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Mobile Phones: A Panacea for the Implementation of E-voting in Nigeria

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Mobile phones have become the most ubiquitous telecommunication technology in developing countries and indeed, the world over, with its penetration rate outstripping those for internet users, fixed phone lines and broadband subscriptions. Services that are offered through mobile phones sometimes referred to as "m-services" could increase the utility of mobile phones to enhance human capabilities. One of such services is mobile voting (m-voting). However, owing to factors such as digital divides, low literacy level, deficits in communication infrastructures, poverty, poor capacity to develop and so on, providing such services except in a highly localized nature, maybe an attendant problem in Nigeria and most developing countries. In this paper, an m-Voting framework was proposed using two of the communication channels of basic phones which are Short Message Service (SMS) and Unstructured Supplementary Service Data (USSD). Basic phones are easy to use and are increasingly able to bypass the barriers of illiteracy and affordability, and they provide access to a wide range of very useful services. The paper investigated the prospects of voting through mobile phones as a substantive voting platform in Nigeria with a view to foster enhanced participation and convenience of voters during electioneering processes.

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1. INTRODUCTION

Electronic voting has been attracting considerable attention during the last years. The interest in e-voting is based on one hand upon interest and attention devoted to e-government, e-democracy, e-participation, to mention but a few. This interest is basically due to advancement in information and telecommunications technologies (ICTs) that have introduced new methods of undertaking many activities by electronic means. Most people are now regular users of mobile phones and keen consumers of ICTs. Also, governments in both the developed and developing worlds have responded by formulating ICT policies, putting in place regulatory frameworks and establishing institutional infrastructures. Their aim is to facilitate and bring order to these "e-developments" that are rapidly changing the world we live in.

On the other hand, interest in e-voting is founded in problems with conventional voting systems. These conventional systems, in which traditional paper is the most popular amongst them, have littered history with examples of elections being manipulated in order to influence their outcome [1]. Allegations of violence, intimidation, ballot stuffing, coercion, under-age and multiple voting, counting error, complicity of the security agencies and the absence or late arrival of election materials often trail elections conducted using this method [2,3,4,5]. Furthermore, the cost and process of manual voting are both increasing geometrically and tedious to execute [6] and there has been a declining participation rate due to: inconvenience of manual system of voting like: inaccuracy in ballot counting and delayed announcement of election results [1,7]; loss of significant time during ballot counting [8]; unacceptable percentages of lost, stolen and miscounted ballot papers, votes loss through unclear or invalid ballot marks and limited accommodations for people with disabilities [1, 9,10].

E-voting is any voting method whereby at least the voter's intention is expressed or collected by electronic means [1,11,12,13]. It encompasses all voting techniques involving electronic voting equipments, including voting over the internet, using booths in polling stations and sometimes even counting of paper ballots [12]. Other terms, for example, e-election (electronic election), i-voting (internet voting) and m-voting are used in order to clarify the specific contents of e-voting. Many countries in the western world have made significant steps to examine and review existing electoral procedures with recommendations that electronic voting be made available to a voting population as a form of voting to guarantee their citizens the freedom to vote, secrecy of the vote, non-modification of the expressed intention of the vote and lack of intimidation during the voting operation.

While the emergence e-voting is well timed to the interest and attention needed for implementing e-government or e-democracy or e-participation and as a significant solution to the problems posed by conventional voting systems, its implementation in developing countries may be flawed given the peculiarity of the contextual ICT infrastructural challenges faced by developing countries. General, developing countries are low ICT resourced countries where poverty, deficit in infrastructures, digital divides and low literacy level are still very significant. However, the increase in affordability, accessibility and adaptability of mobile phones has created a breeding ground for development innovations, which target key areas of economic and social impact. Mobile phones and infrastructures such as mobile telecommunications networks have proliferated [14,15,16]. In Nigeria, for example, the proliferation of mobile phones has resulted in their use even within impoverished rural homesteads. Mobile phones are easy to use, increasingly able to bypass the barriers of illiteracy and affordability, and provide access to a wide range of very useful services. Thus, mobile phones can be considered a good candidate for voting platform in the developing world. Any voting process whereby the voting process/ballot casting is by using a mobile electronic device is referred to as m-voting. M-voting is an additional platform to any e-voting system. It is a mobile government (m-government) initiative with tremendous potentials to enhance democratic participation [17]. It can also serve as an enabler and a convenient way to involve citizens in political decision making. In this paper, an m-Voting framework was proposed using two of the communication channels of basic phones which are SMS and USSD; with intent of providing a platform for an essential ingredient for implementing e-government or e-democracy or e-governance and as a significant alternative solution to the problems posed by

conventional voting systems. The rest of the paper is organized into the following: Section two presents review of relevant literatures to this research; Section three details the research methodologies employed in the development of the m-voting framework; Section four presents the results and Section five summarized and concludes the paper.

2. LITERATURE REVIEW

2.1 E-voting: An Alternative Voting Solution

Elections and voting are fundamental to any consensus-based society. They are one of the most critical functions of democracy. Elections allow the populace to choose their representatives and express their preferences for how they will be governed while voting is a method by which a group of people express their opinion over who will lead them for a specific period of time through electoral processes. Naturally, the integrity of the election process is fundamental to the integrity of democracy itself. Since time immemorial, technology has always influenced and shaped the ways elections are held [18].

