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Creating a technical architecture framework for m-voting application

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South Africa's general election of 2019 posed many challenges, some of which threatened the credibility of its result, and the entire election process. Some of the challenges were multiple voting, many hours of queuing, which led to fatigue, and a significant decline in the number of voters owing to the limited timeframe. These factors heighten the need for m-voting as an alternative or complementary method of voting in the country. Owing to similar challenges, many studies have been conducted, which consequently focused on development and strengthening of security features of e-voting and m-voting applications. However, many countries, including South Africa are not deploying the applications because of their complex nature, such as not being able to trace and track its components. The complexity is attributed to the lack of an architecture framework. This paper presents a technical architecture framework, to support and guide the development and implementation of m-voting applications, to possibly eradicate complexity and enhance the electoral process in South Africa. The outcome of this study was based on findings from analysis of existing materials and semi-structured interviews, in which the hermeneutics approach was employed.

Keywords: framework, technical architecture, e-voting, m-voting, South Africa

Introduction

The 2019 general election in South Africa revealed some fundamental electoral challenges, which have existed since the dawn of the country's legitimate democracy in 1994. This study focuses on four of the fundamental challenges: (1) the time factor, voting stations closed at 21h00 and, as a result, some registered voters could not cast their votes (Donovan 2019; Retief and Tonisi 2019); (2) deaths were recorded during voting process, which were attributed to fatigue from long hours of queuing (Grobler 2019); (3) due to unbearable hostile weather condition in some parts of the country, many voters stayed indoors, and did not vote (Kotze 2019); and (4) there were reported cases of multiple voting by some individuals (Hunter and Umraw 2019). Some of these challenges threatened the credibility of the election process and result, which could potentially endanger the democratic setting of the country. To eradicate or reduce these challenges, this study carried out exploratory research on the concept of m-voting from the perspective of information technology (IT) as an alternative or complementary solution.

Generally, elections are conducted to enact democratic settings, in that they determine the future and stability of a country. It is therefore crucial that elections are well enabled and supported for integrity and credibility purposes, including the stability of the country. For these reasons, a system that is more inclusive and secure is needed for the South African electoral process, as in other countries. In both developing and developed countries electoral systems have for many years been challenged by factors of inclusiveness and manipulations (Ahmad, Abdullah, and Arshad 2015; Gerlach and Gasser 2009). A vote is an individual's right and voice to elective process, which make inclusiveness critical. It is well documented that manipulation of voting processes and results can be prohibitive to political processes, and ultimately affect the economic stability of a country.

These are some of the challenges some developing countries have been confronted with for many years.

Owing to the numerous challenges of the traditional ballot voting method, many countries are seeking alternative systems. In the last two decades, e-voting as an alternative method has been piloted and tried in Europe and North America (Alvarez, Hall and Trachsel 2009; Goodman, Gabel, and Budd 2018). In 2004, e-voting as an alternative method was introduced in Geneva for cantonal and federal voting (Gerlach and Gasser 2009). Only few countries have fully implemented the e-voting system. Some countries have partially employed e-voting systems. Estonia, France, and Norway seem to be the most successful and referenced cases (Alvarez et al. 2013). However, some countries are still sceptical about employing the method, for one reason or the other. It is argued that one of the main challenges to adopting e-voting in many developing countries is poor ICT infrastructure (Ahmad, Abdullah, and Arshad 2015). This can be a vague assertion without specifics, after all the banking and health sectors are enabled and support by technology solutions on daily basis, at 24 h routinely. The specific challenges of IT infrastructure are not often known without architecture framework.

Remote or e-voting systems will continue to pose challenges as the internet and other technology solutions evolve (Gibson et al. 2016), making it essential to employ an architectural framework that enables integration of solutions such as network and mobile security technologies (Chiou, Wang, and Chen 2017) and Near Field Communication (NFC). The NFC allows data transfer between NFC-enabled devices and smart tags within a short distance (Ok, Coskun, and Aydin 2010). In addition, most IT development projects and initiatives in developing countries are greeted with implementation lag which can be attributed to a lack of architectural framework, which enacts flexibility, standardizations, and integration. This view has stressed the need to address the challenges that

arise from contextual diversity of IT comprising of organizational, national, and sectoral aspects which are implicated in the development and use of IT solutions. Selection of a voting system is one of the sensitive tasks capable of endangering confidence and trust in the system. Ahmad, Abdullah, and Arshad (2015) explain that the lack of a framework and inadequate requisite IT infrastructure were the main challenges to adopting e-voting. Other challenges include privacy and confidentiality (Chiou, Wang, and Chen 2017).

