Designing, developing and testing a mobile phone voting system in the South African context

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Abstract

Voting is a critical feature of any democratic process and is a vital expression of the people's power. For centuries, South Africa has been using the popular paper-based voting system though it does not provide the desirable blend of accessibility and efficiency. Missing ballot papers, invalid votes and miscount are some of the challenges associated with the paper-based voting system. Numerous electronic voting technologies have been proposed and presented by researchers that provide an easily accessible and efficient voting mechanism. Electronic voting has been attracting a lot of attention and research for the past few years, for it has some remarkable advantages over traditional paper-based voting. Mobile voting which is a subset of electronic voting, is continuously gaining popularity because it creates an efficient, effective, error free and time saving voting platform. Mobile phone voting has the capability to augment the participation rate and the quality of voting. This research contributes to the voting system reform by designing and developing a mobile phone voting framework and an application. The mobile phone voting application facilitates users to spontaneously and timeously vote using existing mobile phone networks and technologies. We developed the application in C# using Visual studio 2010 and the database was created using MySQL Server 2008. The case study was conducted at a private organisation with 124 participants to enhance the voting processes for the election of the Union president. Data about the system were collected from the participants using a self-completion questionnaire, which showed 88% of participants saying it is easy to use, 92% of participants saying it is easy to learn. The mobile voting application proved its suitability, accessibility, efficiency and feasibility.

Keywords
M-Voting, mobile phones, democracy, voters

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1. INTRODUCTION

Voting is a patriotic right where voters choose their representatives; this allows people to express their opinions. The goal of any voting system is to establish the intent of each individual voter and translate those intents into a final tally. The paper-based voting system was introduced in South Africa (SA) during the apartheid epoch (Alvarez-Rivera 2010:10; Habib & Naidu 2006:82). This system is time consuming and can result in a number of problems (Abu-Shanab *et al* 2010; Kumar *et al*, n.d), including:

- voters leaving without voting because of long queues
- a very high intolerable percentage of lost, stolen, or miscounted ballots
- high number of unclear or invalid ballot
- limited or no accommodation for people with disabilities
- bad weather might also cause people not to walk long distances to voting stations to cast their votes.
- intimidation of voters by agents

Many other countries have made several attempts to replace the traditional paper-based voting system with modern voting technology (Storer & Duncan, 2008:78; Solehria & Jadoon, 2011; Ayo *et al*, n.d). These modern voting systems and equipment evolved through the years with technology advances, from traditional paper-based voting system to paper punching machines to the latest Internet voting system, normally referred to as i-voting.

Literature suggests that electronic voting (e-voting) systems started to emerge as early as in 1892 (Ofori-Dwumfuo & Paatey, 2011: 92). E-voting systems have the potential to improve traditional paper-based voting procedures by providing convenience and flexibility to the voter (Okediran *et al*, 2011:135-142; Feng & Schwiderski-Grosche, 2006). Due to the numerous benefits of e-voting systems, several countries have since introduced e-voting solutions either as a pilot system or in its entirety. Countries that have tested and found e-voting satisfactory include Brazil, Belgium, United States, Canada, UK, India, Ireland, Geneva Venezuela, and Estonia. E-voting is being piloted in a number of African countries as well, like Kenya, Ghana and Nigeria (Enguehard, 2008: 1-13; Ekong & Ekong, 2010: 111-116).

Recently, mobility has become one of the most important ICT trends which affect all of us in our daily lives (Roberto, 2010). Due to these technological revolutions in the ICT industry, the deployment of mobile systems is able to offer sophisticated and complex services for example mobile information systems, mobile television, mobile payments and even mobile government. M-voting is a further development of telephone and e-voting systems. Recently mobile voting systems have received increasing attention, in theory and practice (Ofori-Dwumfuo & Paatey, 2011; Ali, 2010; Gentles & Sankaranarayanan, 2012: 57-68).