Different voting systems that are based on traditional paper ballots and mechanical devices were developed for elections [4]. In traditional paper ballots, voters choose or mark their favourite choices on ballots and place them in boxes, which are sealed and officially opened under special conditions to warrant transparency. The ballots are then counted manually, which is a tedious process that is subject to human error. With voting via mechanical systems, voters make their choices by pulling down on mechanical levers that correspond to their favourite choice of candidates. Each lever has a mechanical counter that reports the number of votes for that position. These machines are no longer manufactured [2]. In Nigeria and most of other developing nations, most elections are conducted using paper ballots. However, there have been countless reported cases of eligible voters being unable or prevented from exercising their right to vote as stated in the Universal Declaration of Human Rights of the United Nations, sometimes due to violence and intimidation, lack of information on physical location of voting poll sites, social discrimination; and by other natural causes like advanced age, physiological disability, terrain, floods, and poor communication infrastructure [5,19].

Most of the issues associated with paper ballots have led to a rapid decline in voters' participation in elections over the years. This is worrying from a democratic point of view in that, if the reasons of the decline are left unchecked, the mandate of those elected to hold the positions might eventually be questionable. Participatory democracy is a major requirement for achieving the millennium development goals (MDGs), particularly, where majority of the citizenry is disenchanted with the electioneering or democratic processes or governance. The primary objective of the MDGs which is reducing poverty in developing nations through the use of ICT requires a lot of innovations. One of such innovations is the implementation of e-voting. The term e-voting is being used from casting of vote by electronic means to asking the internet community for an opinion on a political issue, as well as from tabulating the votes by electronic means to integrated electronic systems from voters' and candidates' registration to the publication of election results [11,20].

Many e-voting schemes have been proposed and used with various degrees of successes in a number of countries during local elections and referenda. These schemes have proven that e-voting can undoubtedly enable voters to cast their vote from a place other than the poll site in their voting district, facilitate the casting of the vote by the voter, facilitate the participation in elections by those who are entitled to vote, widen access to the voting process for voters with disabilities or those having other difficulties in being physically present at a poll site, increased voter turnout by providing additional voting channels, reduce overtime, the overall cost to the electoral authorities of conducting an election, deliver voting results reliably and more quickly amongst many other benefits [5,11].

Furthermore e-voting can enhance polling and votes' security, confidentiality, sincerity and increased cost savings on reduced manpower, logistical materials and tools; and above all instant analysis and reporting. It can enhance accuracy of all valid votes and final outcome; permit voting once for only eligible voters; allow independent verification of all voters; it can also improve voters' turnaround as it flexibly allows a voter to login and vote from any workstation [21]. Therefore, electronic based voting technologies would expand the reach and range of potential voting population.

2.2 Why Mobile Phones over Other ICTs?

Mobile phones are but one form of ICT. Personal computers, laptops, the Internet and broadband, satellite and so on are all used to promote and improve development. However, mobile phones are in the vanguard of ICTs for development. They have been the most adopted means of communication both in the developed and developing countries. The penetration rates of mobile phones are outstripping those for internet users, fixed phone lines and broadband subscriptions. This is indicated in Fig. 1.

As of 2018, the international Telecommunication Union (ITU) estimated that there are over 781 million active mobile cellular telephone subscriptions in Africa, with a penetration rate of 76 per 100 inhabitants (ITU, 2019B). In October 2018, the Nigeria Communication Commission estimated that there more than 164 million active mobile telephone lines in Nigeria. Mobile phone technology has been diffused rapidly in the rural areas of the developing countries in recent years. The rate of proliferation of mobile phone globally in last few years is depicted in Fig. 2.

The proliferation of mobile phones in Nigeria has resulted in their use even within impoverished rural homesteads. Mobile phones are easy to use, are increasingly able to bypass the barriers of illiteracy and affordability, and provide access to a wide range of very useful services. Furthermore, mobile phones have the advantage over other ICT tools in terms of its appropriateness for the under-developed local conditions. It has been found to help improve the productivity of individuals and organizations within resource-constrained environments as it increases efficiency, effectiveness, and reach [23,24,25]. Other than mobile phones, other ICT tools suffers from the problem of feasibility for the poor in geographically disadvantaged areas because of lack of enabling environments such as infrastructure and capital. For example Internet enhanced technologies are not appropriate in the areas lacking electricity and network infrastructure. On the contrary, mobile phone technology has much less requirement on the infrastructure and hence wider applicability [16]. Many services may be provided using the major communication and information access functionalities of mobile devices that include installable mobile applications, Voice/ Interactive Voice Response (IVR), Short Message Service (SMS), Unstructured Supplementary Service Data (USSD) and internet. Other device features that enable a wide array of possibilities in ICT innovations include the ability of devices to capture photos and videos, communicate via Near-field Communication (NFC) and Radio-frequency Identification (RFID), as well as Global Positioning System (GPS) functionalities. Most of these innovations are made to work on basic phones, smart phones, and Internet of Things (IoT) devices, mostly depending on the target users, the available ICT infrastructure and the service being provided.

2.3 The Case for M-voting

In electioneering processes, one essential requirement is that the election system must be sufficiently robust to withstand a variety of fraudulent behaviors and must be sufficiently transparent and comprehensible that voters and candidates can accept the results of an election. However, this cannot be said for conventional voting systems due to the aforementioned problems of these systems that were highlighted in Section 1 of this paper. Electronic voting is emerging as significant alternative to these conventional systems in the delivery of reliable and trusted elections. In general, two main types of e-voting can be identified [11,20]:

i. E-voting supervised by the physical presence of representatives of governmental or independent electoral authorities, for example electronic voting machines at poll sites popularly known as Direct Recording Electronics (DRE) and document based ballot voting systems.
ii. E-voting within the voter's sole influence (remote e-voting), not physically supervised by representatives of governmental authorities, for example voting from one's own or another person's computer via the internet, by mobile phones (including Short Message Service, SMS). This variant of e-voting is termed remote e-voting.

