

# m-voting

*by* Asian Journal

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**Submission date:** 18-Aug-2019 04:42AM (UTC+0200)

**Submission ID:** 1160946489

**File name:** Ms\_AJRCOS\_51163.docx (522.58K)

**Word count:** 6969

**Character count:** 39822

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

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### **ABSTRACT**

38 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**

3 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.

3 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].

41 **2**  
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 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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## 2. LITERATURE REVIEW

### 2.1 E-voting: an alternative voting solution

85 **1**  
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].

93 **4**  
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].

109  
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].

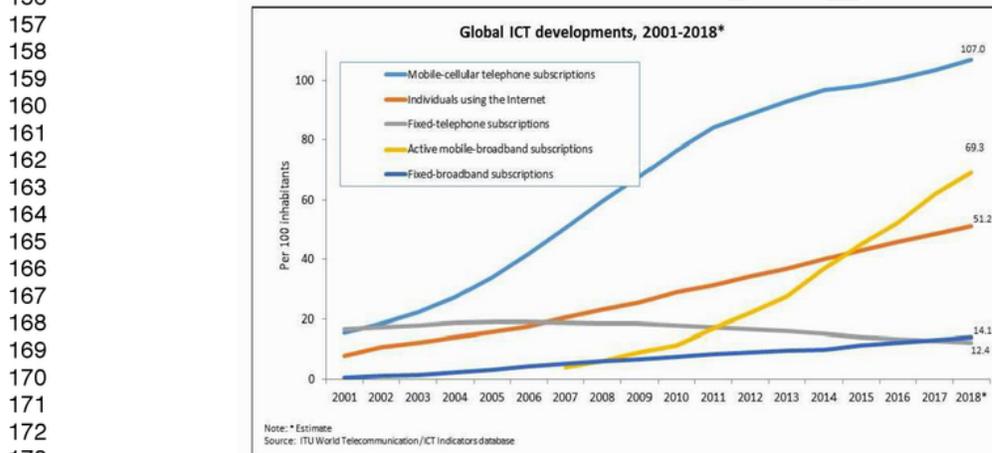
122 **55**  
123 Many e-voting schemes have been proposed and used with various degrees of successes in  
124 a number of countries during local elections and referenda. These schemes have proven  
125 that e-voting can undoubtedly enable voters to cast their vote from a place other than the  
126 poll 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].

132 **3**  
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.  
140

## 141 2.2 Why mobile phones over other ICTs?

142 18  
143 Mobile phones are but one form of ICT. Personal computers, laptops, the Internet and  
144 18 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 7 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.  
156



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

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

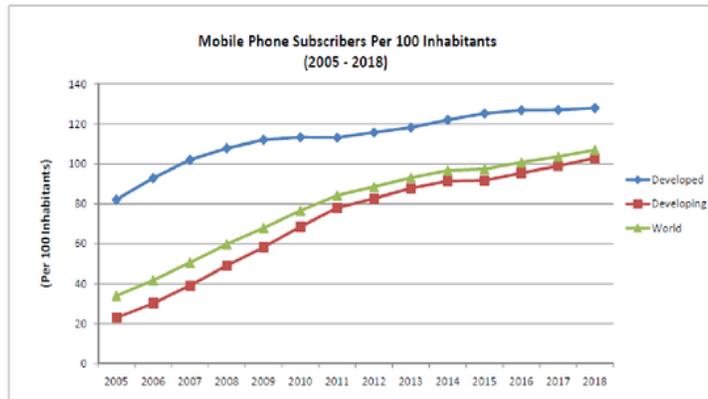


Figure 2: Global Mobile Cellular Subscriptions Growth [26]

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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 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.

- 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.  
229

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.  
248

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 the 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.  
266

## 267 2.4 Related works

268  
269 [29] developed a prototype m-voting system for enhancing participation of electorates during  
270 the pioneering 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.

277

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.

281

282 [30] proposed a mobile<sup>21</sup> 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.

286

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.

293

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.

297

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.

301

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

304

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.

309

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.