Mobile phone voting systems are designed such that a voter can use a mobile phone to cast their vote via the Global System for Mobile Communications (GSM) network, outside the restricted boundaries of the electoral staff. There are numerous methods of using a mobile phone to cast a vote, for example using SMS (Enguehard, 2008; Okediran *et al*,

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2011) or using a third party application for voting (Pallav *et al*, 2012; Ayo *et al*, n.d). Mobile phone voting is still in its infancy more so in SA, there is still enormous research needed around this topic. Specific issues that we encountered during this research include security, audit trial which has a potential of making the voters trust the system and also providing the system in all eleven SA official languages.

This paper is organised as follows: In Section 2, we present the literature review. In Section 3, we discuss the proposed mobile phone voting architecture and Section 4 presents the research methodology adopted for the study. Section 5 presents the prototype voting application we developed and Section 6 explains the data analysis method used. In Section 7, we discuss the usability testing results and Section 8 concludes the paper.

2. LITERATURE REVIEW

2. 1. Voting History

Elections have been utilized to decide various questions for at least 2000 years. An election enables certain formal decisions to be made through participation of a given population (Rexha *et al*, 2012). Research indicates that voting systems started from the oral voting system, the famous raising of the hand, to the Kudavolai system which was used in ancient India. In ancient Greece, people would vote by putting a white or a black stone/ball in a bucket. The first paper ballot substituted the oral voting in Rome in 139BC that is according to Douglas Jones (cited by Ofori-Dwumfuo & Paatey, 2011). South Africa still makes use of this paper-based voting system.

Literature suggests that improvements in voting systems started as early as in 1892 with the introduction of the lever arch machine, then the introduction of optical-scan machines and punch card systems for voting (Ofori-Dwumfuo & Paatey, 2011). The next evolution saw the introduction of Direct Recording Electronic (DREs), Telephone, Kiosk, Internet voting systems and lastly the mobile phone voting systems (Okediran *et al*, 2011). Electronic voting (e-voting) has been attracting a lot of attention and research for the past few years all over the world, for it has some remarkable advantages over traditional paper-based voting.

In a modern society, mobility has become one of the most important ICT trends, affecting all facets of modern life (Kumar *et al*, n.d). In South Africa and in most countries, mobile phones are the easiest and least expensive and are in fact more pervasive than Internet access. Mobile phones exhibit some unique characteristics that distinguish them from the online medium (Little & Duncan, n.d).

These ubiquitous devices are portable, affordable and in wide-spread use today, with about a third of the world's population having at least one. This phenomenon offers instant connection to friends, family, information, entertainment and resources all around the globe from anywhere. This experience has been driven primarily by the rapid growth of mobile phone subscribers in the world (Kumar *et al*, n.d). The massive mobile phone user base in our country presents us with an extraordinary opportunity to expand the reach of public services, public elections in particular to every resident, especially in the rural areas

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(South Africa, 2012; South Africa Online, 2011).

2. 2. Related Work

As a result of mobile phone penetration, there has been a growing number of authors who have done research in mobile phone voting. Some of these are discussed:
The SMS Based Voting machine developed by (Ofori-Dwumfuo & Paatey, 2011) allows voters to cast their vote by sending a sms in a predefined format with a unique password and identification number in the comfort of their own homes. The voting system makes use of a pic microcontroller and a GSM modem to receive messages from voters. In this system, there are no security measures put in place to provide integrity and open to security threats. On the other hand, Little & Duncan developed a biometrics authenticated mobile voting system, which makes us of fingerprint supported biometric control information and encryption as well as Secure Socket Layer to make the software more secure. Their system utilizes the existing GSM mobile system, which consists of a GSM SIM card and the software developed operates only on Android 3.0 operating system. The voter must possess a smart phone to be able to use this system as it requires high tech camera and scanning capabilities to capture ridges of the fingerprints and biometrics information for authentication.

