

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

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. These services can expand existing functionalities to those available through the mobile phone itself. One of such services can be 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 (that is tailored specifically to distinct conditions) 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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Keywords: Mobile phone, election, e-voting, m-voting, SMS, USSD

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-governance, and so on. 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.

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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,

32 under-age and multiple voting, counting error, complicity of the security agencies and the
33 absence or late arrival of election materials and so on often trail elections conducted using
34 this method [2, 3, 4, 5]. Furthermore, the cost and process of manual voting are both
35 increasing geometrically and tedious to execute [6] and there has been a declining
36 participation rate due to: inconvenience of manual system of voting like: inaccuracy in ballot
37 counting and delayed announcement of election results [1,7]; loss of significant time during
38 ballot counting [8]; unacceptable percentages of lost, stolen and miscounted ballot papers,
39 votes loss through unclear or invalid ballot marks and limited accommodations for people
40 with disabilities [1, 9,10].

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

52
53 While the emergence e-voting is well timed to the interest and attention needed for
54 implementing e-government or e-democracy or e-governance and as a significant solution to
55 the problems posed by conventional voting systems, its implementation in developing
56 countries may be flawed given the peculiarity of the contextual ICT infrastructural challenges
57 faced by developing countries. General, developing countries are low ICT resourced
58 countries where poverty, deficit in infrastructures, digital divides and low literacy level are still
59 very significant. However, the increase in affordability, accessibility and adaptability of
60 mobile phones has created a breeding ground for development innovations, which target key
61 areas of economic and social impact. Mobile phones and infrastructures such as mobile
62 telecommunications networks have proliferated [14, 15, 16]. In Nigeria, for example, the
63 proliferation of mobile phones has resulted in their use even within impoverished rural
64 homesteads. Mobile phones are easy to use, increasingly able to bypass the barriers of
65 illiteracy and affordability, and provide access to a wide range of very useful services. Thus,
66 mobile phones can be considered a good candidate for voting platform in the developing
67 world. Any voting process whereby the voting process/ballot casting is by using a mobile
68 electronic device is referred to as m-voting. M-voting is an additional platform to any e-voting
69 system. It is a mobile government (m-government) initiative with tremendous potentials to
70 enhance democratic participation [17]. It can also serve as an enabler and a convenient way
71 to involve citizens in political decision making. In this paper, an m-Voting framework was
72 proposed using two of the communication channels of basic phones which are SMS and
73 USSD; with intent of providing a platform for an essential ingredient for implementing e-
74 government or e-democracy or e-governance and as a significant alternative solution to the
75 problems posed by conventional voting systems. The rest of the paper is organized into the
76 following: Section two presents review of relevant literatures to this research; Section three
77 details the research methodologies employed in the development of the m-voting framework;
78 Section four presents the results and Section five summarized and concludes the paper.

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82 **2. LITERATURE REVIEW**

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84 **2.1 E-voting: an alternative voting solution**

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

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

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

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

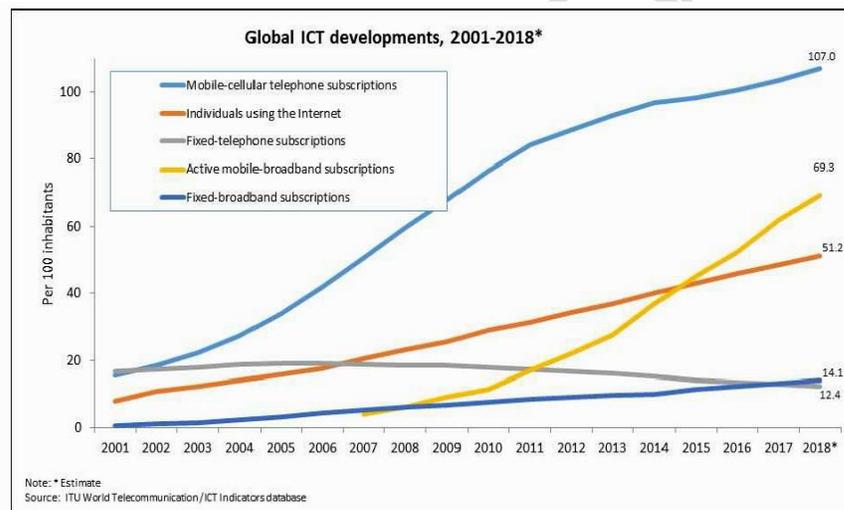
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133 Furthermore e-voting can enhance polling and votes' security, confidentiality, sincerity and
134 increased cost savings on reduced manpower, logistical materials and tools; and above all
135 instant analysis and reporting. It can enhance accuracy of all valid votes and final outcome;
136 permit voting once for only eligible voters; allow independent verification of all voters; it can
137 also improve voters' turnaround as it flexibly allows a voter to login and vote from any

