

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

12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33

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.

Keywords: Election, E-voting, M-voting, Mobile phone, 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, 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

34 [2, 3, 4, 5]. Furthermore, the cost and process of manual voting are both increasing
35 geometrically and tedious to execute [6] and there has been a declining participation rate
36 due to: inconvenience of manual system of voting like: inaccuracy in ballot counting and
37 delayed announcement of election results [1,7]; loss of significant time during ballot counting
38 [8]; unacceptable percentages of lost, stolen and miscounted ballot papers, votes loss
39 through unclear or invalid ballot marks and limited accommodations for people with
40 disabilities [1, 9,10].

41
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.

79

80 **2. LITERATURE REVIEW**

81

82 **2.1 E-voting: an alternative voting solution**

83

84 Elections and voting are fundamental to any consensus-based society. They are one of the
85 most critical functions of democracy. Elections allow the populace to choose their
86 representatives and express their preferences for how they will be governed while voting is a

87 method by which a group of people express their opinion over who will lead them for a
88 specific period of time through electoral processes. Naturally, the integrity of the election
89 process is fundamental to the integrity of democracy itself. Since time immemorial,
90 technology has always influenced and shaped the ways elections are held [18].

91
92 Different voting systems that are based on traditional paper ballots and mechanical devices
93 were developed for elections [4]. In traditional paper ballots, voters choose or mark their
94 favourite choices on ballots and place them in boxes, which are sealed and officially opened
95 under special conditions to warrant transparency. The ballots are then counted manually,
96 which is a tedious process that is subject to human error. With voting via mechanical
97 systems, voters make their choices by pulling down on mechanical levers that correspond to
98 their favourite choice of candidates. Each lever has a mechanical counter that reports the
99 number of votes for that position. These machines are no longer manufactured [2]. In Nigeria
100 and most of other developing nations, most elections are conducted using paper ballots.
101 However, there have been countless reported cases of eligible voters being unable or
102 prevented from exercising their right to vote as stated in the Universal Declaration of Human
103 Rights of the United Nations, sometimes due to violence and intimidation, lack of information
104 on physical location of voting poll sites, social discrimination; and by other natural causes
105 like advanced age, physiological disability, terrain, floods, and poor communication
106 infrastructure [5, 19].

107
108 Most of the issues associated with paper ballots have led to a rapid decline in voters'
109 participation in elections over the years. This is worrying from a democratic point of view in
110 that, if the reasons of the decline are left unchecked, the mandate of those elected to hold
111 the positions might eventually be questionable. Participatory democracy is a major
112 requirement for achieving the millennium development goals (MDGs), particularly, where
113 majority of the citizenry is disenchanted with the electioneering or democratic processes or
114 governance. The primary objective of the MDGs which is reducing poverty in developing
115 nations through the use of ICT requires a lot of innovations. One of such innovations is the
116 implementation of e-voting. The term e-voting is being used from casting of vote by
117 electronic means to asking the internet community for an opinion on a political issue, as well
118 as from tabulating the votes by electronic means to integrated electronic systems from
119 voters' and candidates' registration to the publication of election results [11, 20].

120
121 Many e-voting schemes have been proposed and used with various degrees of successes in
122 a number of countries during local elections and referenda. These schemes have proven
123 that e-voting can undoubtedly enable voters to cast their vote from a place other than the
124 poll site in their voting district, facilitate the casting of the vote by the voter, facilitate the
125 participation in elections by those who are entitled to vote, widen access to the voting
126 process for voters with disabilities or those having other difficulties in being physically
127 present at a poll site, increased voter turnout by providing additional voting channels, reduce
128 overtime, the overall cost to the electoral authorities of conducting an election, deliver voting
129 results reliably and more quickly amongst many other benefits [5, 11].

130
131 Furthermore e-voting can enhance polling and votes' security, confidentiality, sincerity and
132 increased cost savings on reduced manpower, logistical materials and tools; and above all
133 instant analysis and reporting. It can enhance accuracy of all valid votes and final outcome;
134 permit voting once for only eligible voters; allow independent verification of all voters; it can
135 also improve voters' turnaround as it flexibly allows a voter to login and vote from any
136 workstation [21]. Therefore, electronic based voting technologies would expand the reach
137 and range of potential voting population.

138
139

140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191

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 Figure 1.