Over the years, the majority of studies have focused on e-voting, and not so much on m-voting. The e-voting and m-voting applications are not the same: e-voting doesn't necessarily enable mobility, particularly in the use of desktop machines, which means it is restrictive to some degree (Ondrisek 2009). In contrast, m-voting enables voting from any location (Khelifi et al. 2013). Currently, there is no universal definition for either e-voting or m-voting (Gibson et al. 2016; Khelifi et al. 2013; Zissis and Lekkas 2011). In the context of this study, the concept of m-voting is defined as a mobile phone application used for casting votes from any location in an election.

Most current studies about m-voting seem to focus more on security and functionalities rather than on the trajectory of the applications from a technical framework perspective. Most of the studies that have been conducted in both developed and developing countries focus on developing mobile voting application (Abdelghaffar and Galal 2012; Kogeda and Mpekoa 2013; Thakur et al. 2014), use of different technologies to strengthen the security aspects of existing applications (Lian et al. 2013; More et al. 2015; Yun and Lim 2013), or an evaluation and understanding of the complexities involved (Alvarez, Hall, and Trechsel 2009; Kascak et al. 2015; Mpekoa and Greunen 2016). However, none of these studies has examined how the development, implementation, and post-implementation of e-voting or m-voting systems were guided. Thus, the question of the current research is: How can m-voting be enabled or guided through the technical architecture framework (TAF)? The TAF generally describes and defines the structure of application system (Iyamu 2012). Foorthuis et al. (2016), in a similar vein, argued that the development of the TAF provides insights into processes, available IT solutions, and integration methods.

This project is divided into two phases. The first phase is to develop a TAF for the development, implementation, and post-implementation of an m-voting application, which is the objective of this study. The second phase is the development of a mobile application (m-voting), and it is based on phase 1 (TAF). The structure of the paper begins with this introduction, which covers re-echoing the concept and significance of elections in a democratic setting, contextualizing the problem, and ushering in of an IT solution (m-voting). This is followed by a review of literature and the research methodology in sections two and three, respectively. Thereafter, the findings are discussed in the fourth section. In the fifth section, an IT solution in the form of TAF is presented. A conclusion is drawn at the end.

Review of related literature and cases

E-voting and m-voting are not the same. According to Khelifi et al. (2013), m-voting systems were developed to address the gaps identified in both manual (traditional) and e-voting systems. The use of the manual system in the 2019 general election in South Africa posed serious challenges that cannot be ignored or taken for granted if reaping the gains from the democratic setting remains the national goal. Factors such as incidents of double voting (Hunter and Umraw 2019), loss of lives (Grobler 2019), deprivation of registered voters (Donovan 2019; Retief and Tonisi 2019), and disruption by weather condition (Kotze 2019) posed various challenges for the electoral commission, political parties, and voters themselves in that the credibility of the result was threatened, and right to vote was denied. These challenges necessitate an alternative or complementary method through m-voting solution. M-voting system is preferred because of the challenges already identified with the e-voting concept. According to Gerlach and Gasser (2009), e-voting systems are confronted with challenges such as web spoofing, use of diverse software, browsers, hardware, and system failure primarily because of factors such as signatures. Gibson et al. (2016) argue that additional security systems such as E2E-V REV do not guarantee that e-voting can be free from manipulation. The ballot box voting (tradition) and e-voting systems will probably never be completely safe from manipulation or unlawful observation (Gerlach and Gasser 2009).

Few studies have been carried out m-voting in the last decade, in both developed and developing countries. Thakur et al. (2014) focused on the use of biometrics for verification, and More et al. (2015) explored security requirements of voting process through a three-step approach. Moloja and Mpekoa (2017) proposed a solution to enhance the security of the m-voting systems. Marky et al.'s (2019) interest was in implementing the verifiability of an end-to-end solution. None of these studies tried to address the concept of architecture framework. The results from Khelifi et al. (2013) however showed that m-vote applications can be highly secure, which means that the more recent studies have made little contribution to the advancement of m-voting for electoral processes.