316

### 317 3. METHODOLOGY

318

319 The research methods employed are of two phases:

320

a) Needs assessment and analysis

321

b) Development of a m-voting framework

322

#### 323 3.1 Needs assessment and analysis

324

325 Prior to the development of the m-voting system, a comprehensive needs assessment and  
326 analysis<sup>22</sup> 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.  
344

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.  
350

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

352  
353 The phases involved in developing the m-voting framework are depicted in the following  
354 subsections.  
355

#### 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.

### 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.  
 394

### 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).  
 398

## 4. RESULTS AND DISCUSSION

### 4.1 Descriptive analysis of respondents

403 The data analysis of the collated information from the questionnaires is presented in Table 1.  
 404

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

405 **Table 1: The data analysis of the collated information**  
 406

- 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 system.
- 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.

436  
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.

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

442 <sup>1</sup> The architectural framework for the mobile voting system is depicted in Figure 3. The  
443 framework uses the technology available to a large majority of voters (mobile phone) and the  
444 technological infrastructure exposed to them. There are two communication channels for the  
445 target users to access the services available on the framework. They are SMS and USSD.  
446 The communication will be facilitated by existing mobile telecommunication infrastructures in  
447 the communities of the target users. The application server contain applications running at  
448 the back-end to integrate SMS and USSD from the voters 'end and web from the supervised  
449 registration centres' end. The SMS component of the framework provides premium SMS  
450 services. These services are micropayment services by SMS. The premium SMS allow  
451 users to buy or subscribe to various services or micro-payment services by SMS or digital  
452 content via a short code from 3 to 5 digits. A voter accessing the service on the framework  
453 would be required to send a "keyword" to an SMS premium number and in return the  
454 application server (content provider) delivers the requested content or service. The apt  
455 details of the "keyword" are described explicitly in sub-sections 4.2A and 4.2B. The USSD  
456 component of the framework provides instant messaging services. It requires generation of  
457 query from the mobile phone of the voter. Once this request is sent, the USSD gateway  
458 forwards it to the USSD application on the application server. The application then responds  
459 to the request, and the process is repeated in reverse: the response goes back to the USSD  
460 gateway, which displays the content of that response on the voter's mobile phone.

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463 <sup>1</sup> 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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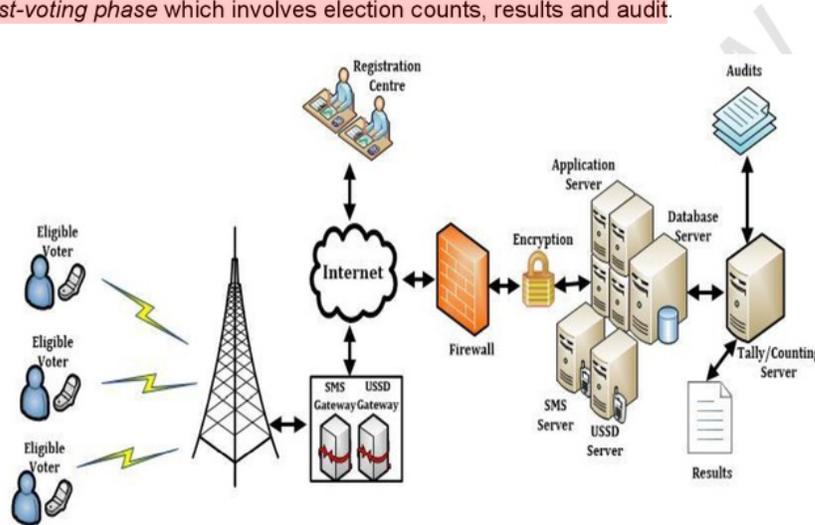
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**Figure 3: The Developed Architectural Framework for Mobile Voting**

493 <sup>1</sup> 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.