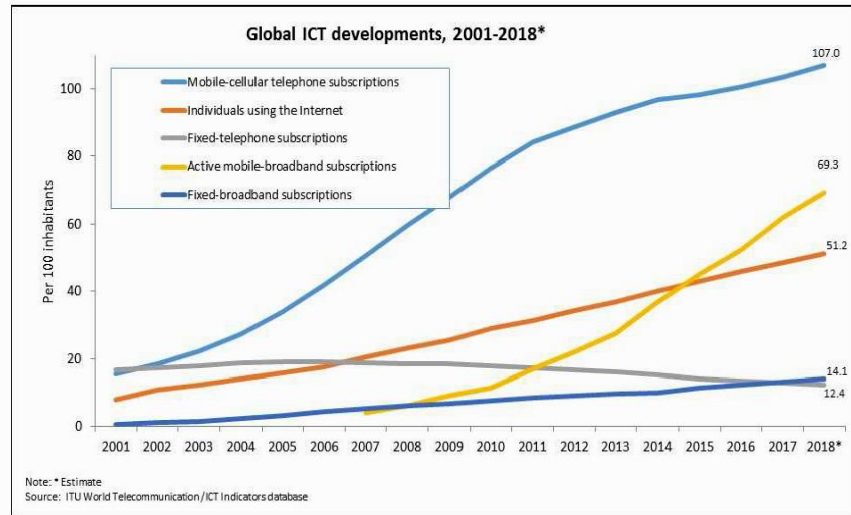


Figure 1: Global ICT Development [22]

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 Figure 2.

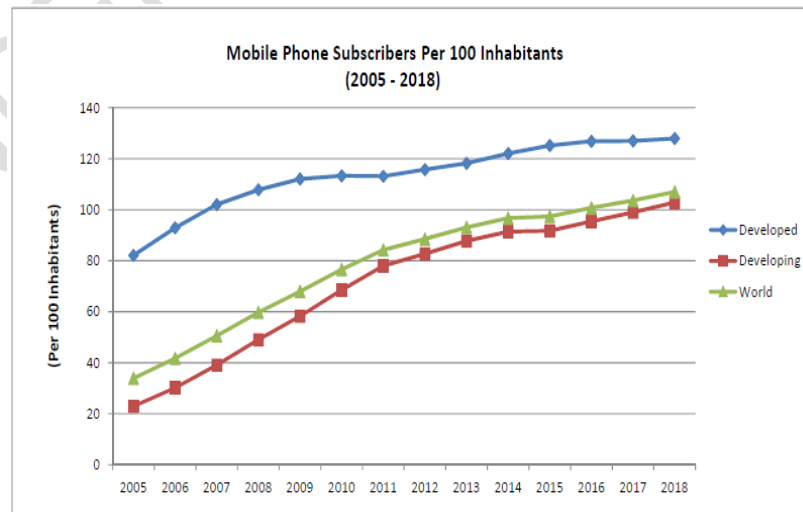


Figure 2: Global Mobile Cellular Subscriptions Growth [26]

192 The proliferation of mobile phones in Nigeria has resulted in their use even within
193 impoverished rural homesteads. Mobile phones are easy to use, are increasingly able to
194 bypass the barriers of illiteracy and affordability, and provide access to a wide range of very
195 useful services. Furthermore, mobile phones have the advantage over other ICT tools in
196 terms of its appropriateness for the under-developed local conditions. It has been found to
197 help improve the productivity of individuals and organizations within resource-constrained
198 environments as it increases efficiency, effectiveness, and reach [23, 24, 25]. Other than
199 mobile phones, other ICT tools suffers from the problem of feasibility for the poor in
200 geographically disadvantaged areas because of lack of enabling environments such as
201 infrastructure and capital. For example Internet enhanced technologies are not appropriate
202 in the areas lacking electricity and network infrastructure. On the contrary, mobile phone
203 technology has much less requirement on the infrastructure and hence wider applicability
204 [16]. Many services may be provided using the major communication and information access
205 functionalities of mobile devices that include installable mobile applications, Voice/
206 Interactive Voice Response (IVR), Short Message Service (SMS), Unstructured
207 Supplementary Service Data (USSD) and internet. Other device features that enable a wide
208 array of possibilities in ICT innovations include the ability of devices to capture photos and
209 videos, communicate via Near-field Communication (NFC) and Radio-frequency
210 Identification (RFID), as well as Global Positioning System (GPS) functionalities. Most of
211 these innovations are made to work on basic phones, smart phones, and Internet of Things
212 (IoT) devices, mostly depending on the target users, the available ICT infrastructure and the
213 service being provided.