138 workstation [21]. Therefore, electronic based voting technologies would expand the reach
139 and range of potential voting population.
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141 2.2 Why mobile phones over other ICTs? 142

143 Mobile phones are but one form of ICT. Personal computers, laptops, the Internet and
144 broadband, satellite and so on are all used to promote and improve development. However,
145 mobile phones are in the vanguard of ICTs for development. They have been the most
146 adopted means of communication both in the developed and developing countries. The
147 penetration rates of mobile phones are outstripping those for internet users, fixed phone
148 lines and broadband subscriptions. This is indicated in Figure 1. As of 2018, the international
149 Telecommunication Union (ITU) estimated that there are over 781 million active mobile
150 cellular telephone subscriptions in Africa, with a penetration rate of 76 per 100 inhabitants
151 (ITU, 2019B). In October 2018, the Nigeria Communication Commission estimated that
152 there more than 164 million active mobile telephone lines in Nigeria. Mobile phone
153 technology has been diffused rapidly in the rural areas of the developing countries in recent
154 years. The rate of proliferation of mobile phone globally in last few years is depicted in
155 Figure 2.



174 **Figure 1: Global ICT Development [22]**

175 The proliferation of mobile phones in Nigeria has resulted in their use even within
176 impoverished rural homesteads. Mobile phones are easy to use, are increasingly able to
177 bypass the barriers of illiteracy and affordability, and provide access to a wide range of very
178 useful services. Furthermore, mobile phones have the advantage over other ICT tools in
179 terms of its appropriateness for the under-developed local conditions. It have been found to
180 help improve the productivity of individuals and organizations within resource-constrained
181 environments as it increases efficiency, effectiveness, and reach [23, 24, 25]. Other than
182 mobile phones, other ICT tools suffers from the problem of feasibility for the poor in
183 geographically disadvantaged areas because of lack of enabling environments such as
184 infrastructure and capital.
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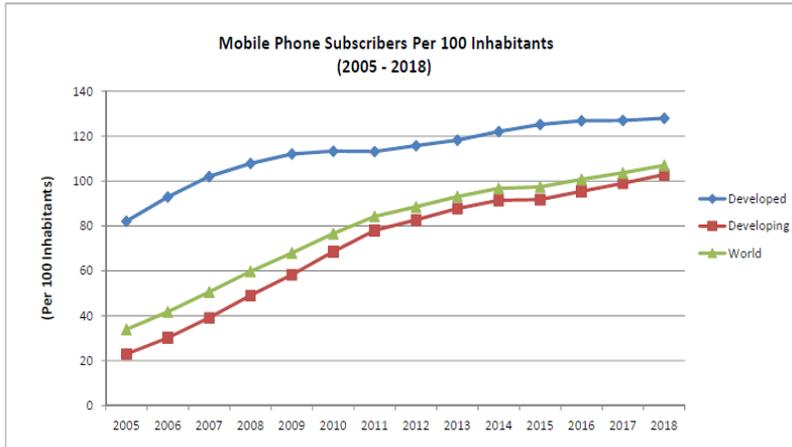


Figure 2: Global Mobile Cellular Subscriptions Growth [26]

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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 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.