Literature surveys on e-voting implementation in the context of developing countries suggest the implementation of remote e-voting schemes. The reason is not far to seek; some of the attendant problems faced by the conventional voting systems such as violence, intimidation, coercion, disenfranchisement, complicity of the security agencies and so on are more probably to be evident in e-voting schemes supervised by physical presence of governmental or independent electoral authorities. However most

implementation of existing remote e-voting systems revealed that these systems are designed and implemented as a specific case of remote electronic voting called internet voting (i-voting); whereby remote voting takes place only over the internet such as via a web site or voting applet. In Nigeria and most developing countries, deployment of only internet voting (i-voting) may be a failure as the affordability of the average nationals of these countries with very low per capital income of a personal computer with internet facilities or mobile terminals with internet support (smart phones) is highly improbable. Also, the need of appropriate technical support on the usage on the part of the nationals is an impediment to the implementation of remote i-voting. These are referred to as the digital divides. Proposed remote e-voting solutions for such nationals should be therefore extended to the use of ICT technologies that are affordable. Basic phones are able to address these challenges as they are cheaper than personal computers (PCs) and they require minimal technical know-how.

Mobile voting can be seen as an additional platform to the electronic voting systems. It is a mobile government (m-government) initiative with tremendous potentials to enhance democratic participation [17]. It will also serve as an enabler and a convenient way to involve citizens in political decision making. It is a cheaper, convenient, and a simple to administer voting alternative. M-voting is not a replacement for e-voting, but rather a complement [27,28]. The use of mobile devices in political participation simplifies and eases access to and the integrating of persons and institutions in political processes. M-voting has the potential to increase election turnout by providing voters with a convenient voting mode that does not require them to leave their homes or offices. Even geographic distance is no longer a limitation on participation in elections as soldiers, students, tourists, and business persons can exercise their civic right and vote from anywhere around the world regardless of any time differences. Since many democracies are faced with an ever decreasing voting rate, the opportunity to turn the tide and increase turnout seems particularly promising. There is no doubt that remote electronic voting offers a convenience that would be appreciated by many people. M-voting enables citizens to participate electronically in democracy and provides them with more information about candidates and the election/survey they are being asked to participate in.

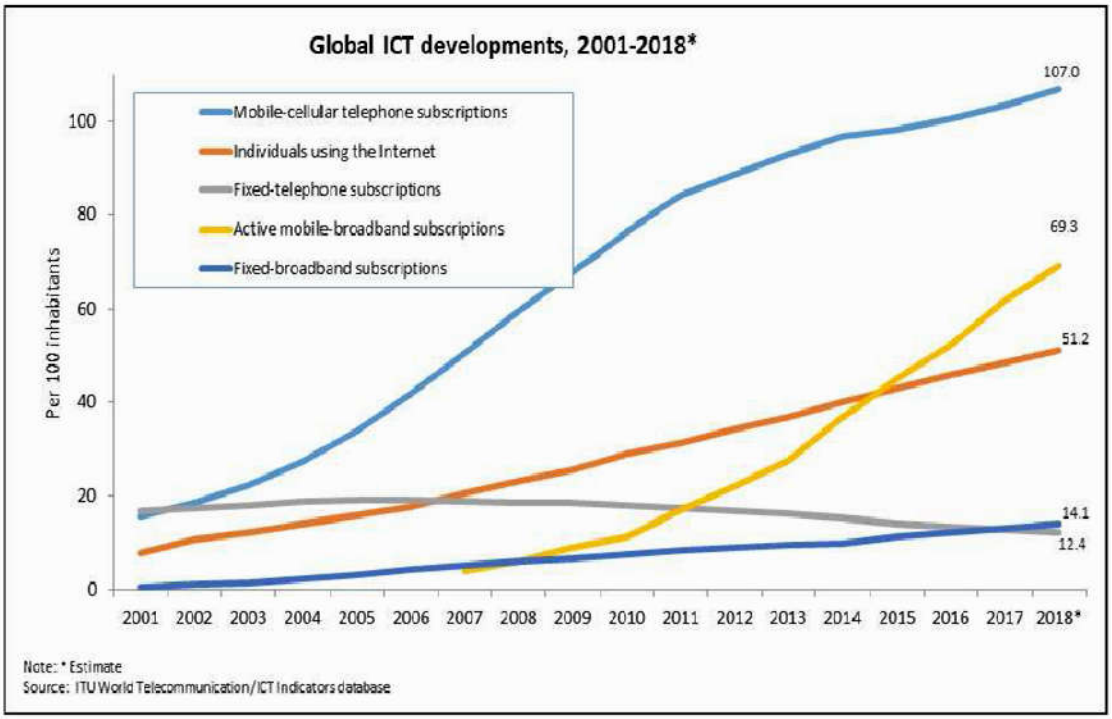

Fig. 1. Global ICT development [22]