214

215 **2.3 The case for m-voting**

216

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

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

234

235 Literature surveys on e-voting implementation in the context of developing countries suggest
236 the implementation of remote e-voting schemes. The reason is not far to seek; some of the
237 attendant problems faced by the conventional voting systems such as violence, intimidation,
238 coercion, disenfranchisement, complicity of the security agencies and so on are more
239 probably to be evident in e-voting schemes supervised by physical presence of
240 governmental or independent electoral authorities. However most implementation of existing
241 remote e-voting systems revealed that these systems are designed and implemented as a
242 specific case of remote electronic voting called internet voting (i-voting); whereby remote
243 voting takes place only over the internet such as via a web site or voting applet. In Nigeria
244 and most developing countries, deployment of only internet voting (i-voting) may be a failure

245 as the affordability of the average nationals of these countries with very low per capital
246 income of a personal computer with internet facilities or mobile terminals with internet
247 support (smart phones) is highly improbable. Also, the need of appropriate technical support
248 on the usage on the part of the nationals is an impediment to the implementation of remote i-
249 voting. These are referred to as the digital divides. Proposed remote e-voting solutions for
250 such nationals should be therefore extended to the use of ICT technologies that are
251 affordable. Basic phones are able to address these challenges as they are cheaper than
252 personal computers (PCs) and they require minimal technical know-how.
253

254 Mobile voting can be seen as an additional platform to the electronic voting systems. It is a
255 mobile government (m-government) initiative with tremendous potentials to enhance
256 democratic participation [17]. It will also serve as an enabler and a convenient way to involve
257 citizens in political decision making. It is a cheaper, convenient, and a simple to administer
258 voting alternative. M-voting is not a replacement for e-voting, but rather a complement [27,
259 28]. The use of mobile devices in political participation simplifies and eases access to and
260 the integrating of persons and institutions in political processes. M-voting has the potential to
261 increase election turnout by providing voters with a convenient voting mode that does not
262 require them to leave their homes or offices. Even geographic distance is no longer a
263 limitation on participation in elections as soldiers, students, tourists, and business persons
264 can exercise their civic right and vote from anywhere around the world regardless of any
265 time differences. Since many democracies are faced with an ever decreasing voting rate, the
266 opportunity to turn the tide and increase turnout seems particularly promising. There is no
267 doubt that remote electronic voting offers a convenience that would be appreciated by many
268 people. M-voting enables citizens to participate electronically in democracy and provides
269 them with more information about candidates and the election/survey they are being asked
270 to participate in.
271

272 **2.4 Related works**

273

274 [29] developed a prototype m-voting system for enhancing participation of electorates during
275 electioneering process using Nigeria as a case study. The system was developed using
276 Wireless Markup Language (WML), Hypertext Preprocessor (PHP) and MySQL server as
277 the database server and tested using mobile explorer emulator (Openwave V7 Simulator).
278

279 [1] designed and implemented a generic and secure electronic voting system where voters
280 can cast their votes anytime, anywhere and using a number of electronic devices including
281 private computer networks, web and mobile phones.
282

283 [28] proposed a framework for m-voting which can be used for conducting electronic voting
284 or survey. The framework described how smart phones (with Symbian, Blackberry, Android
285 and ios mobile operating systems) are useful and efficient devices for voting.
286

287 [30] proposed a mobile voting system that aims to preserve the integrity of elections. The
288 system called "MVote" is a mobile phone application that uses three level of security, which
289 are username and password, national ID and fingerprint, and a strong dedicated security
290 algorithm.
291

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

298 [32] developed a mobile voting system that was developed on the android mobile operating
299 system. The intent of the system is to proffer solutions to problems posed by traditional
300 voting systems.

301
302 [33] developed an electronic voting system based on the proposed oblivious and proxy
303 signature scheme and implemented the scheme in a smart phone application to allow users
304 to vote securely and conveniently.

305
306 [34] developed an android application for mobile voting with the intent of proffering solutions
307 to the problems associated with conventional voting systems.

308
309 [35] proposed an android-based mobile voting application for students' elections at
310 Infrastructure University Kuala Lumpur, Malaysia. The application allows students to cast
311 their votes online and track the results in real time. The application also provides candidates
312 with a centralized platform to campaign and attract voters.

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

320 321 **3. METHODOLOGY**

322
323 The research methods employed are of two phases:

- 324 a) Needs assessment and analysis
325 b) Development of a m-voting framework
326

327 **3.1 Needs assessment and analysis**

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

- 334 i. *Defining the needs of the target users:* The design goal of the framework is to
335 provide a voting platform which can be easily accessible and available for a voting
336 population regardless of their location.
337 ii. *The availability and appropriateness of the technology to be employed:* The
338 framework utilized basic phones which are the most readily available technology at
339 the disposal of most users. Also, availability of telecommunication infrastructures to
340 support the available technology at the disposal of the users was considered.
341 iii. *The literacy levels of the target users:* The mode of content delivery of the
342 framework was based on the literacy level of the target users. The communication
343 channels deployed for usage by the target users possesses high ease of usage and
344 low technical know-how requirements.
345 iv. *The willingness of the target users to pay for service(s):* The cost of accessing the
346 services to be provided by the framework was prioritized in the design process of the
347 framework. SMS and USSD were employed as they are relatively affordable.
348

349 A questionnaire was designed and administered to 1500 eligible electorates (18 years and
350 older). A total of 1364 responses were received. Two out of the sources of data collection

351 techniques proposed by [36] for case study research (direct observation and field interviews)
352 were employed to collect information on mobile phone ownership, device capabilities,
353 services and usage, literacy level and availability of telecommunications infrastructures.