- 224 ii. e-voting within the voter's sole influence (remote e-voting), not physically
225 supervised by representatives of governmental authorities, for example voting from
226 one's own or another person's computer via the internet, by mobile phones
227 (including Short Message Service, SMS). This variant of e-voting is termed remote
228 e-voting.
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230 Literature surveys on e-voting implementation in the context of developing countries suggest
231 the implementation of remote e-voting schemes. The reason is not far to seek; some of the
232 attendant problems faced by the conventional voting systems such as violence, intimidation,
233 coercion, disenfranchisement, complicity of the security agencies and so on are more
234 probably to be evident in e-voting schemes supervised by physical presence of
235 governmental or independent electoral authorities. However most implementation of existing
236 remote e-voting systems revealed that these systems are designed and implemented as a
237 specific case of remote electronic voting called internet voting (i-voting); whereby remote
238 voting takes place only over the internet such as via a web site or voting applet. In Nigeria
239 and most developing countries, deployment of only internet voting (i-voting) may be a failure
240 as the affordability of the average nationals of these countries with very low per capital
241 income of a personal computer with internet facilities or mobile terminals with internet
242 support (smart phones) is highly improbable. Also, the need of appropriate technical support
243 on the usage on the part of the nationals is an impediment to the implementation of remote i-
244 voting. These are referred to as the digital divides. Proposed remote e-voting solutions for
245 such nationals should be therefore extended to the use of ICT technologies that are
246 affordable. Basic phones are able to address these challenges as they are cheaper than
247 personal computers (PCs) and they require minimal technical know-how.
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249 Mobile voting can be seen as an additional platform to the electronic voting systems. It is a
250 mobile government (m-government) initiative with tremendous potentials to enhance
251 democratic participation [17]. It will also serve as an enabler and a convenient way to involve
252 citizens in political decision making. It is a cheaper, convenient, and a simple to administer
253 voting alternative. M-voting is not a replacement for e-voting, but rather a complement [27,
254 28]. The use of mobile devices in political participation simplifies and eases access to and
255 the integrating of persons and institutions in political processes. M-voting has the potential to
256 increase election turnout by providing voters with a convenient voting mode that does not
257 require them to leave their homes or offices. Even geographic distance is no longer a
258 limitation on participation in elections as soldiers, students, tourists, and business persons
259 can exercise their civic right and vote from anywhere around the world regardless of any
260 time differences. Since many democracies are faced with an ever decreasing voting rate, the
261 opportunity to turn the tide and increase turnout seems particularly promising. There is no
262 doubt that remote electronic voting offers a convenience that would be appreciated by many
263 people. M-voting enables citizens to participate electronically in democracy and provides
264 them with more information about candidates and the election/survey they are being asked
265 to participate in.
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267 **2.4 Related works**

268

269 [29] developed a prototype m-voting system for enhancing participation of electorates during
270 electioneering process using Nigeria as a case study. The system was developed using
271 Wireless Markup Language (WML), Hypertext Preprocessor (PHP) and MySQL server as
272 the database server and tested using mobile explorer emulator (Openwave V7 Simulator).
273

274 [1] designed and implemented a generic and secure electronic voting system where voters
275 can cast their votes anytime, anywhere and using a number of electronic devices including
276 private computer networks, web and mobile phones.

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278 [28] proposed a framework for m-voting which can be used for conducting electronic voting
279 or survey. The framework described how smart phones (with Symbian, Blackberry, Android
280 and iOS mobile operating systems) are useful and efficient devices for voting.

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282 [30] proposed a mobile voting system that aims to preserve the integrity of elections. The
283 system called "MVote" is a mobile phone application that uses three level of security, which
284 are username and password, national ID and fingerprint, and a strong dedicated security
285 algorithm.

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287 [31] suggested a mobile phone voting protocol based on hybrid cryptosystem. The protocol
288 consists of three phases: online registration; vote casting and vote collecting and result
289 phase. The protocol provides secure and efficient online vote casting and can also be
290 implemented parallel with paper ballot voting system. The said protocol is efficient, secured
291 and deployable in developing countries due to its reliance on SMS messaging without
292 requiring internet connectivity.

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294 [32] developed a mobile voting system that was developed on the android mobile operating
295 system. The intent of the system is to proffer solutions to problems posed by traditional
296 voting systems.

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298 [33] developed an electronic voting system based on the proposed oblivious and proxy
299 signature scheme and implemented the scheme in a smart phone application to allow users
300 to vote securely and conveniently.

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302 [34] developed an android application for mobile voting with the intent of proffering solutions
303 to the problems associated with conventional voting systems.

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305 [35] proposed an android-based mobile voting application for students' elections at
306 Infrastructure University Kuala Lumpur, Malaysia. The application allows students to cast
307 their votes online and track the results in real time. The application also provides candidates
308 with a centralized platform to campaign and attract voters.

