballot, e-voting, voting process, voter's card, radio frequency identification, integrity, bank verification number, national identification number

1. INTRODUCTION
Critical in choosing credible candidates to govern a nation such as Nigeria, is the integrity of the voting method or system adopted in the voting process. Elections in Nigeria been marred by all manner of malpractices arising from the faulty voting process [1]. The traditional methods of voting have either been by open ballot, where voters queue up for their preferred candidates or by secret ballot, in which voters choose candidates by casting votes, normally on paper for their preferred candidates. The open ballot system is more difficult to coordinate but results are not easily manipulated because each voter's intent is known to everyone at the venue. For obvious reasons, the secret ballot system has always been manipulated.

The existing Nigerian electoral process is characterized by various integrity impairments, such as: participation of non-citizens and under-aged children, high cost of conducting elections, snatching of ballot boxes and ballot papers, voter impersonation, wasting of voter's time, multiple voting, ballot stuffing, inaccurate counting of votes, result manipulation, and so on. Most of these electoral impairment issues can be curtailed or prevented by the introduction of electronic voting (e-voting) system (EVS). An EVS uses electronic means to handle activities in a voting process. Electronic voting machines (EVMs) are used for accreditation of voters, casting and counting of votes, reporting or displaying election results as well as producing and maintaining documentations required for audit and litigation purposes. Electronic voting, which could be done at a polling station or a remote station ensures security, reliability, smooth conduct of elections as well as the safety of equipment and personnel [2, 3, 4, 5].

For an effective and credible voting process in future elections in Nigeria, a radio frequency identification (RFID) based enhanced electronic voting machine (EEVM) with additional verification process is hereby designed and implemented. The system consists of hardware and software designs. The hardware uses an Arduinonano microcontroller, a radio frequency card or tag to store valid information of the voter, an RFID card reader to read the information stored in the card, a liquid crystal display unit to display the details captured by the machine, a secured digital (SD) card to back up vital records and push buttons to enable a voter select his/her party of choice. The RFID reader and tag are used to authenticate voters and verify their identity to ensure that no false entry is made. C++ language was used to write the source codes [5, 6, 7, 8, 9, 10, 11, 12].

The enhanced e-voting system incorporates a mechanism that captures the voter's national identification number (NIN) or bank verification number (BVN) to ensure that only citizens and eligible Nigerians are registered and accredited for the voting process. The proposed EVM will therefore ensure a fast, free and fair (FFF) electoral process.

2. RELATED WORKS
RFID technology and microcontrollers have been used for

various purposes in various systems. The deployments include access control in restricted environments, security/surveillance monitoring systems, business/commerce, object tracking, car/bike hiring, class/meeting attendance, seat reservation and e-voting systems [13, 14, 15, 16, 17, 18, 19, 20]. Different e-voting machines have been deployed in different democratic nations over the years for polling-place and remote-place e-voting. The different e-voting systems employ different technologies and levels of authentication, such as passwords, fingerprints, voter identification number (VIN) and face recognition, as requested by the users and determined by the designers. [21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31].

Though many works have been proposed in the design and deployment of e-voting systems at various levels of elections across the nations of the world, none has been designed and deployed for the national electoral process in Nigeria. Owing to the heightened insecurity arising from the uncontrolled influx of foreigners into the country, using only biometrics and passwords could amount to capturing individuals who are not citizens as well as under-aged voters. Hence, BVNs or NINs was adopted in this work as an appropriate enhancement and means to identify every legitimate voter so as to curtail the inherent malpractices in the Nigerian national electoral process.

3. DESIGN METHODOLOGY AND SYSTEM IMPLEMENTATION

The methodology comprises the hardware design and software design. The designed e-voting system was implemented using two processes, namely, the authentication and verification (or accreditation) process and the voting process.

3.1 Hardware Design

The block diagram representationof the hardware circuitry is shown in Figure 1.The microcontroller unit is a complete and breadboard-friendly Arduino Nano board based on the ATmega328 (Arduino Nano 3.x). It is powered via the Mini-B USB connection, 6-20V unregulated external power supply or 5V regulated external power supply. It is programmed with Arduino Integrated Development Environment (IDE) software. It has 16 MHz clock speed and 32kB of flash memory[12].