Countries employ specific requirements and standards, which ultimately dictate the development and implementation of their particular m-voting system. The United Kingdom has conducted a broad set of trials with alternate voting methods, allowing individuals to vote in pilot projects by using different channels such as postal voting, internet voting, and SMS voting (text messaging from a cellular telephone) (Xenakis and Macintosh 2005). Similar to the South African five-year term, Estonian parliamentary elections are conducted every four years, and it is open to eligible citizens that are 18 years of age or older (Alvarez, Hall, and Trechsel 2009), a requirement that requires logical computational validation between when an individual is registered and the time voting take place.

Despite the promises of e-voting, Ok, Coskun, and Aydin (2010) identified confidentiality and security at login, as the main voters' challenges. Also, new technologies will continue to emerge, and while they enable

opportunities to improve efficiency, at the same time they pose new threats to privacy, ownership and influence (James et al. 2019). Other challenges of m-voting systems include platform integration (Kascak et al. 2015) and limited computational capacity of mobile devices (Kumar et al. 2008). Serdult et al. (2015) explained how the electronic voting system in Zurich was halted for four years (2011–2015) due to technical reasons, which included integration with electoral management systems and the municipal vote registries. An application is challenged and can easily be derailed if the building blocks are not architected (Da Silva and e Abreu 2010). Through the technical architecture framework, design patterns, integrated network components, and best practices are assessed and enabled in an iterative approach. The support and enablement of interoperability, the coexistence of systems, and alignment of technology components depend on the architecture design (Booch 2010). According to Da Silva and Abreu (2010), the consistency of a set of network connectivity, routing, load balancing, and security mechanisms is influenced and facilitated by the architecture framework.

Some of the challenges are attributable to the gap that exists between components of an application (Dale and Scheepers 2020). These challenges make the voting application process intensive. These challenges are ascribed to lack of technical architecture framework, which aims to detect early technical deficiencies. This necessitates assessing the deficiency between the entities of an application through the technical architecture framework (Dale and Scheepers 2020), for secure and efficient purposes. The framework facilitates the collaboration, integration, deduplication, standardization, and reengineering of IT solutions. Silo deployment of a domain or domains leads to a lack of leverage and alignment between the enabled and the enabler (Foorthuis et al. 2016).

The technical architecture framework consists of data, middleware, network, platform, and security domains, which have unique and specific entities, deliverables, analysis methods, and processes (Iyamu 2012). The architecture framework makes the logical flow, and connectivity of its domains, and the collaboration of their entities explicit, which is of critical importance to an application's runtime (Mei and Lü 2016). Booch (2010) argues that the technical architecture enables an intensive system that support an organization's processes. This means that without the technical architecture framework it is difficult or near impossible to provide and maintain adaptiveness of infrastructure for application development, implementation, and post-implementation (Iyamu 2012). Many software applications has been unsuccessful because of challenges related to these factors.

Research methodology

The data towards designing a technical architecture framework to guide the deployment (development, implementation, and post-implementation) of an m-voting application were gathered in South Africa. South Africa is a country of over 55 million people. Its constitution dictates that general (National and Provincial) elections are held on a five-yearly basis. The elections are organized and managed by the country's Independent Electoral

Commission (IEC). The first democratic election was in 1994. The results of the 2004, 2009, and 2014 general elections show a steady decline in the number of voters, influenced by various factors, some of which are technology related. In the 2019 general election, there were many challenges (Dlulane 2019), some of which could be addressed by technology solution (m-voting): (1) there were allegations of double voting by some individuals, owing to lapses in the current manual system (Hunter and Umraw 2019), which can be addressed by authentication, validation, and verification security features in an IT solution as mobile application; (2) many registered voters had to queue for many hours, resulting in fatalities of aged citizens, whereas with m-voting they could have voted from homes; and (3) some voters couldn't cast their votes owing to the limited timeframe, with voting stations closed at a given time. As a result, there was a significant decline in voters' participation in the general election.

Data collection

The data used in this study were gathered from semi-structured interviews and existing documentation. The sources of documentations include print media (*Sunday Times*, *News 24*, and *Eyewitness*) reports, South African Independence Electoral Commission (IEC) documents, and the South African Police Service (SAPS) press releases. Media reports by the South African Broadcasting Corporation (SABC) were used as existing documentation. The SABC is state owned. The *Sunday Times* and *News 24* have more readership than other media outlets in the country and are regarded as credible by the majority of South Africans. Election result and reports were accessed on the IEC website. In addition, press briefings by the IEC before, during, and post-election, which were recorded, form part of the data. Media reports were recorded. In total, 17 documents were collected, which consisted of 10 media reports, and 7 IEC reports. These were combined with the transcripts from the semi-structured interviews conducted with law enforcement personnel and voters.