354

355 **3.2 Developing the m-voting framework**

356

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

359

360 **3.2.1 Requirements Definition**

361 The design of any voting system, whether electronic or manual, must satisfy a number of
362 sometimes competing criteria including a high degree of security and accuracy, eligibility and
363 authentication, integrity, verifiability and auditability, reliability, flexibility, performance and
364 scalability [1]. The anonymity of a voter's ballot must be preserved, both to guarantee the
365 voter's safety when voting against a malevolent candidate, and to guarantee that voters
366 have no evidence that proves which candidates received their votes. The existence of such
367 evidence would allow votes to be purchased by a candidate. The voting system must also be
368 tamper-resistant to thwart a wide range of attacks, including ballot stuffing by voters and
369 incorrect tallying by insiders. Another factor, of immense importance is the "human factors".
370 A voting system must be comprehensible to and usable by the entire voting population,
371 regardless of age, infirmity, or disability. Providing accessibility to such a diverse population
372 is an important engineering problem and one where, if other security is done well, electronic
373 voting could be a great improvement over current paper systems. Flaws in any of these
374 aspects of a voting system, however, can lead to indecisive or incorrect election results.
375 Guided by the design requirements' definition for electronic voting systems documented in
376 [2, 13, 28], the design requirements of the m-voting framework proposed in this paper are
377 divided into two groups, namely, generic and system-specific. The framework is to cater for
378 the following generic requirements:

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

390 The system-specific requirements of the framework allow:

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

394

395

396 **3.2.2 Framework design**

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

400

401 **3.3.3 Infrastructural model architecting and development**

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

404 **4. RESULTS AND DISCUSSION**

405

406 **4.1 Descriptive analysis of respondents**

407

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

409

410 **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%
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%

411

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

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

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

428 d) *Willingness to use their mobile device to cast vote:* A total of 923 respondents
 429 representing 67.67% of the mobile phone owners are willing to use their mobile
 430 phones for voting while 307 of them representing 22.51% do not prefer using mobile
 431 phones. 9.82% respondents representing did not respond to the question.

432 Respondents that preferred to use their mobile devices to cast their ballots believed
433 it is more convenient and faster.
434 e) *d) Acceptance of e-voting as a substantive form of voting system:* 965 respondents
435 preferred e-voting to be implemented as a substantive form of voting system. They
436 believe it will increase voters' participation in Nigeria and help in the delivery of
437 credible elections as issues of ballot stuffing, multiple voting, counting error, violence
438 e.t.c will be reduced or eliminated. 21.77% of the respondents do not support the
439 introduction of electronic voting while 7.48% of the respondents did not respond to
440 the question.
441

442 In summary, the analysis of responses obtained from the administered questionnaire is a
443 pointer that the introduction of mobile voting as a form of voting platform to electorates in
444 Nigeria will enhance participatory democracy in Nigeria.
445

446 **4.2 The developed architectural framework for mobile voting**

447

448 The architectural framework for the mobile voting system is depicted in Figure 3. The
449 framework uses the technology available to a large majority of voters (mobile phone) and the
450 technological infrastructure exposed to them. There are two communication channels for the
451 target users to access the services available on the framework. They are SMS and USSD.
452 The communication will be facilitated by existing mobile telecommunication infrastructures in
453 the communities of the target users. The application server contain applications running at
454 the back-end to integrate SMS and USSD from the voters 'end and web from the supervised
455 registration centres' end. The SMS component of the framework provides premium SMS
456 services. These services are micropayment services by SMS. The premium SMS allow
457 users to buy or subscribe to various services or micro-payment services by SMS or digital
458 content via a short code from 3 to 5 digits. A voter accessing the service on the framework
459 would be required to send a "keyword" to an SMS premium number and in return the
460 application server (content provider) delivers the requested content or service. The apt
461 details of the "keyword" are described explicitly in sub-sections 4.2A and 4.2B. The USSD
462 component of the framework provides instant messaging services. It requires generation of
463 query from the mobile phone of the voter. Once this request is sent, the USSD gateway
464 forwards it to the USSD application on the application server. The application then responds
465 to the request, and the process is repeated in reverse: the response goes back to the USSD
466 gateway, which displays the content of that response on the voter's mobile phone.
467