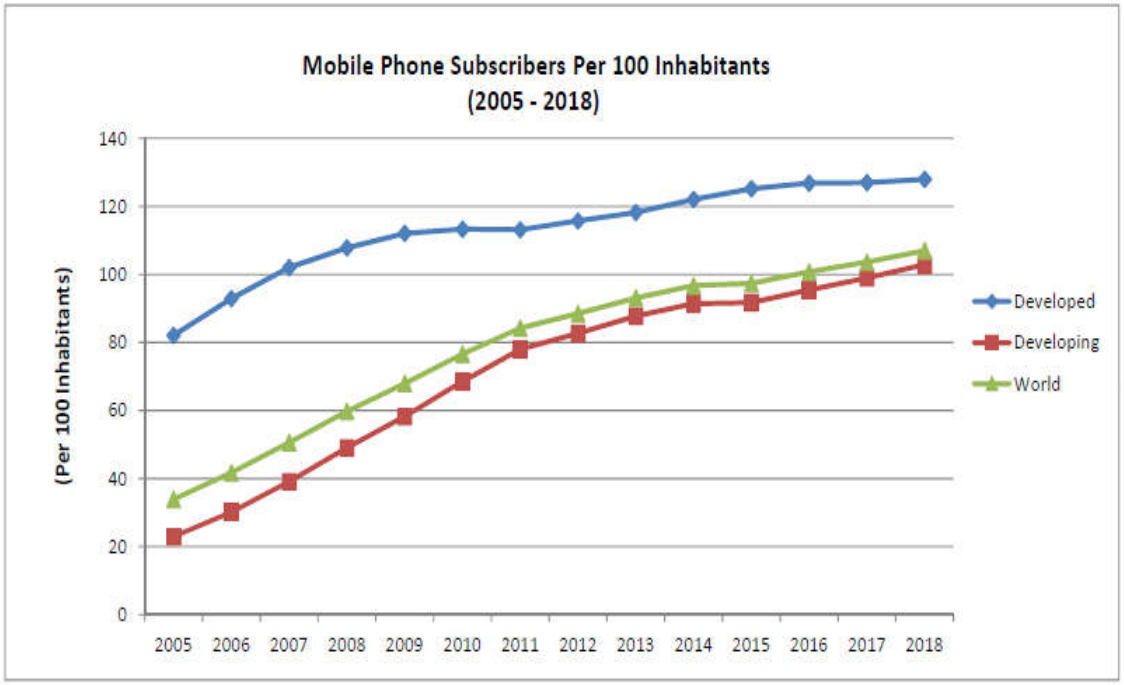

Fig. 2. Global mobile cellular subscriptions growth [26]

2.4 Related Works

Ekong and Ekong [29] developed a prototype m-voting system for enhancing participation of electorates during electioneering process using Nigeria as a case study. The system was developed using Wireless Markup Language (WML), Hypertext Preprocessor (PHP) and MySQL server as the database server and tested using mobile explorer emulator (Openwave V7 Simulator).

Okediran and Ganiyu [1] designed and implemented a generic and secure electronic voting system where voters can cast their votes anytime, anywhere and using a number of electronic devices including private computer networks, web and mobile phones.

Okediran et al. [28] proposed a framework for m-voting which can be used for conducting electronic voting or survey. The framework described how smart phones (with Smybian, Blackberry, Android and Ios mobile operating systems) are useful and efficient devices for voting.

Khelifi et al. [30] proposed a mobile voting system that aims to preserve the integrity of elections. The system called “MVote” is a mobile phone application that uses three level of security, which are username and password, national ID and fingerprint, and a strong dedicated security algorithm.

Ullah et al. [31] suggested a mobile phone voting protocol based on hybrid cryptosystem. The protocol consists of three phases: online registration; vote casting and vote collecting and result phase. The protocol provides secure and efficient online vote casting and can also be implemented parallel with paper ballot voting system. The said protocol is efficient, secured and deployable in developing countries due to its reliance on SMS messaging without requiring internet connectivity.

Thakkar et al. [32] developed a mobile voting system that was developed on the android mobile operating system. The intent of the system is to proffer solutions to problems posed by traditional voting systems.

Shin-Yan et al. [33] developed an electronic voting system based on the proposed oblivious and proxy signature scheme and implemented the scheme in a smart phone application to allow users to vote securely and conveniently.

Ganaraj [34] developed an android application for mobile voting with the intent of proffering

solutions to the problems associated with conventional voting systems.

Yakubu [35] proposed an android-based mobile voting application for students' elections at Infrastructure University Kuala Lumpur, Malaysia. The application allows students to cast their votes online and track the results in real time. The application also provides candidates with a centralized platform to campaign and attract voters.

Most of the reviewed works presented implementations of m-voting on smart phones. However, considering the peculiarity of contextual ICT infrastructural challenges and other issues of digital divides, literacy level which translates to ease of usage, affordability of relevant technologies on the part of the target users amongst other issues, this paper proposed an m-voting solution for developing nations, using two of the communication channels of a basic phone, which are SMS and USSD.

3. METHODOLOGY

The research methods employed are of two phases:

a) Needs assessment and analysis.
b) Development of an m-voting framework.

3.1 Needs Assessment and Analysis

Prior to the development of the m-voting system, a comprehensive needs assessment and analysis of a selected voting population in Nigeria was done. This process was carried out to sample their opinions on the introduction and usage of m-voting in electioneering process in Nigeria. Of utmost importance in the needs assessment and analysis were considerations for:

i. Defining the needs of the target users: The design goal of the framework is to provide a voting platform which can be easily accessible and available for a voting population regardless of their location.
ii. The availability and appropriateness of the technology to be employed: The framework utilized basic phones which are the most readily available technology at the disposal of most users. Also, availability of telecommunication infrastructures to support the available technology at the disposal of the users was considered.
iii. The literacy levels of the target users: The mode of content delivery of the framework was based on the literacy level of the target users. The communication channels deployed for usage by the target users possesses high ease of usage and low technical know-how requirements.
iv. The willingness of the target users to pay for service(s): The cost of accessing the services to be provided by the framework was prioritized in the design process of the framework. SMS and USSD were employed as they are relatively affordable.

A questionnaire was designed and administered to 1500 eligible electorates (18 years and older). A total of 1364 responses were received. Two out of the sources of data collection techniques proposed by Yin [36] for case study research (direct observation and field interviews) were employed to collect information on mobile phone ownership, device capabilities, services and usage, literacy level and availability of telecommunications infrastructures.