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

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317 **3. METHODOLOGY**

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319 The research methods employed are of two phases:

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a) Needs assessment and analysis

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b) Development of a m-voting framework

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323 **3.1 Needs assessment and analysis**

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

- 330 i. *Defining the needs of the target users:* The design goal of the framework is to
331 provide a voting platform which can be easily accessible and available for a voting
332 population regardless of their location.
- 333 ii. *The availability and appropriateness of the technology to be employed:* The
334 framework utilized basic phones which are the most readily available technology at
335 the disposal of most users. Also, availability of telecommunication infrastructures to
336 support the available technology at the disposal of the users was considered.
- 337 iii. *The literacy levels of the target users:* The mode of content delivery of the
338 framework was based on the literacy level of the target users. The communication
339 channels deployed for usage by the target users possesses high ease of usage and
340 low technical know-how requirements.
- 341 iv. *The willingness of the target users to pay for service(s):* The cost of accessing the
342 services to be provided by the framework was prioritized in the design process of the
343 framework. SMS and USSD were employed as they are relatively affordable.
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345 A questionnaire was designed and administered to 1500 eligible electorates (18 years and
346 older). A total of 1364 responses were received. Two out of the sources of data collection
347 techniques proposed by [36] for case study research (direct observation and field interviews)
348 were employed to collect information on mobile phone ownership, device capabilities,
349 services and usage, literacy level and availability of telecommunications infrastructures.

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351 **3.2 Developing the m-voting framework**

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

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356 **3.2.1 Requirements Definition**

357 The design of any voting system, whether electronic or manual, must satisfy a number of
358 sometimes competing criteria including a high degree of security and accuracy, eligibility and
359 authentication, integrity, verifiability and auditability, reliability, flexibility, performance and
360 scalability [1]. The anonymity of a voter's ballot must be preserved, both to guarantee the
361 voter's safety when voting against a malevolent candidate, and to guarantee that voters
362 have no evidence that proves which candidates received their votes. The existence of such
363 evidence would allow votes to be purchased by a candidate. The voting system must also be
364 tamper-resistant to thwart a wide range of attacks, including ballot stuffing by voters and
365 incorrect tallying by insiders. Another factor, of immense importance is the "human factors".
366 A voting system must be comprehensible to and usable by the entire voting population,
367 regardless of age, infirmity, or disability. Providing accessibility to such a diverse population
368 is an important engineering problem and one where, if other security is done well, electronic
369 voting could be a great improvement over current paper systems. Flaws in any of these
370 aspects of a voting system, however, can lead to indecisive or incorrect election results.
371 Guided by the design requirements' definition for electronic voting systems documented in
372 [2, 13, 28], the design requirements of the m-voting framework proposed in this paper are
373 divided into two groups, namely, generic and system-specific. The framework is to cater for
374 the following generic requirements:

- 375 i. *Privacy:* After casting a vote, no one should be able to link the voter to this vote and
376 no voter can prove that he or she voted in a particular way;
- 377 ii. *Authenticity:* Only eligible voters can cast their votes;
- 378 iii. *Accuracy:* Once a voter cast a vote, no alternation to this vote is permitted.
379 Moreover, all valid votes must be counted, whereas all invalid votes must not be
380 discarded;
- 381 iv. *Security:* Throughout the voting process, a vote can't be tampered with;

- 382 v. *Democracy*: All eligible voters must be able to vote, one person - one vote and no
 383 one can vote more than once or vote for others.
 384 vi. *Verifiability*: Voters can independently verify that their votes have been counted
 385 correctly and are included in the final tally.