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

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

478

479

480

481

482

483

484

485

486

487

488

489

490

491

492

493

494

495

496

497

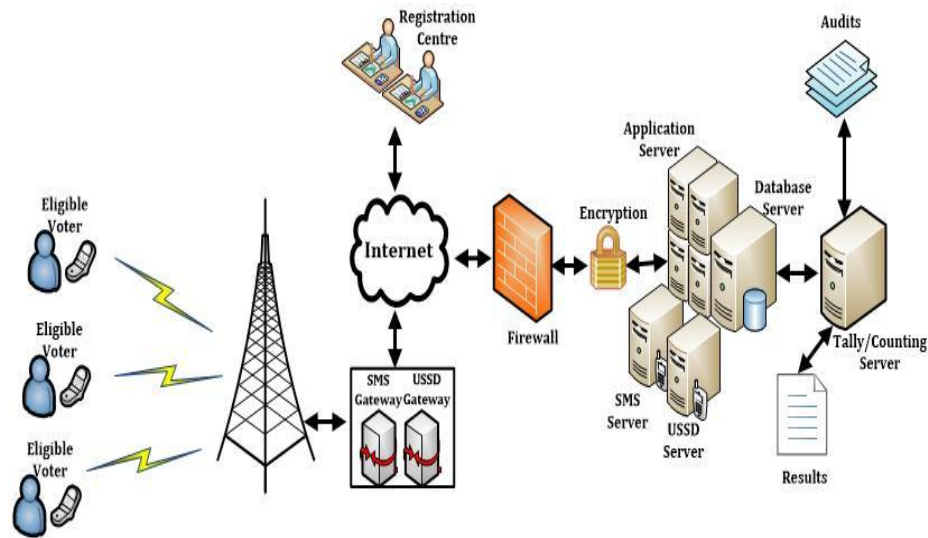


Figure 3: The Developed Architectural Framework for Mobile Voting

498

499

500

501

502

503

504

505

506

507

508

509

510

511

512

513

514

515

516

517

518

519

520

521

522

523

524

525

526

527

528

529

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.

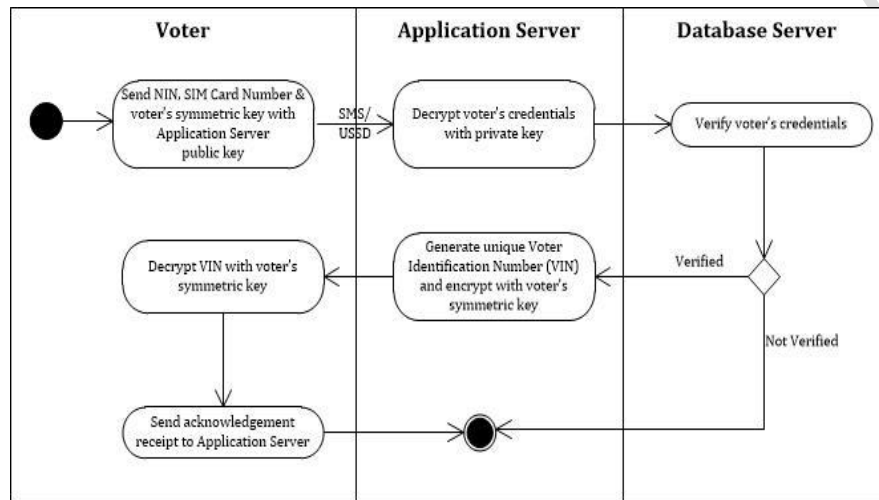
A. Pre-voting Phase

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.

- 530 v. The voter on receipt of the VIN will decrypt it his/her symmetric key. The VIN is
 531 expected to be kept secured by the voter in order not to comprise confidentiality.
 532 vi. The voter sends an acknowledgement receipt of the VIN to the Application Server.
 533

534 A voter who does not want to use his/her mobile phone may also visit a designated electoral
 535 registration centre to register as an eligible voter using the aforementioned credentials that
 536 is, NIN and SIM card number. A unique VIN will be generated for the intending voter upon
 537 verification and authentication by the application server through the electoral officer in
 538 charge. The activity diagram for the pre-voting phase of the framework is depicted in Figure
 539 4.



557
 558 **Figure 4: Activity Diagram for the Pre-voting Phase of the Framework**
 559

560 **B. Voting Phase**

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

- 562 i. About the time the voting process will commence, the Application Server sets a time
 563 lock system which will be implemented on the Tally/Counting Server.
 564 ii. The Application Server will send the candidates' list for the election being held to all
 565 verified voters by SMS (using the SIM card number used for enrollment during the
 566 pre-voting phase). The SMS will be encrypted with the voter's symmetric key.
 567 Hence only duly registered and verified voters can access the candidates' list.
 568 iii. At the voters' end, upon the reception of the SMS, voters will decrypt the message
 569 with their symmetric key. A voter can then select the candidate of his/her choice
 570 from the candidate list.
 571 iv. The voter will then encrypt his/her choice with the Application Server public key,
 572 which is then string together with the VIN and encrypt both with voter's symmetric
 573 key and then string together with the NIN number and send to the Application Server
 574 using SMS or USSD.
 575 v. The Application Server fetches the voter's symmetric key by calling his/her NIN. The
 576 server will afterwards decrypt the later part of the SMS/USSD request, using the
 577 voter's symmetric key. The Application Server will only assign a notation to the VIN
 578 component of the SMS/USSD request for the record purposes and to avoid multiple
 579 voting. The remaining encrypted candidates' list message will be forwarded to the
 580 Tally/Counting Server.