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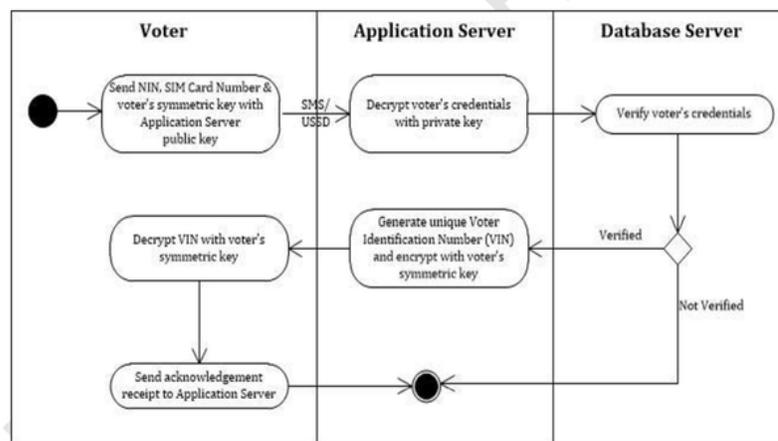
#### A. Pre-voting Phase

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 <sup>33</sup> 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<sup>6</sup>.
- 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<sup>31</sup> 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.



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

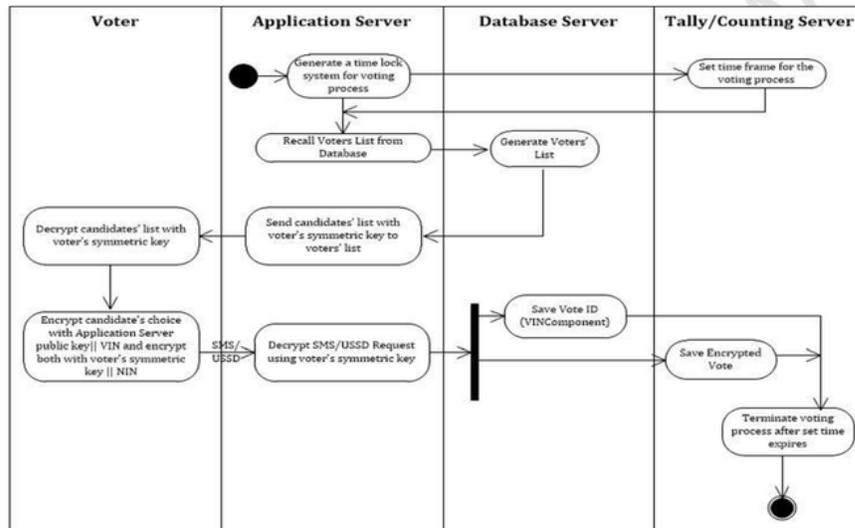
556 The underlisted steps depict the process involved for voting on Election Day:

- 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<sup>23</sup> 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<sup>6</sup> 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 <sup>31</sup> Tally/Counting Server.

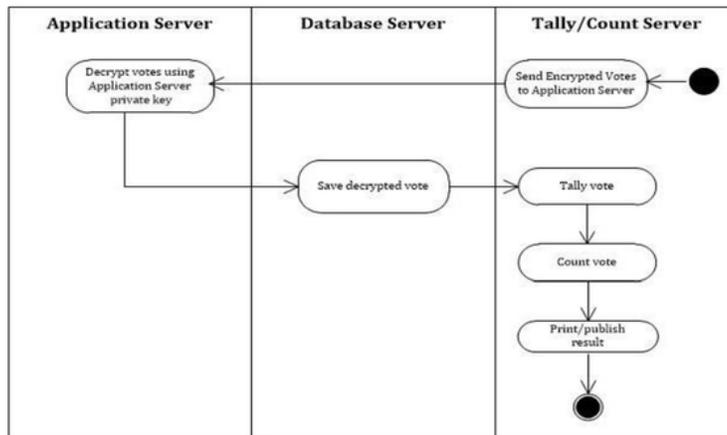
576 The activity diagram for the voting phase of the framework is depicted in Figure 5.



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

599 **C. Post Voting Phase**

600 The time lock system in the Tally/Counting Server of (i) of the Voting Phase, keeps the vote  
 601 encrypted until the voting process ends. Decryption of casted votes only commences when  
 602 the voting process has been terminated. Therefore, no instantaneous result can be known or  
 603 viewed by anyone until the official voting time ends, hence guaranteeing the secrecy of the  
 604 ballots casted. <sup>34</sup> Each ballot casted will be decrypted by the Application Server private key.  
 605 The decrypted ballots will be counted by the Tally/Counting Server and results will then be  
 606 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 i<sup>11</sup> 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 ha<sup>11</sup> 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.

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