386 The system-specific requirements of the framework allow:

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

390 3.2.2 Framework design

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

395 3.3.3 Infrastructural model architecting and development

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

399 4. RESULTS AND DISCUSSION

401 4.1 Descriptive analysis of respondents

402 The data analysis of the collated information from the questionnaires is presented in Table 1.
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	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%
Reason for not participating in 2019 general elections	Personal	156	17.35%
	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%

405 **Table 1: The data analysis of the collated information**

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 407 a) *Ownership of mobile devices*: Out of the 1364 respondents, 1351 of them owns
 408 mobile phones which represent 99.05%. Out of this percentage, 69.06% of the
 409 respondent possesses basic phone while 30.94 % possesses smart phones (mobile

- 410 phones with operating system that includes Google's Android and Apples' iOS). It
411 follows therefore that there is a high tendency for m-voting and e-participation to
412 thrive in Nigeria.
- 413 b) *Participation in the 2019 general elections*: 438 respondents representing 32.11%
414 participated in the last general election of 2019. 926 respondents did not participate.
415 This shows a further decline in voters' participation in elections in Nigeria when
416 compared with a similar survey conducted in 2013 by the author.
- 417 c) *Reason for non-participation in electioneering process*: 52.39% of the respondents
418 gave instances of problems associated with conventional voting systems as reasons
419 for not participating in 2019 general elections in Nigeria. Such instances include:
420 fear of violence, intimidation, complicity of the security agencies, the absence or late
421 arrival of election materials and general lack of trust and confidence in the electoral
422 system and so on.
- 423 d) *Willingness to use their mobile device to cast vote*: A total of 923 respondents
424 representing 67.67% of the mobile phone owners are willing to use their mobile
425 phones for voting while 307 of them representing 22.51% do not prefer using mobile
426 phones. 9.82% respondents representing did not respond to the question.
427 Respondents that preferred to use their mobile devices to cast their ballots believed
428 it is more convenient and faster.
- 429 e) *d) Acceptance of e-voting as a substantive form of voting system*: 965 respondents
430 preferred e-voting to be implemented as a substantive form of voting system. They
431 believe it will increase voters' participation in Nigeria and help in the delivery of
432 credible elections as issues of ballot stuffing, multiple voting, counting error, violence
433 e.t.c will be reduced or eliminated. 21.77% of the respondents do not support the
434 introduction of electronic voting while 7.48% of the respondents did not respond to
435 the question.
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437 In summary, the analysis of responses obtained from the administered questionnaire is a
438 pointer that the introduction of mobile voting as a form of voting platform to electorates in
439 Nigeria will enhance participatory democracy in Nigeria.

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441 **4.2 The developed architectural framework for mobile voting**

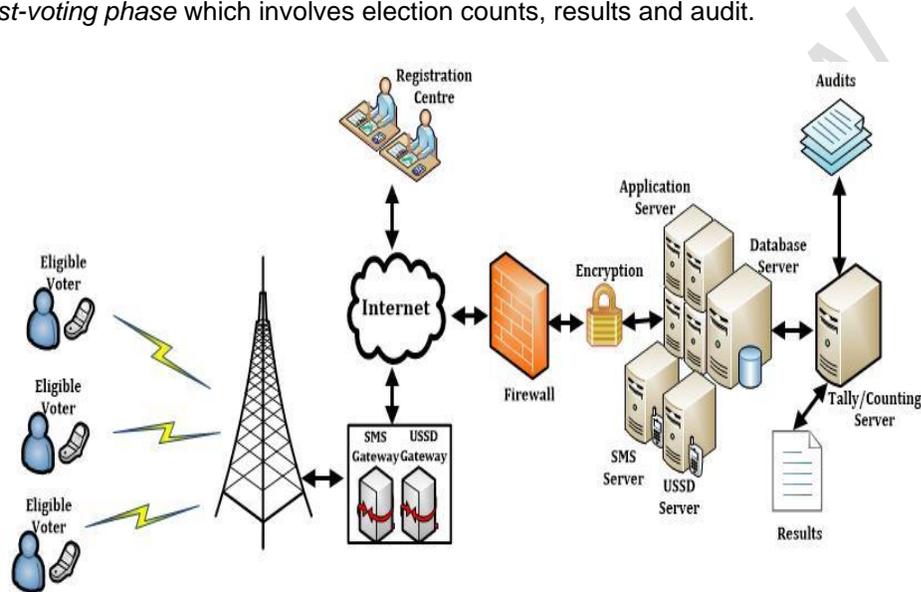
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443 The architectural framework for the mobile voting system is depicted in Figure 3. The
444 framework uses the technology available to a large majority of voters (mobile phone) and the
445 technological infrastructure exposed to them. There are two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