According to Kumar *et al*, there are more than one billion GSM users worldwide, hence in his system he proposes the use of GSM integrated into an electronic voting scheme. In this way his system exploits the existing GSM authentication mechanism which is provided by mobile operators and provides improved voter authentication and mobility while maintaining voter privacy. Their scheme performed well with improvements needed to address the importance of trust on the Authentication Centre.

eVOTZ founder Klein 2010 who won the North American portion of the European Satellite Navigation Competition developed a mobile phone voting system that helps solve the problems of authentication and verification, providing a secure and trustworthy e-voting solution. He combines cloud computing, GNSS, cell-ID triangulation, GPS location-based services, SIM card technologies and social-media which offers voting into the hands of the voters. For future reference or auditing his system makes use of the onboard camera of the mobile phone that scans the signature document to provide a paper-based record. The research question for this study is: How can mobility, efficiency and effectiveness be provided to all participants of an electioneering system? Our main objective is to design an efficient and effective system that allows the voters to instantly cast a vote without the limit of time and place. This research examines the existing methods of public elections and explores alternatives to more efficiently meet the needs of voters.

3. SYSTEM DESIGN AND ARCHITECTURE

3.1. Proposed Architecture

Our goal was to design an efficient and effective system that allows the voters to instantly cast a vote without the limit of time and place. We developed an application that is installed on user mobile phones, which is simple for everyone to use.

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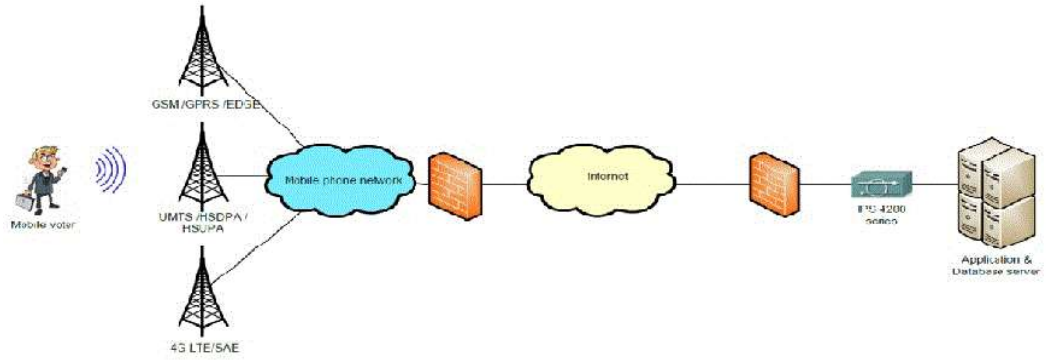

Figure 1. Proposed MPVS architecture

In our architecture in Figure 1, we propose the use of a mobile phone by the voter to cast the vote. The mobile voter connects to the mobile network using the 2G, 3G or the 4G technology that allows the mobile voter to connect to the application server to download the application. Once the application is downloaded and installed, the mobile voter registers to vote using the application. During the registration, the application connects to the Staff database to verify the Identity Document (ID) number of the mobile voter. After a successful registration, the mobile voter can cast his/her vote.

3.1.1. Mobile Voter

The mobile phone allows the voter to download the application from the MPVS application server. Once the application is installed, the voter can register to vote and then cast their vote using their mobile phones. Our proposed application allows voters to share one mobile phone, from one person to the other by registering their own individual account on the system. Voting using this application is not per phone but per person registered, so it is not linked to the mobile phone or mobile phone number.

3.1.2. Mobile Network Operators

The Mobile Network Operators (MNOs) provides communication between the mobile voter and the application server. All voters are to be registered with any of the MNOs in South Africa; this information will not be linked with voter's choice.