The power supply unit used is a 9-volt, 1-ampere battery cell, which provides power to the hardware circuitry. A 9-volt, 1-ampere power pack can also be used. It incorporates an LM7805 voltage regulator that regulates the input voltage of 9V and gives an output voltage of 5V required by the microcontroller.

A 125 KHz, 64 bit, MCU ATmega 168 RFID reader and tags with a range of 5cm to 8cm were used. The RFID reader is used to receive data from the RFID tags without any contact between the reader and the tags. The output of the RFID reader is serial and is connected to the receiver (RX) pin of the controller. The communication baud rate is 9600. The tags contain antennas which are used to communicate and transmit data to the RFID card reader. The reader is a transceiver and can read and write to RFID tags or cards. It can detect registered and unregistered cards. Its internal memory can register up to 100 RFID cards[12].

A 20x4 liquid crystal display (LCD) screen was used as the output display unit of the system. The micro SD card is used to back up the data that comes from the RFID reader, which were read from the tags. It therefore adds mass storage and data logging enhancement to the designed system. The buzzer serves as an indicator for invalid votes or any error made at any point during the voting process. The push buttons are used to select a party of choice by a voter during the voting process.

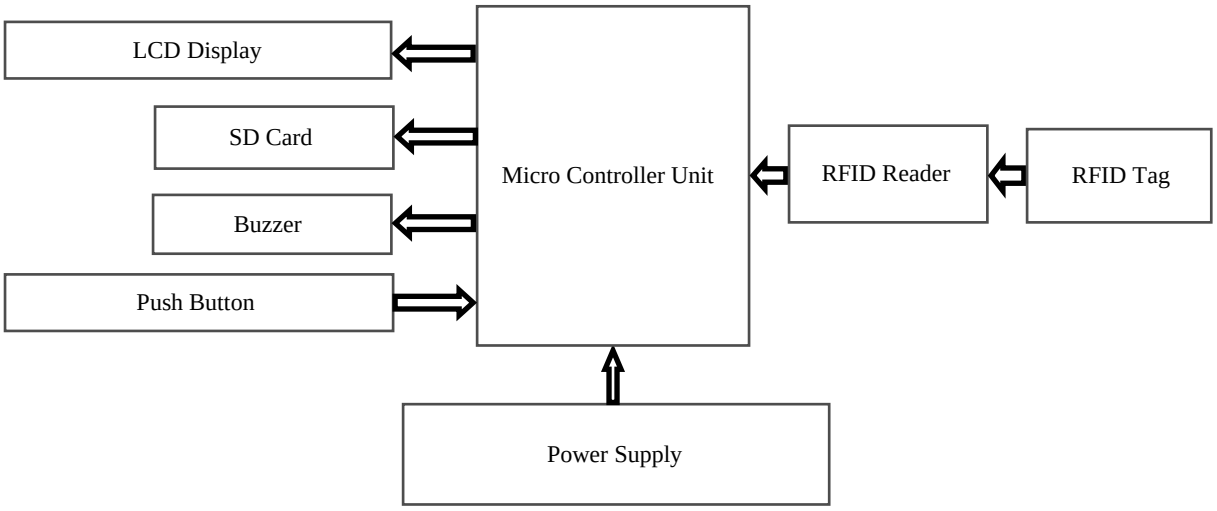


Fig 1: Block diagram description of the proposed e-voting machine.

3.2 Software Design

The software design was done using C++ language over the Arduino Integrated Development Environment (IDE). The IDE converts the C++ code (.cpp) to machine code (. hex) which the controller uses [12].