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

- 468 i. *Pre-voting phase* which involves election declaration, candidate nomination,
 469 referendum options and voters' registration.
- 470 ii. *Voting phase* which involves ballot information, voter authentication, vote casting
 471 and confirmation.
- 472 iii. *Post-voting phase* which involves election counts, results and audit.
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Figure 3: The Developed Architectural Framework for Mobile Voting

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

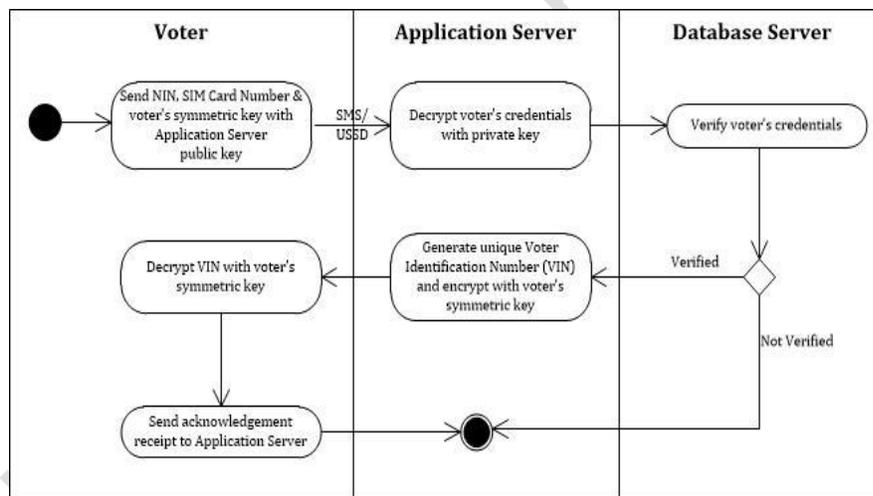
503
504
A. Pre-voting Phase

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

513 application server. The following steps are involved for electronic registration via mobile
 514 phone:

- 515 i. A voter intending to register will send his/her NIN, SIM card number and symmetric
 516 key encrypted with public key (available on the Application Server) to the Application
 517 Server.
- 518 ii. On receipt of the voter's credentials of (i) above, the Application Server will decrypt
 519 these credentials with its private key.
- 520 iii. The Application Server will then verify the user credentials (NIN and SIM card
 521 number) with its two databases of public records.
- 522 iv. If the voter is verified as who he/she claims, the application server will generate and
 523 send a unique Voter Identification Number (VIN), which the voter will use for
 524 authentication during the voting phase.
- 525 v. The voter on receipt of the VIN will decrypt it his/her symmetric key. The VIN is
 526 expected to be kept secured by the voter in order not to compromise confidentiality.
- 527 vi. The voter sends an acknowledgement receipt of the VIN to the Application Server.
 528

529 A voter who does not want to use his/her mobile phone may also visit a designated electoral
 530 registration centre to register as an eligible voter using the aforementioned credentials that
 531 is, NIN and SIM card number. A unique VIN will be generated for the intending voter upon
 532 verification and authentication by the application server through the electoral officer in
 533 charge. The activity diagram for the pre-voting phase of the framework is depicted in Figure
 534 4.



552
 553 **Figure 4: Activity Diagram for the Pre-voting Phase of the Framework**
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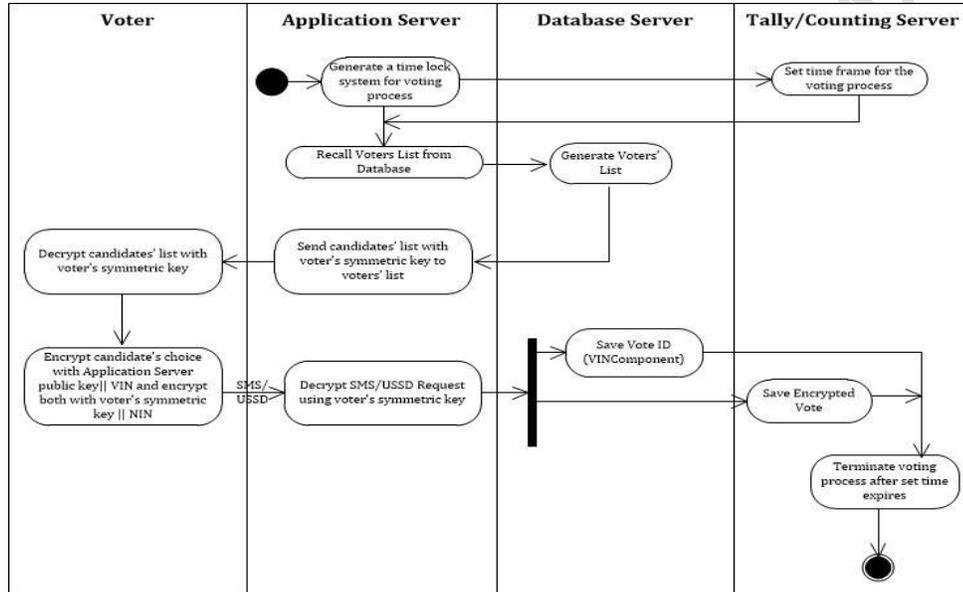
555 **B. Voting Phase**