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

582
 583
 584
 585
 586
 587
 588
 589
 590
 591
 592
 593
 594
 595
 596
 597
 598
 599
 600
 601
 602
 603
 604
 605
 606
 607
 608
 609
 610
 611
 612
 613
 614
 615
 616
 617
 618
 619
 620
 621
 622
 623
 624
 625
 626
 627
 628
 629
 630
 631
 632
 633
 634

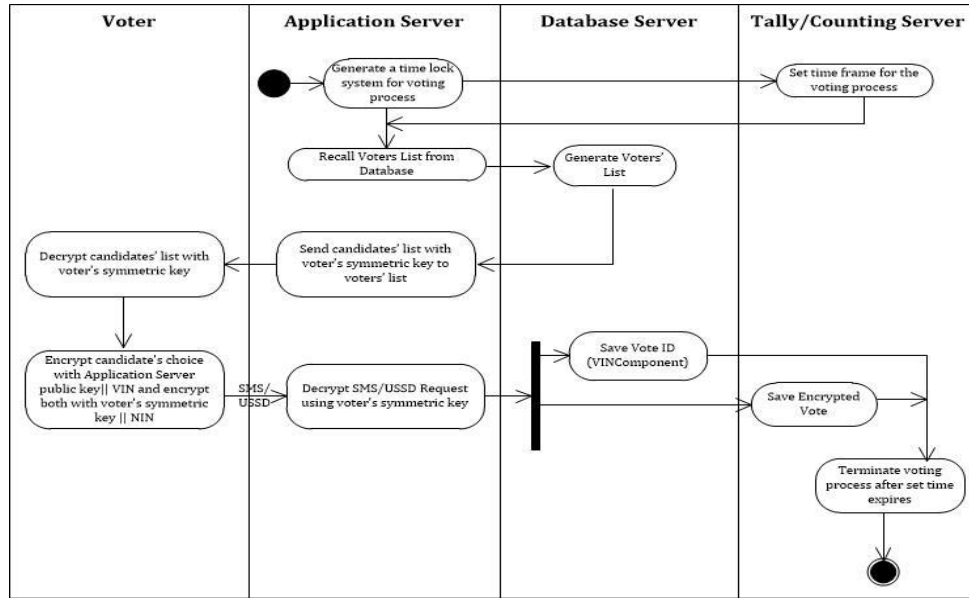


Figure 5: Activity Diagram for the Voting Phase of the Framework

C. 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. Figure 6 depicts the activity diagram of the post voting phase of the framework.

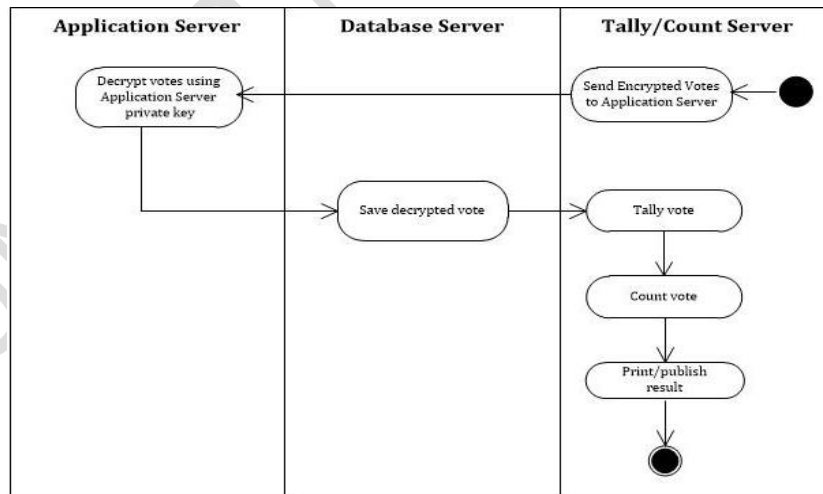


Figure 6: Activity Diagram for the Post Voting Phase of the Framework

635 **5 CONCLUSION**

636

637

638

639

640

641

642

643

644

645

646

647

648

649

650

651

652

653

654

655

656

657

658

659

660

661

662

663

664

665

666

667

668

669

670

671

672

673

674

675

676

677

678

679

680

681

682

683

684

685

686

687

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.