3.2 Developing the M-voting Framework

The phases involved in developing the m-voting framework are depicted in the following subsections.

3.2.1 Requirements definition

The design of any voting system, whether electronic or manual, must satisfy a number of sometimes competing criteria including a high degree of security and accuracy, eligibility and authentication, integrity, verifiability and auditability, reliability, flexibility, performance and scalability [1]. The anonymity of a voter's ballot must be preserved, both to guarantee the voter's safety when voting against a malevolent candidate, and to guarantee that voters have no evidence that proves which candidates received their votes. The existence of such evidence would allow votes to be purchased by a candidate. The voting system must also be tamper-resistant to thwart a wide range of attacks, including ballot stuffing by voters and incorrect tallying by insiders. Another factor, of immense importance is the "human factors". A voting system must be comprehensible to and usable by the entire voting population, regardless of age, infirmity, or disability. Providing accessibility to such a diverse population is an important engineering problem and one where, if other security is done well, electronic voting could be a great improvement over current paper systems. Flaws in any of these aspects of a

voting system, however, can lead to indecisive or incorrect election results. Guided by the design requirements' definition for electronic voting systems documented in [2,13,28], the design requirements of the m-voting framework proposed in this paper are divided into two groups, namely, generic and system-specific. The framework is to cater for the following generic requirements:

i. **Privacy:** After casting a vote, no one should be able to link the voter to this vote and no voter can prove that he or she voted in a particular way;
ii. **Authenticity:** Only eligible voters can cast their votes;
iii. **Accuracy:** Once a voter cast a vote, no alternation to this vote is permitted. Moreover, all valid votes must be counted, whereas all invalid votes must not be discarded;
iv. **Security:** Throughout the voting process, a vote can't be tampered with;
v. **Democracy:** All eligible voters must be able to vote, one person - one vote and no one can vote more than once or vote for others.
vi. **Verifiability:** Voters can independently verify that their votes have been counted correctly and are included in the final tally.

The system-specific requirements of the framework allow:

i. **Multi-user:** A number of voters can vote simultaneously;
ii. **Multi-campaign:** A number of elections can be running simultaneously;
iii. **Availability:** The framework must have high-availability during an election campaign.

3.2.2 Framework design

The framework design was done to determine applications architectural framework. The emerging framework from this design process is a representation of the structure for the realization of the defined goal.

3.2.3 Infrastructural model architecting and development

Models will be developed on the framework. The models are graphical model developed using unified modeling language (UML).

4. RESULTS AND DISCUSSION

4.1 Descriptive Analysis of Respondents

The data analysis of the collated information from the questionnaires is presented in Table 1.

Table 1. Descriptive analysis of respondents

	Category	Frequency	Percentage
Gender	Male	887	65.03%
	Female	477	34.97%
Possession of Mobile Phones	Yes	1351	99.05%
	No	13	0.95%
Type of Mobile Phone	Basic Phone	942	69.06%
	Smartphone	422	30.94%
Purpose of Mobile Phone Adoption	Kinship maintenance only	91	6.67%
	Kinship maintenance & other purposes	1273	93.33%
Participation in the 2019 general elections	Yes	438	32.11%
	No	926	67.89%
	Personal	156	17.35%
Reason for not participating in 2019 general elections	Problems associated with voting system used	471	52.39%
	Others	272	30.26%
Willingness to use their mobile device to cast vote	Yes	923	67.67%
	Neutral	134	9.82%
	No	307	22.51%
Willingness to accept e-voting as a substantive form of voting system	Yes	965	70.75%
	Neutral	102	7.48%
	No	297	21.77%

a) Ownership of mobile devices: Out of the 1364 respondents, 1351 of them owns mobile phones which represent 99.05%. Out of this percentage, 69.06% of the respondent possesses basic phone while 30.94 % possesses smart phones (mobile phones with operating system that includes Google's Android and Apples' iOS). It follows therefore that there is a high tendency for m-voting and e-participation to thrive in Nigeria.

b) Participation in the 2019 general elections: 438 respondents representing 32.11% participated in the last general election of 2019. 926 respondents did not participate. This shows a further decline in voters' participation in elections in Nigeria when compared with a similar survey conducted in 2013 by the author.

c) Reason for non-participation in electioneering process: 52.39% of the respondents gave instances of problems associated with conventional voting systems as reasons for not participating in 2019 general elections in Nigeria. Such instances include: fear of violence, intimidation, complicity of the security agencies, the absence or late arrival of election materials and general lack of trust and confidence in the electoral system and so on.

d) Willingness to use their mobile device to cast vote: A total of 923 respondents representing 67.67% of the mobile phone owners are willing to use their mobile phones for voting while 307 of them representing 22.51% do not prefer using mobile phones. 9.82% respondents representing did not respond to the question. Respondents that preferred to use their mobile devices to cast their ballots believed it is more convenient and faster.

e) Acceptance of e-voting as a substantive form of voting system: 965 respondents preferred e-voting to be implemented as a substantive form of voting system. They believe it will increase voters' participation in Nigeria and help in the delivery of credible elections as issues of ballot stuffing, multiple voting, counting error, violence e.t.c will be reduced or eliminated. 21.77% of the respondents do not support the introduction of electronic voting while 7.48% of the respondents did not respond to the question.

In summary, the analysis of responses obtained from the administered questionnaire is a pointer that the introduction of mobile voting as a form of voting platform to electorates in Nigeria will enhance participatory democracy in Nigeria.