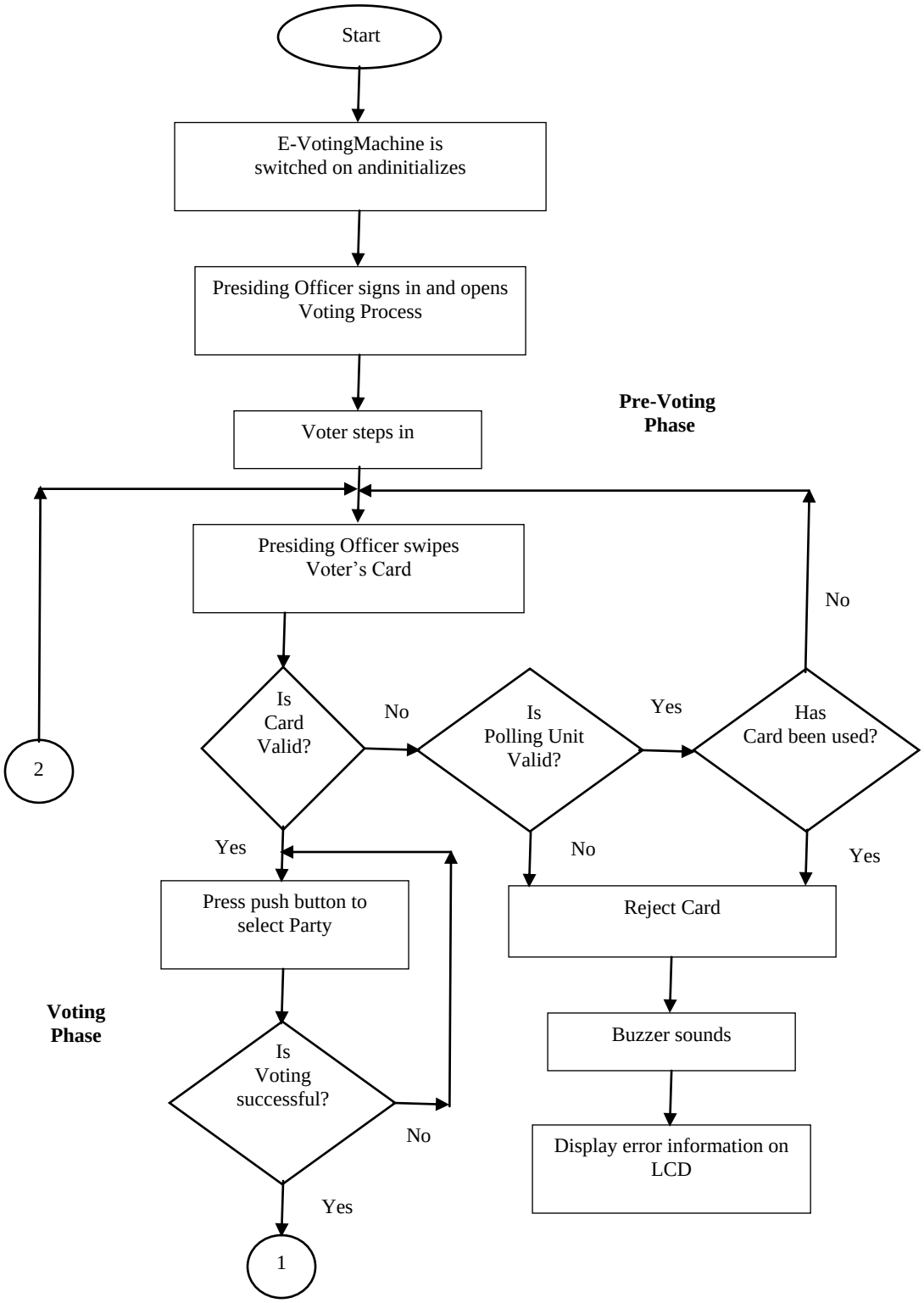
3.3 The Authentication and Verification(or Accreditation) Process

A three-level verification process is adopted in this prototype. Every valid voting card or tag has a unique identification (UID) number as well as the name and BVN or NIN of the voter, which are registered to a particular polling station and the information saved in the memory of the microcontroller.

The cards registered to a polling station are programed to be used for accreditation. The voter is required to provide this card on the day of election to be eligible to vote.

The Authentication process involves the verification of the voting cards that will be used for a particular voting process. At authentication, the voting card is held for about three seconds towards the reader unit. The system verifies the card's UID number, voter's name and BVN. These data must match those already stored in the microcontroller during registration. Once validated, the user is qualified and granted access to cast his/her vote. All the data captured in this process are recorded and backed up in the micro secure digital (SD) card.

Two polling stations, Polling Unit 1 and Polling Unit 2 were programed in this implementation. Table 1 shows the vital information of some of the voters that are contained in the voter's card, which were programmed into the microcontroller. The bank verification and unique identification numbers captured were arbitrarily chosen.