In the use of semi-structured interview technique, a total of 22 police officers who were directly involved in the 2019 election process were contacted. Only three of the officers (a brigadier and two sergeants) were willing to participate in this study. Each of the officers requested anonymity, which I pledged to uphold, and formed part of the ethics of this research. Eleven voters were interviewed at the point of saturation. Iyamu (2012, 2) describes saturation as point where no new information was forthcoming. To ensure balanced demographics, the selection of participants was across age groups: 18–24; 25–40; and above 40 years of age. Eighteen years is the age limit for voters in South Africa. The data collection happened from June to August 2019, soon after the election in May. To avoid disclosure of identities, participants were assigned codenames as follows: police officers: POE01, POE02, and POE03; and voters – VOE01, VOE02 ... VOE11.

Data analysis

The hermeneutics approach from the interpretivist perspective was employed in the analysis of the data, which consisted of both text and graphics. As prescribed by the

approach, the set of data was read repeatedly, in order to subjectively make sense of them (Kalaga 2015). This helped in the gaining of a better understanding of how the challenges arise in the current ballot (manual) system. The hermeneutics approach was most appropriate for the study in that the meaning which people associate with things are often not expressed directly but are embedded in artefacts by their creators, and can be known through interpreting these artefacts (Yanow and Schwart-Shea 2015). From reading the reports repeatedly, I was able to validate the contents against each other, from which findings were made. Based on the findings, a technical architecture framework for m-voting application was designed. It is intended to guide the development of a mobile application, and address the challenges presented at the beginning of this paper: multiple voting by individuals, declining number of voters, and deaths during voting (Donovan 2019; Grobler 2019; Hunter and Umraw 2019; Kotze 2019; Retief and Tonisi 2019).

Technical architecture framework for m-voting application

From the analysis of the data, a technical architecture framework (TAF) for m-voting application is proposed, as shown in Figure 1. The TAF has three layers: (1) application layer, which presents the user interface; (2) technology layer that defines the integrated component; and (3) the data layer, interactive and management of databases. The data layer is enabled and supported by the technology layer, and the logic and process of m-voting are realized through the application layer (Pourzolfaghar and Helfert 2017). The TAF is a vehicle which ensures and guides the design approach, development standard, and implementation principles, toward yielding an acceptable system. It encompasses the technologies and databases such as the Regulation of Interception of Communications and Provision of Communication-Related Information Act

(RICA), which is used to regulate the interception of communication, monitoring of radio signals, radio frequency spectrums, and the provision of communication-related information in South Africa (Mashida 2013). Structuralizing of TAF layers is associated with the relationships between the various components in achieving the development and implementation of m-voting application. The five main components of the TAF layers are (1) Registration process, (2) User voting, (3) User verification, (4) Security and clustering theorem, and (5) Computational abilities.

The five main components of the technical architecture framework, which are split into three layers, are discussed in the following sub-sections.

Registration process

Based on the TAF, the application enables only registered users to login. This includes a sequential split of the registration process into three dimensional parts, referred to as RP^1 , RP^2 , and RP^3 . The RP^1 user registers for mobile voting by creating a username, which is generated by the system, and a password. This requires personal information such as a national identity document (ID) number, mobile phone number, email address, and physical residential address. Additional requirements, such as a driving licence may be included. In RP^2 , the application server sends two verifications codes: one to the user's mobile phone and the other to his or her email address. Finally, RP^3 authenticates the codes, through verification with the RICA database. This process enables maximizing of the security features.