4.2 The Developed Architectural Framework for Mobile Voting

The architectural framework for the mobile voting system is depicted in Fig. 3. The framework uses the technology available to a large majority of voters (mobile phone) and the technological infrastructure exposed to them. There are two communication channels for the target users to access the services available on the framework. They are SMS and USSD. The communication will be facilitated by existing mobile telecommunication infrastructures in the communities of the target users. The application server contain applications running at the back-end to integrate SMS and USSD from the voters 'end and web from the supervised registration centres' end. The SMS component of the framework provides premium SMS services. These services are micropayment services by SMS. The premium SMS allow users to buy or subscribe to various services or micro-payment services by SMS or digital content via a short code from 3 to 5 digits. A voter accessing the service on the framework would be required to send a "keyword" to an SMS premium number and in return the application server (content provider) delivers the requested content or service. The apt details of the "keyword" are described explicitly in sub-sections 4.2A and 4.2B. The USSD component of the framework provides instant messaging services. It requires generation of query from the mobile phone of the voter. Once this request is sent, the USSD gateway forwards it to the USSD application on the application server. The application then responds to the request, and the process is repeated in reverse: the response goes back to the USSD gateway, which displays the content of that response on the voter's mobile phone.

The framework follows the conceptual perspective of e-voting as defined by the Organisation for the Advancement of Structured Information Standard (OASIS). The OASIS consortium is a standard for the structured interchange among hardware, software, and service providers who engage in providing election or voter services to public or private organizations. OASIS in 2003 conceptualized e-voting to be made of three phases [37]:

i. Pre-voting phase which involves election declaration, candidate nomination, referendum options and voters' registration.
ii. Voting phase which involves ballot information, voter authentication, vote casting and confirmation.
iii. Post-voting phase which involves election counts, results and audit.

Considering e-voting systems this way follows the high level models of election systems given by the OASIS. The OASIS consortium specifies Election Markup Language (EML) especially for the exchange of data within e-voting processes. Therefore, OASIS drafts a high level overview and a high level model dealing with the human view and a high level model dealing with the technical view. In this paper, mainly the human view is taken as a basis for talking about e-voting systems from the conceptional point of view. These models should be the initial point of creating e-voting concepts. EML is in particular useful for interoperability reasons. Separating the process into these phases gives a good abstraction of an election process. Moreover, these models provide a common terminology and a conceptional perspective.

4.2.1 Pre-voting phase

Voters' registration on the framework requires all eligible voters to have a duly registered (as required by the Nigerian Communications Commission) subscriber identity module (SIM) card number and a National Identification Number (NIN). Updated copies of databases containing these two public records will be available on the application and database servers at the Electoral Commission by relevant authorities. This is very essential for voters' verification and authentication purposes during registration. Electronic voters' registration can be accomplished by SMS or USSD. The Application Server will generate public/private key pair. The private key will be kept secret while the public key will be available on the application server. The following steps are involved for electronic registration via mobile phone:

i. A voter intending to register will send his/her NIN, SIM card number and symmetric key encrypted with public key (available on the Application Server) to the Application Server.
ii. On receipt of the voter's credentials of (i) above, the Application Server will decrypt these credentials with its private key.
iii. The Application Server will then verify the user credentials (NIN and SIM card number) with its two databases of public records.
iv. If the voter is verified as who he/she claims, the application server will generate and send a unique Voter Identification Number (VIN), which the voter will use for authentication during the voting phase.
v. The voter on receipt of the VIN will decrypt it his/her symmetric key. The VIN is expected to be kept secured by the voter in order not to comprise confidentiality.
vi. The voter sends an acknowledgement receipt of the VIN to the Application Server.

A voter who does not want to use his/her mobile phone may also visit a designated electoral registration centre to register as an eligible voter using the aforementioned credentials that is, NIN and SIM card number. A unique VIN will be generated for the intending voter upon verification and authentication by the application server through the electoral officer in charge. The activity diagram for the pre-voting phase of the framework is depicted in Fig. 4.

4.2.2 Voting phase

The underlisted steps depict the process involved for voting on Election Day:

i. About the time the voting process will commence, the Application Server sets a time lock system which will be implemented on the Tally/Counting Server.
ii. The Application Server will send the candidates' list for the election being held to all verified voters by SMS (using the SIM card number used for enrollment during the pre-voting phase). The SMS will be encrypted with the voter's symmetric key. Hence only duly registered and verified voters can access the candidates' list.
iii. At the voters' end, upon the reception of the SMS, voters will decrypt the message with their symmetric key. A voter can then select the candidate of his/her choice from the candidate list.
iv. The voter will then encrypt his/her choice with the Application Server public key, which is then string together with the VIN and encrypt both with voter's symmetric key and then string together with the NIN number and send to the Application Server using SMS or USSD.

v. The Application Server fetches the voter's symmetric key by calling his/her NIN. The server will afterwards decrypt the later part of the SMS/USSD request, using the voter's symmetric key. The Application Server will only assign a notation to the VIN component of the SMS/USSD request for the record purposes and to avoid multiple voting. The remaining encrypted candidates' list message will be forwarded to the Tally/Counting Server.

The activity diagram for the voting phase of the framework is depicted in Fig. 5.