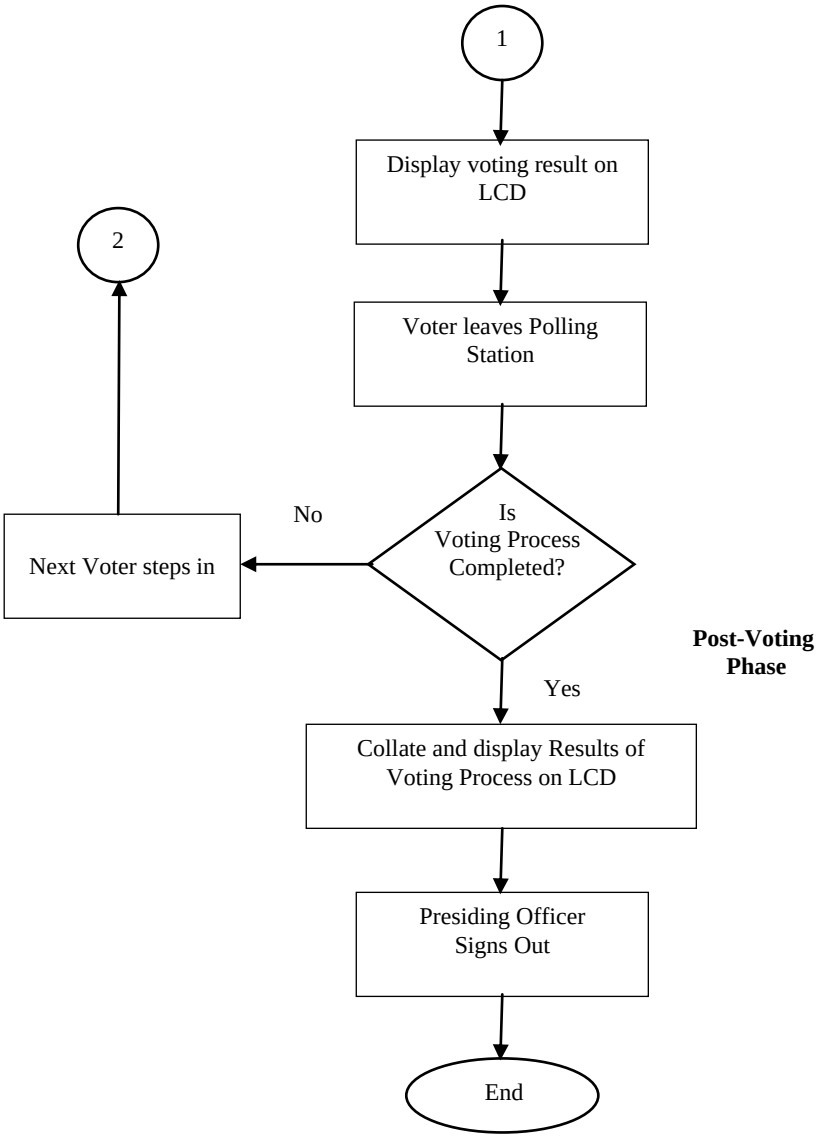


Fig 2: Voting process flowchart.

Table 1: Voters' vital information.

S/N	Voter's Name	Voter's BVN	Card's UID Number
1	Dr. Dike	2289106746	90, 81, 229, 63
2	AkhereOkodugha	0224564125	153, 211, 149, 178
3	Alex O. Gift	2546725636	215, 234, 128, 99

For this implementation, seven voters were programed into the microcontroller. Six voters were registered in Polling Unit 1 while Alex O. Gift was registered in Polling Unit 2. The list of registered political parties are shown in Table 2.

Table 2 List of registered parties

PARTIES	PDP	APC	YDP	ADC

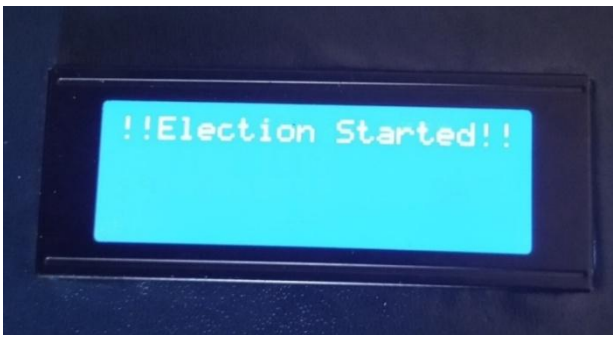
3.4 The Voting Process

The voting process was demonstrated in Polling Unit 1. As the RFID card reader senses the voter's UID, it sends the information to the microcontroller. The microcontroller checks whether the received voter's UID belongs to the Polling Unit or not. If yes, the microcontroller checks if the voter has voted or not. If not, it makes the voting machine ready for voting. But if the card has already been used, the microcontroller will detect it and send a sound signal via the buzzer, indicating "card used previously" on the LCD display. If the card was registered to Polling Unit 2, the buzzer will also sound and "card rejected, Polling Unit 2" indicated on the LCD display. This process is repeated for every voter. The voting process flowchart is shown in Figure 2.