3.1.3. Mobile Phone Voting System Application and Database server

The application server houses the mobile phone voting application and also handles all application operations between the voters and the MPVS database. During the voting process, the voter interacts with MPVS database through the MPVS application interface. Mobile phone devices have small screens with restricted display and navigation capabilities; restricted data-entry capability due to the size of the key-pad; with the disadvantage of low bandwidth and network latency. Consequently, the application developed is simple, user friendly but still detailed with no ambiguities so that voters can cast their votes with little or no assistance regardless of their educational background. The simplicity allows the voters to register and cast their vote at a very minimum time as possible.

The ballot design takes form of the traditional paper-based ballot which incorporates the candidate name and photo. To further enhance usability and friendliness, we propose a multi-lingual application, this assist voter of different backgrounds. Voters can decide to stop the voting process at any time before they confirm the vote, but the vote will not be counted.

The MPVS database performs back-end tasks such as data analysis, storage, data manipulation and archiving. The database is built using MsSQL and stores all registered voters, all contesting candidates and the voter's roll according to the Staff database. The databases stores complete information about each eligible voter and also status information related to them. Each voter record has two status flags, the first flag automatically becomes "True" once the voter has registered and the second flag represents whether the voter has casted the vote or not. Initially all status flags are "False". The vote choice is not linked with the voter to provide privacy to the voters.

3.2. System Design

The application was developed as follows:

3.2.1. User Interface

The mobile voter downloads the application from the application server. The voter installs the application, then registers to use the application which saves all relevant details into the application database. Once registered, the voter is allowed to cast his vote and all relevant information is stored into the application database. The "Check Status" menu allows the voter to check registration status; check personal details - under this sub-menu, the voter can update their personal details; check vote status and results

3.2.2. Backend Servers

The application server stores the application and connects the mobile voter interface and the database server. The database server authenticates, authorizes, and performs auto tallying of the votes. During the registration process, authentication is provided through the Staff table.

3.2.3. Registration

After the mobile voter has downloaded and installed the application. The voter initiates the registration process. In this process, the voter is prompted to enter his/her ID Number, which is checked for validity against the Staff database.

If the ID number is invalid, the voter receives the proper message with another opportunity to enter a valid ID number. If the person is found to be inactive (e.g. maternity leave), the proper message is sent to the voter and given another opportunity to enter a valid ID number. If the person is under 18 years of age, they also received a proper message and given two option, to either continue with the registration knowing that they are not able to continue with voting otherwise, they terminate the registration process.

The voter is then prompted to enter their personal details like: name, surname, address,

race and gender. This information is also compared with information in the Staff database still using the voter ID number. If name and surname are incorrect, then the voter gets proper message and prompted for personal details again. If all information is correct, then the voter creates a pin which is purely a numeric value, a password which should be ten or more mixed characters of letters, numbers and symbols. The voter also selects a secret question and its relevant answer that is used when the voter recovers a pin or a password. If the password does not meet the above criteria, the voter receives the necessary message and prompted to enter it again. If the security question and its relevant answer are not selected then the system also sends the voter a message and given a chance to select these again. Once everything has been checked and is ok, the voter information is saved in the voter's roll. The voter is ready to cast the vote.

3.2.4. Casting a vote

The voter opens the application and login by using his/her ID number, pin and password. The combination of the three makes sure that even if another person pilfers the ID number, they cannot guess the pin and password. If the combination is incorrect, the voter is given two more attempts then the system blocks them. Then the voter has to vote manually. This provides authenticity to the system. If the combination is correct, the voter is given a menu where they can choose "vote" to cast their vote. The electronic ballot appears and the voter has to make a choice from a list of contestants.

A confirmation is needed before the choice is saved into the database which has automatic tallying capability. The voter receives a message that they have voted for their contestant. The vote is not attached to the voter but to the contestant. In this way anonymity is still maintained and also accuracy provided as each vote is counted immediately. The automatic tallying capability of mobile voting systems means that there results are available instantly after closing time and also there is no room for invalid votes, spoilt votes, over-voting or under-voting providing accuracy. Once the voter has voted, the "vote" menu is no longer accessible as they have already voted, which offers uniqueness to the system.