666 **COMPETING INTERESTS**

668 Authors have declared that no competing interests exist.

672 **REFERENCES**

- 674 [1] Okediran O. O. and Ganiyu R. A. (2015), "A Framework for Electronic Voting in
675 Nigeria" International Journal of Computer Applications, New York, United States,
676 129(3):13-16
- 678 [2] NSF, (2001)" Report on the National Workshop on Internet Voting: Issues and
679 Research Agenda", National Science Foundation, at http://news.findlaw.com/cnn/docs/voting/nsfe-vo_terprt.pdf.
- 682 [3] Muir H, Laville S. and Gillan A., (2005) "New Fears over Postal Vote Fraud",
683 Accessed at <http://politics.guardian.co.uk/election/story/0,15803,1458341,00.html>.
- 685 [4] Malkawi M., Khasawneh M., Al-Jarrah O., (2009) "Modeling and Simulation of a
686 Robust E-voting System", Communications of the IBIMA, Volume 8, 2009.

- 688 [5] Okediran O. O., Omidiora E. O., Olabiyisi S. O., Ganiyu R. A. and Alo O. O., (2011):
689 "A Framework for a Multifaceted Electronic Voting System", International Journal of
690 Applied Science and Technology, Philadelphia, USA, 1(4): 135-142
691
- 692 [6] Ibrahim S., Kamat, M., Salleh M., and Abdul-Aziz, S. (2003), "Secure Voting Using
693 Blind Signature "accessed at [http://eprints.utm.my/3262/1/IEEE02VS_full_paper_](http://eprints.utm.my/3262/1/IEEE02VS_full_paper_ver14Nov.pdf)
694 [ver14Nov.pdf](http://eprints.utm.my/3262/1/IEEE02VS_full_paper_ver14Nov.pdf)
695
- 696 [7] Kalaichevi V. and Chandrasekaran R. M. (2011), "Secured Single Transaction of E-
697 Voting Protocol: Design and Implementation", European Journal of Scientific
698 Research, Vol. 51 No.2, pp. 276-284.
699
- 700 [8] Akinyede R.O. (2010),"Nigerian Voting System: Present and Future States",
701 Proceedings of 23rd National Conference of Nigeria Computer Society July 26th -30th,
702 Volume 21, pp. 77-81.
703
- 704 [9] Ayannuga O. O. and Folorunso O. (2010), " Electronic Voter's Authentication
705 Management System (eVams)", Proceedings of 23rd National Conference of Nigeria
706 Computer Society July 26th -30th 2010,Vol. 21,pp. 105-110.
707
- 708 [10] Manish K, Suresh K. T, Hanumanthappa M. and Evangelin G. D. (2005), "Secure
709 Mobile Based Voting System", accessed at [http:// www.iceg.net /2008/ books /](http://www.iceg.net/2008/books/2/35_324_350.pdf)
710 [2/35_324_350.pdf](http://www.iceg.net/2008/books/2/35_324_350.pdf).
711
- 712 [11] Buchsbaum T. M., (2004). E-voting: International Developments and Lessons Learnt.
713 Proceedings of Workshop on Electronic Voting in Europe –Technology, Law, Politics
714 and Society, Austria, at [www.subs.emis.de/LNI/ Proceedings/ Proceedings47/](http://www.subs.emis.de/LNI/Proceedings/Proceedings47/Proceeding.GI.47-4.pdf)
715 [Proceeding.GI.47-4.pdf](http://www.subs.emis.de/LNI/Proceedings/Proceedings47/Proceeding.GI.47-4.pdf).
716
- 717 [12] Magi T., (2007). Practical Security Analysis of E-Voting Systems. Master of
718 Information Technology Thesis, Department of Informatics, Tallinn, University of
719 Technology, Estonia.
720
- 721 [13] Nestas L. H., (2010). Building Trust in Remote Internet Voting. M. Sc Thesis,
722 Department of Informatics, University of Bergen.
723
- 724 [14] Mcnamara K., Belden C., Kelly T., Pehu E. and Donovan K. (2011) Introduction: ICT in
725 Agricultural Development, ICT in Agriculture, The World Bank, p3-14.
726
- 727 [15] Deloitte (2012). eTransform Africa: "Agriculture Sector Study Sector Assessment and
728 Opportunities for ICT " Deloitte
729
- 730 [16] Okediran O. O. Ganiyu R. A. and Badmus T. A. (2018), "An m-Agriculture Framework
731 for Agriculture Information Services Delivery" LAUTECH Journal of Engineering and
732 Technology 12(2) 2018: 72-79
733
- 734 [17] Heide B. and Baumberger P.,(2003): "Using Mobile Technology to Support e-
735 Democracy", Proceedings of the 36th Hawaii International Conference on System
736 Sciences, available at [http://www.csd.computer .org/comp/proceeding/](http://www.csd.computer.org/comp/proceeding/hicc/2003/1874/05/187450144b.pdf)
737 [hicc/2003/1874/05/187450144b.pdf](http://www.csd.computer.org/comp/proceeding/hicc/2003/1874/05/187450144b.pdf)
738
- 739 [18] Held D. (2006)," Models of Democracy", Third edition, Malden: Polity Press,
740 Cambridge, UK.