4. RESULTS AND DISCUSSION

The system implementation starts with the Presiding Officer validating the e-voting machine or signing in with an RFID master card. This displays the status of the machine on the LCD with each contesting party having zero votes. At this stage, the machine is ready for voting to start. This is the enhanced e-voting machine's validation implementation. The displayed results are shown in Figure 3.

(a)



(b)

(c)

Fig 3: Machine validation implementation

In the voter's card validation and voting implementation, the voting card is inserted into the RFID card reader. The status of the card as well as the name and bank verification number of the voter are displayed. If the card is valid, the machine grants access to the voter to vote by selecting the Party of interest. The displayed results are shown in Figure 4.

(a)

(b)

Fig 4: Voter's card validation and voting implementation

If the voter was registered in Polling Unit 2 and has come to vote in Polling Unit 1, the machine will reject the card as shown in the display of Figure 5.

Fig 5: Display of a voter in wrong polling station

If the voting card has been used to vote previously in the same voting process, the machine rejects the card as shown in the displays of Figure 6. This is a case of multiple voting or election rigging.

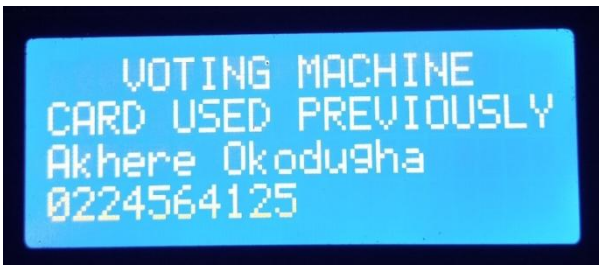
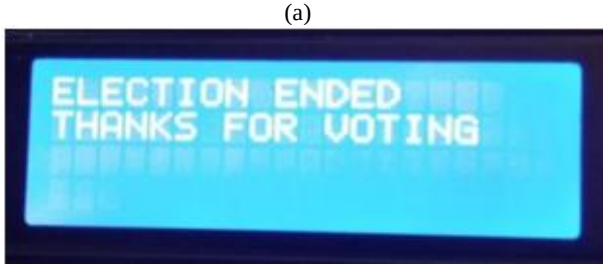


Fig 6: Multiple voting validation implementation

When the voting process is concluded, the results are collated. The collated results display all the contesting parties with their total number of votes. This summary is gotten as the Presiding Officer signs out by inserting the RFID master card into the card reader. This action brings the voting process to an end. The displays obtained are shown in Figure 7. The details of the entire voting process are backed up in the micro SD card incorporated in the enhanced e-voting machine. The results from the various polling stations can then be transmitted through appropriate means to a central data base from where the general result of the conducted election can be released.

(a)



(b)

Fig 7: Summary of results obtained at the end of the voting process

5. CONCLUSIONS

A secure e-voting machine with enhanced verification process has been successfully designed and implemented. The results obtained show that this device is able to minimize the possibility of rigging in elections. It also eliminates the need for much manual work. The cost of the device is relatively low and the system is very convenient to use. This enhanced system has several advantages over the voting system currently used in the Nigerian Electoral Process. Some of the advantages recorded in this work include: denial of access to register and vote to non-citizens and under-aged voters, improved accessibility, credible accreditation of voters, safety of equipment and personnel and faster collation of results, which ensure a fast, free and fair (FFF) voting process. The incorporated security mechanism affords additional and enhanced security by granting eligible voters the opportunity to vote only once. By assigning unique identification (UID) numbers to voters' cards and capturing the bank verification numbers (BVNs) or national identification numbers (NINs) of eligible voters as well as integrating this system with the earlier biometric and password models, the inherent and endemic menace of election malpractices will be completely solved. Hence, the integrity of future general elections in Nigeria will be assured. We therefore, recommend that this device be deployed by the Independent National Electoral Commission (INEC) for the 2023 general elections in Nigeria.

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