4. RESEARCH METHODOLOGY

This study adopted a quantitative research approach. The study used literature review, which assisted us in understanding the different types of elections existing in South Africa and the stakeholders of the election ecosystem. The literature review was conducted through the collection and review of relevant documentation on the study area. Primary investigation was undertaken through interviews. Oral interviews were used for election stakeholders. The questions were a combination of structured and unstructured questions; the interviews were a good way of collecting detailed information from the election stakeholders and more importantly the voters. The interviews focused on obtaining information about role player involvement, their roles and responsibilities. A selective quantitative assessment which used questionnaires was administered through structured questionnaires to participants.

The mobile phone voting system was implemented by developing an application in C# using Visual Studio 2010 and the database was created using MsSQL Server 2008. Then

the study conducted a usability testing, during the usability testing the participants filled in both the pre and the post test questionnaires, which gave us background information about the participants and the feelings of the participants with regards to the application. The prototype system we developed was tested by both novice and more advanced mobile users in different age groups. The facilitator collected data on how the system performs according to the participant's expectations (success rate, speed of performance and general satisfaction). The findings were both qualitative and quantitative data.

5. IMPLEMENTATION

We implemented the m-voting solution by developing a client (voter) application in Visual Studio 2010 for Windows-based mobile phones. The application is called XaP because it cuts (X) out the queuing time and all other inconveniences brought by traditional paper-based voting system, which makes voting fast and easy as possible. Before the registration can start, the voters are expected to have registered their mobile phone with the MNOs, downloaded the mobile application from the application server, and install the application on their mobile phone.

Figure 2. User initial screen

All users of the system are required to be registered to be able to use the system, but voting is not compulsory. The initial screen after the application has loaded is the login screen as shown in Figure 2 above. To register the voter must click on the "+" option.

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Figure 3. User registration

The log-in button is inactive as all necessary information is not entered yet. During the registration process (Figure 3), the voter is required to enter the ID number, which is verified with the Staff database. Once the voter has been verified (Figure 3), then all other fields become available to fill-in. The date of birth will be used to calculate the actual age of the voter, if a voter is less than 18 years of age he/she can register but cannot vote. The voter must create a password, which must be a mix of 10 or more characters (letters, numbers and symbols).

Figure 4. Registered User message

Once the voter has been registered, a message appears with the PIN (Figure 4).

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Figure 5. Active log-in

Once the voter has successfully registered, then they log-in to access the main menu of the system as shown in Figure 5. The voter enters the ID number, the password they created during the registration process and also the PIN they received after the registration.

Figure 6. Voter Main menu

After a successful log-in, the voter can now access the system main menu (Figure 6). The voter has three options to choose from the main menu which is voting, check results or up-date personal details.

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Figure 7. Voter casting a vote

Once the voter clicks on "Voting" option, the ballot appears on the screen as shown in Figure 7 and the "Save" button is inactive. After the voter has made the choice, the "Save" button becomes available. The radio button associated with each party can only accept one choice, so there will be no over or under voting or otherwise invalid votes. The voter confirms their choice by clicking "OK" or otherwise cancels it by clicking "Cancel". Once the voter has confirmed the choice the system will give a message that shows that the vote has been cast. After a successful voting process, the "Vote" option in the main menu becomes inactive because the voter has already casted his/her vote.

6. DATA ANALYSIS

ISO 9241-11 define usability as the effectiveness, efficiency, and satisfaction with which the intended users can achieve their tasks in the intended context of product use (ISO, 1998). In this study, we assessed effectiveness as success or failure in completing the task and efficiency as time spent performing the task. To assess user satisfaction, we took note of user comments as they performed tasks, and we also used their ratings and comments on the post-test questionnaire. According to Laskowski et al. (2004) effectiveness in usability is defined as the degree to which an interface facilitates users in accomplishing their tasks and goals.