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

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

- 566 iv. The voter will then encrypt his/her choice with the Application Server public key,
 567 which is then string together with the VIN and encrypt both with voter's symmetric
 568 key and then string together with the NIN number and send to the Application Server
 569 using SMS or USSD.
 570 v. The Application Server fetches the voter's symmetric key by calling his/her NIN. The
 571 server will afterwards decrypt the later part of the SMS/USSD request, using the
 572 voter's symmetric key. The Application Server will only assign a notation to the VIN
 573 component of the SMS/USSD request for the record purposes and to avoid multiple
 574 voting. The remaining encrypted candidates' list message will be forwarded to the
 575 Tally/Counting Server.

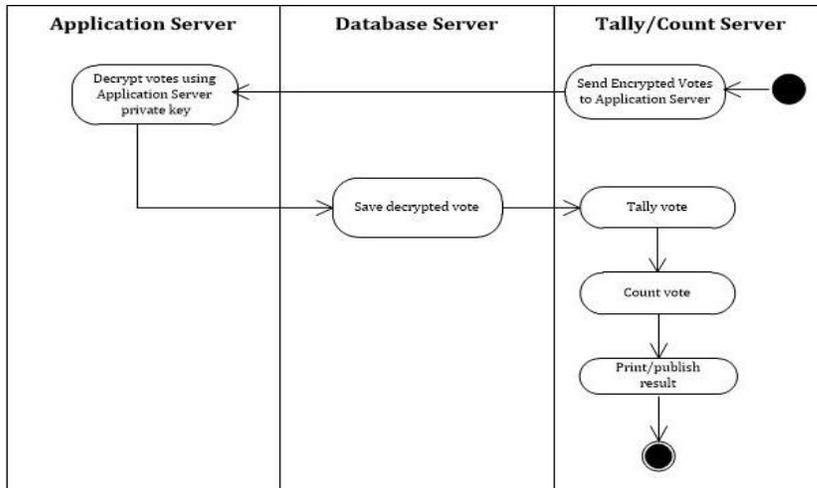
576 The activity diagram for the voting phase of the framework is depicted in Figure 5.



597 **Figure 5: Activity Diagram for the Voting Phase of the Framework**

600 C. Post Voting Phase

602 The time lock system in the Tally/Counting Server of (i) of the Voting Phase, keeps the vote
 603 encrypted until the voting process ends. Decryption of casted votes only commences when
 604 the voting process has been terminated. Therefore, no instantaneous result can be known or
 605 viewed by anyone until the official voting time ends, hence guaranteeing the secrecy of the
 606 ballots. Each ballot casted will be decrypted by the Application Server private key.
 607 The decrypted ballots will be counted by the Tally/Counting Server and results will then be
 608 made public.



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Figure 6: Activity Diagram for 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

646 to cast their vote from a place other than the poll site in their voting district, facilitate the
647 casting of the vote by the voter, facilitate the participation in elections by those who are
648 entitled to vote, widen access to the voting process for voters with disabilities or those
649 having other difficulties in being physically present at a poll site, increased voter turnout,
650 reduce the overall cost to the electoral authorities of conducting an election, deliver voting
651 results reliably and more quickly amongst many other benefits.

652

653 **COMPETING INTERESTS**

654

655 Authors have declared that no competing interests exist.

656

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