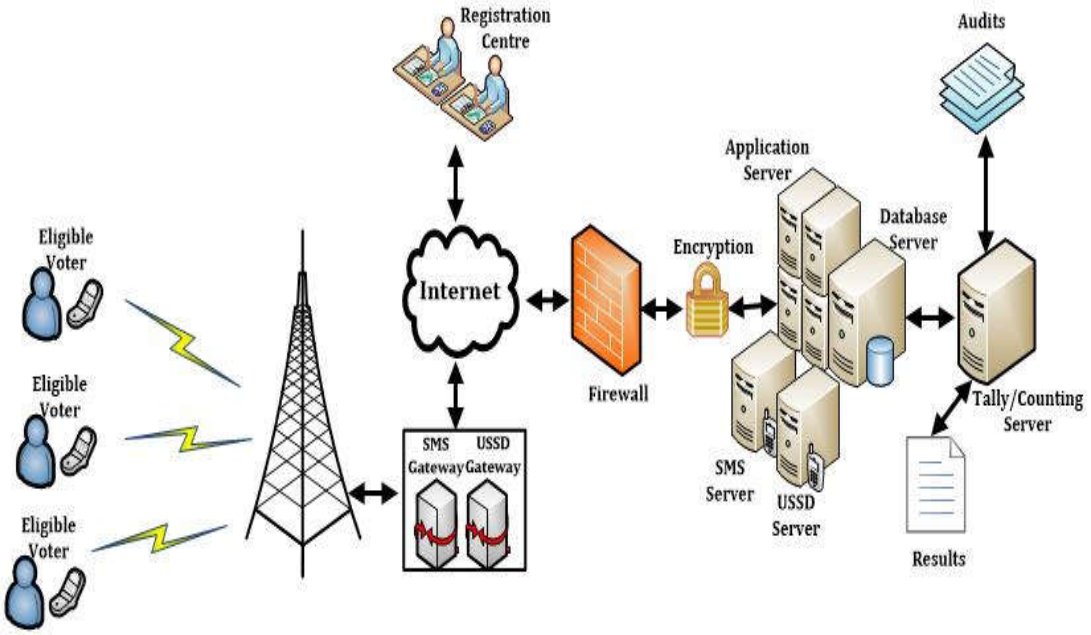

Fig. 3. The developed architectural framework for mobile voting

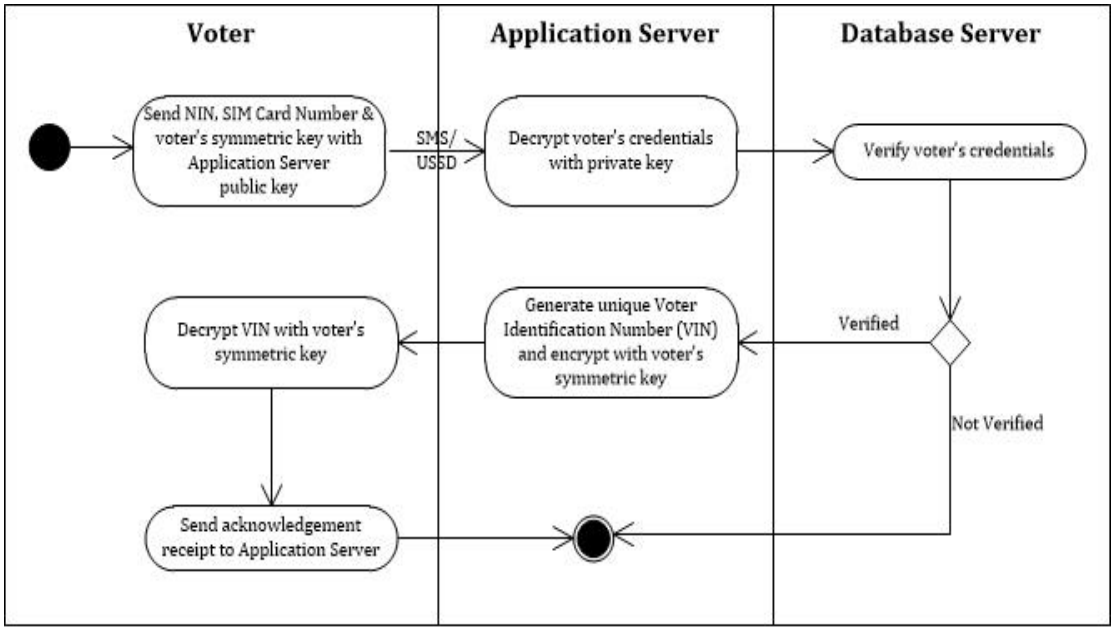

Fig. 4. Activity diagram for the pre-voting phase of the framework

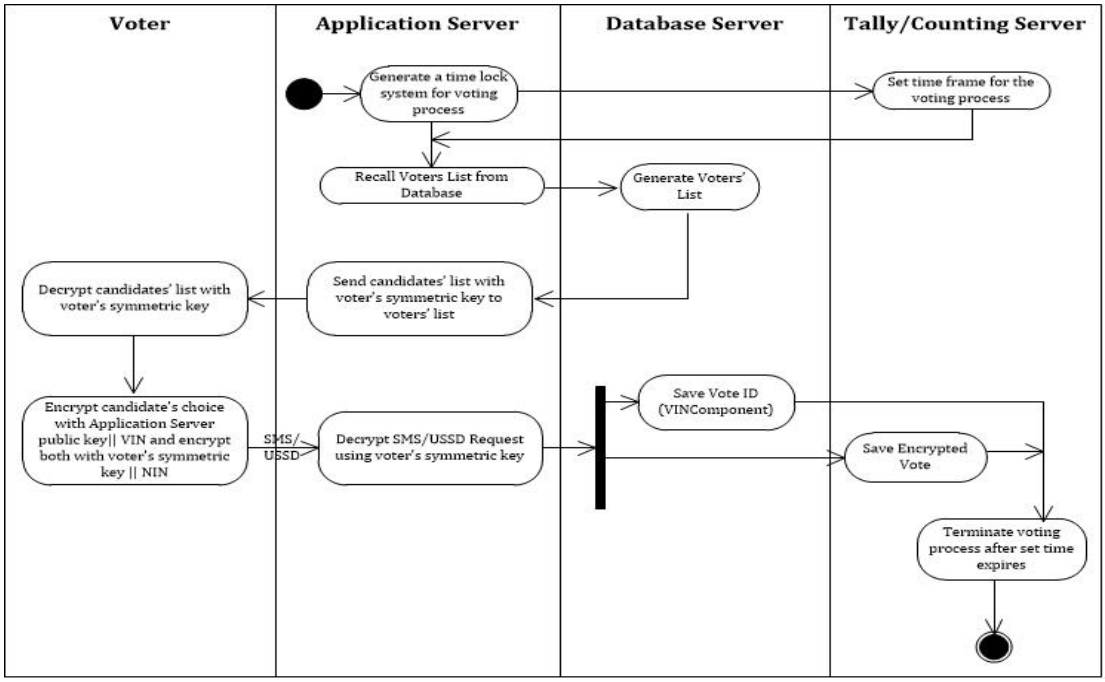

Fig. 5. Activity diagram for the voting phase of the framework

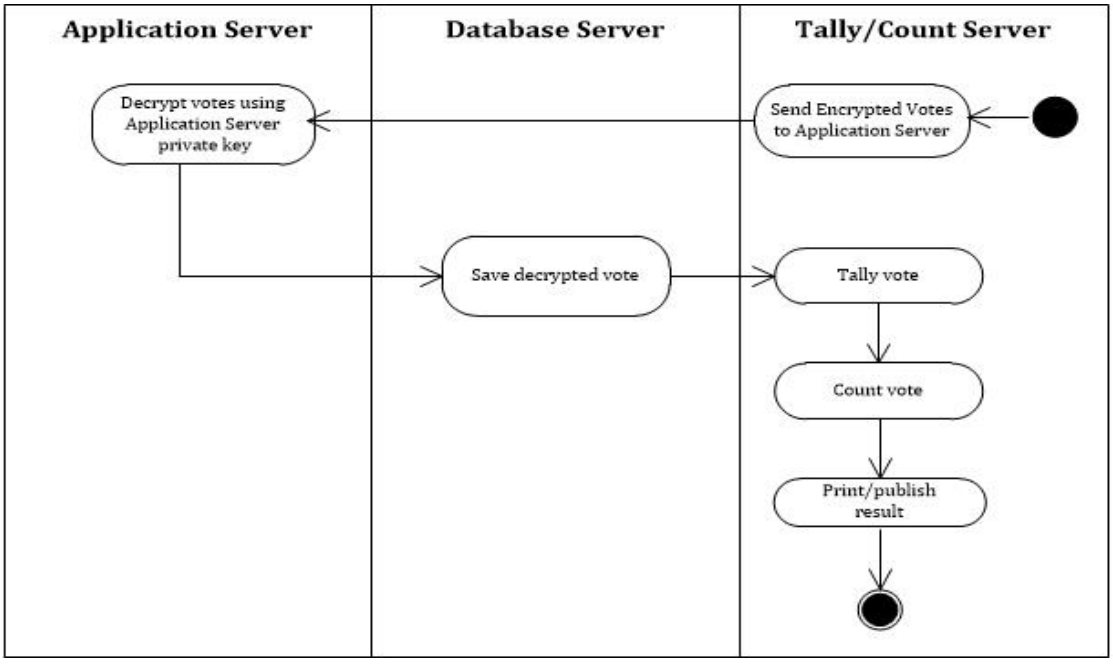

Fig. 6. Activity diagram for the post voting phase of the framework

4.2.3 Post voting phase

The time lock system in the Tally/Counting Server of (i) of the Voting Phase, keeps the vote encrypted until the voting process ends. Decryption of casted votes only commences when the voting process has been terminated. Therefore, no instantaneous result can be known or viewed by anyone until the official voting time ends, hence guaranteeing the secrecy of the

ballots casted. Each ballot casted will be decrypted by the Application Server private key. The decrypted ballots will be counted by the Tally/Counting Server and results will then be made public. Fig. 6 depicts the activity diagram of the post voting phase of the framework.

5. CONCLUSION

Mobile phones are the most adopted means of communication with its penetration more than all other information and communication devices put together. Looking at the access statistics alone, it gives a little insight into the developmental potentials and impacts mobile phones could wrought if well harnessed. Instances of these developmental potentials and impacts are being seen in education (m-learning), finance (m-banking), health (e-health and telemedicine), agriculture (m-agriculture), government (m-government and m-voting) to mention but a few. In all of the aforementioned, literature survey have shown that the starting point of such mobile interventions should be a needs analysis of what extent people choose and are able to utilise their mobile phones to improve their well-being.

In paper this paper, a mobile voting framework was presented. A survey of needs analysis, mobile phone ownership, mobile phone utilization and willingness to use them for participatory democracy by a randomly selected voting population in Nigeria was initially carried out. An m-voting framework which could be implemented for large scale e-election was then evolved based on the results of the survey. The developed m-voting framework satisfied majority of the generic requirements for e-voting. These include authentication, verifiability, security, democracy and privacy. The implementation of the framework will undoubtedly enable voters to cast their vote from a place other than the poll site in their voting district, facilitate the casting of the vote by the voter, facilitate the participation in elections by those who are entitled to vote, widen access to the voting process for voters with disabilities or those having other difficulties in being physically present at a poll site, increased voter turnout, reduce the overall cost to the electoral authorities of conducting an election, deliver voting results reliably and more quickly amongst many other benefits.

Future research may focus on extending the framework to cater for post-voting activity of total vote auditing. Vote auditing is that phase of election systems that check that eligible voters were capable to vote and their votes participate in the computation of final tally.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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