In this study, we looked at the number of participants who were able to complete each task. The effectiveness of the system communicated to us how well users can achieve specific goals. During the usability test sessions, the time participants took to complete each task was observed. The length of time recorded for each participant for each task was used to measure the application's efficiency. Time limits were used to ensure participants were able to complete all tasks within the expected session time and also used to analyze the level of efficiency of the application.

Another element of efficiency that was also analyzed for the usability test results was the number and types of errors that were observed while users were completing the five tasks.

The usability errors analyzed provided us with information on the errors and key improvements on design features of the application. Errors were observed and categorized as either a user error or system error. Satisfaction consists of a set of subjective measures regarding a user's perception of usability and evaluation. For this study, we made use of one standardized rating scale which is the System Usability Scale (SUS). The SUS has sub-scales for efficiency, effective, satisfaction, helpfulness, ease of use and learnability. Immediately after performing the five tasks, the participants were asked to rate the application in terms of the above mentioned sub-scales.

The post-test questionnaire had 15 statements, which aimed to investigate the opinions and impressions of the participants about the application. The participants were asked to use the five-point agreement Likert scale (Strongly Agree, Agree, Undecided, Disagree, Strongly Disagree) about the statements. We chose the Likert scale because of the technique used for selecting items that help identify items which lead to extreme expressions of the attitude that had to be captured.

7. RESULTS

The study was conducted at a private organisation and the 124 participants were staff members there. The staff members were electing the Union president for the 2014/2015 period. For the elections, the organisation introduced mobile phone voting which ran parallel with the traditional paper based voting. The voters' role had 124 eligible voters who casted their votes using mobile technologies while there was none who opted to use the traditional paper based voting system. The study consisted of three parts: the completion of the pre-test questionnaire, the five tasks to be completed using the application, and a post-test questionnaire. A semi-structured questionnaire was distributed to the participants and 100% of the questionnaires were returned.

The pre-test questionnaire gathered information about the participants' age, gender, education, mobile phone use, voting behavior and interests. From the analyzed data, 113 participants (91%) were registered to vote and 8 participants (6%) were not registered to vote for the 2014 national elections. 93% of the participants said what they disliked mostly about the current paper-based voting system is the time they have to waist queuing to vote and the terrible blue mark that remains for a long time after voting. Ninety-five per cent of the participants had mobile phones and used it mostly for SMS, MMS, visiting social sites, Internet banking and browsing.

Immediately after performing the five tasks using the voting application, the participants were asked to rate the application. The post-test questionnaire had 15 statements, which aimed to investigate the opinions and impressions of the participants about the application. The participants were asked to use the five-point agreement Likert scale about the statements. Seventy-three percent of the participants both strongly agreed and agreed that the application was comfortable and satisfying to use.

For ease of use, 88% of the participants both used strongly agree and agree to rate the application. In terms of learnability, the application scored the highest among the participants, with 92% of the participants finding the XaP application easy to learn.

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The XaP application received an overwhelming response from the participants, the overall participant satisfaction of the application was rather worthy. Participants described the overall usability test experience as exciting, interesting and very cool. The results proved to the team that the XaP application is what South Africans want and need.

8. CONCLUSION

Mobile phone voting is still in its infancy more so in SA, there is still enormous research needed around this topic. Specific issues that we encountered during this research include security, audit trial which has a potential of making the voters trust the system and also providing the system in all eleven South Africa official languages.

The technological infrastructure in SA is well developed, enough to support mobile voting for those who need it, more especially the disabled people. The application would assist avoid many of the architectural and practical problems that are faced during the election time. Furthermore, election generals must drive for adoption of these emerging technologies since they reduce election costs.

This research forms a guideline for election generals in developing a fully functional system that has the potential to increase voter turnout and participation. This research is also a ground work for the research for their PhD project; the researcher will focus on mobile phone voting system security, as this is the major key to winning voters trust.

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