- 741 [19] Boniface M., (2008). A Secure Internet-Based Voting System for Low ICT Resourced
742 Countries. Master of Information Technology Thesis, Department of Information
743 Technology, Makerere University, Uganda.
744
- 745 [20] Okediran O. O., Omidiora E. O., Olabiyisi S. O. and Ganiyu R. A., (2012):" A Review
746 of the Underlying Concepts of Electronic Voting", Journal of Information and
747 Knowledge Management, International Institute of Science, Technology and
748 Education, New York, USA, 2(1):8-21.
749
- 750 [21] Alan, D. S. and John, S. C., (2005)," Revolutionising the Voting Process through
751 Online Strategies, USA Journal on Online Voting Vol. 29, No.5, pp 513-530.
752
- 753 [22] ITU, (2019) <https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx>
754
- 755 [23] Burrell, J. (2008) "Livelihoods and the mobile phone in rural Uganda". Retrieved from
756 <http://www.grameenfoundation.applab.org/section/ethnographic-research>
757
- 758 [24] Qiang C. Z., Kuek S. C., Dymond A., and Esselaar S. (2012), "Mobile Applications for
759 Agriculture and Rural Development", ICT Sector Unit World Bank, Washington D.C.
760
- 761 [25] Hudson, H. (2006) "From rural village to global village: Telecommunications for
762 development in the information Age". Danbury, CT: Lawrence Erlbaum.
763
- 764 [26] ITU, (2019b) [https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2018/](https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2018/Mobile_cellular_2000-2017_Dec2018.xls)
765 [Mobile_cellular_2000-2017_Dec2018.xls](https://www.itu.int/en/ITU-D/Statistics/Documents/statistics/2018/Mobile_cellular_2000-2017_Dec2018.xls)
766
- 767 [27] Wallace S., (2005): "M-government Gets Serious", available at
768 <http://www.thefeaturearhives.com/topic/technology/m-government-get-serious.html>
769
- 770 [28] Okediran O. O., Omidiora E. O., Olabiyisi S. O. and Ganiyu R. A. (2013): " An M-
771 voting System Framework for Electronic Voting", Proceedings of the Second
772 International Conference on Engineering and Technology Research, Lautech,
773 Ogbomoso, Nigeria, 2:241-245
774
- 775 [29] Ekong U. O. and Ekong V. O., (2010) "M- Voting: A Panacea for Enhanced E-
776 Participation" Asian Journal of Information Technology, Medwell Journals 9(2), pp 111-
777 116
778
- 779 [30] Khelifi A., Grisi Y., Soufi D., Mohanad D. and Shastry P. V. (2013) "M-Vote: A
780 Reliable and Highly Secure Mobile Voting System" Proceedings of IEEE Palestinian
781 International Conference on Information and Communication Technology.
782
- 783 [31] Ullah M., Umar A. I., Amin N. , Nizamuddin, (2013) " An Efficient and Secure Mobile
784 Phone Voting System" IEEE Conference Proceedings.
785
- 786 [32] Thakkar S., Pawar N., Sarang N., and Kadrolli V. (2016) "Online Voting System
787 (Android Application)", IOSR Journal of Computer Engineering, 18(2), pp 42-45.
788
- 789 [33] Shin-Yan C., Tsung-Ju W., and Jiun-Ming C., (2017) "Design and Implementation of a
790 Mobile Voting System Using a Novel Oblivious and Proxy Signature" Security and
791 Communication Networks, Hindawi pp1-16.
792

- 793 [34] Ganaraj K., (2017) "Advanced E-Voting Application Using Android Platform"
794 International Journal of Computer- Aided Technologies 4(2) pp 1-9
795
- 796 [35] Yakubu K. Y., (2018) "Implementation of Mobile Voting Application in Infrastructure
797 University Kuala Lumpur, Malaysia" International Journal of Computer Applications
798 180(47), pp 26-31
799
- 800 [36] Yin, R. K. (1984) "Case Study Research: Design and Methods". Sage Publications,
801 Beverly Hills, California.
802
- 803 [37] OASIS, (2003), "Election Markup Language (EML) 4.0a", Organization for the
804 Advancement of Structured Information Standards.

UNDER PEER REVIEW