The TAF design helps to refine and compose the components and connectors including the process of an application (Mei and Lü 2016), which are the RP^{n+1} . The dimensional parts are an approach with a strong dedicated security algorithm technique, which enhances the integrity of the voting process (Khelifi et al. 2013). The process allows citizens to register and cast their votes from any

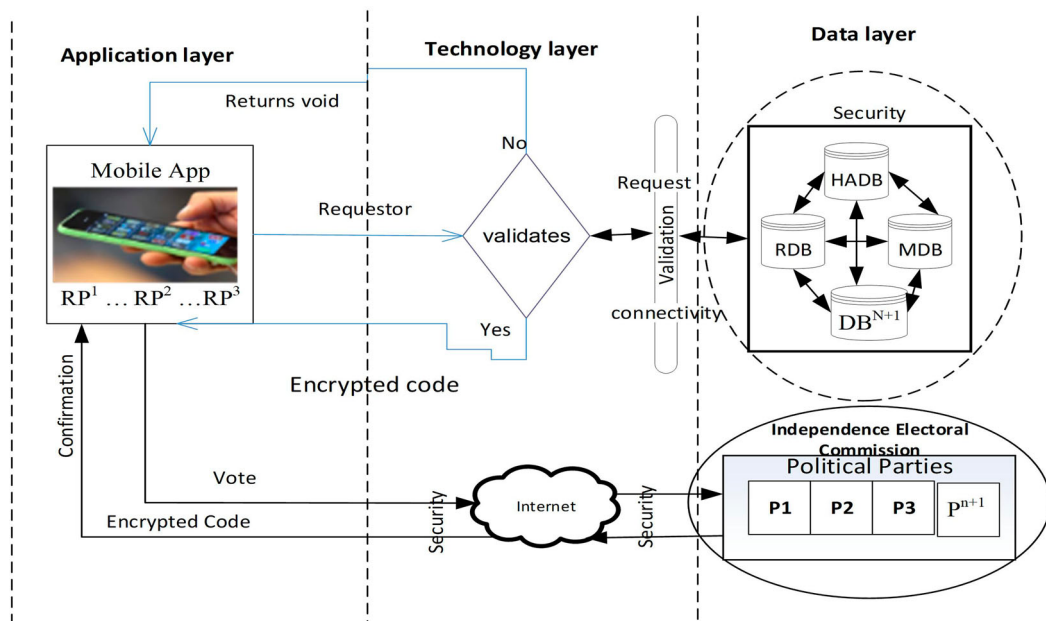


Figure 1: Technical architecture framework for m-voting application.

location, within or outside of the country. The voter is identified via remote verification mechanisms such as digital signature, biometrics, and PIN codes. The vote is transmitted over the internet and recorded in the database of the South African Independent Electoral Commission's system.

Voting process

The user logs in by using either a captcha or image detection, which verifies whether the user is human, and not a robot. Next, Public Key (PK) is used to exchange a Symmetric Key (SK). Thereafter, SK is used for onward communication. This procedure grants or denies a user access to the process of voting. Permission allows the user to have virtual access to contesting candidates and parties for whom he/she chooses to cast his or her vote. At this point, the user is requested to reconfirm his or her voting decision, to ensure that a mistake has not been made. Once the vote is successfully cast, the counter assigned to the candidate increases by one ($N+1$), without the voter's credentials. The session variables are then permanently deleted, for confidentiality purposes, and avoids unauthorized access. The application is disabled, and the user is marked as 'voted', which makes multiple voting impossible, through another device or manually (at a polling station).

The TAF enables m-voting systems to allow voters to cast their votes from any geographical location, and at a time (within voting hours) suitable for them. The TAF enables flexibility, scalability, and the application's compatibility with various types of mobile devices, thereby making m-voting system more convenient (Chiou, Wang, and Chen 2017). The aim of m-voting is primarily to promote convenience and increase inclusiveness, which is critical to the democratic process. Alvarez, Hall, and Trechsel (2009) argue that this type of flexibility encourages young voters to be more participatory in the electoral process.

User verification in voting process

A user's login details are verified against his or her profile in the integrated databases: Home Affairs database (HADB); Rica database (RDB); and Municipal database (MDB). The primary key is the South African ID number. It consists of thirteen (13) numeric digits in the following format: 'YYMMDDSSSSCAZ'. The first 6 digits are the individual's date of birth, in the order of year, month, and day (YYMMDD). For example, 20 February 1992 is displayed as 920220. The 6 digits are used to indicate the age of the user (System Date – Date of birth). The next 4 digits (SSSS) are for identification of the user's gender. The ranges 0000–4999 and 5000–9999 are for female and male, respectively. The digit (C) that follows is for identification of citizens by birth or naturalization. Born in SA is denoted with 1, while 0 is for naturalization. The citizenship of the user is verified using this digit. The last digit (Z) is a checksum digit – used to check that the number sequence is accurate using a set formula called the Luhn algorithm.

The verification entails three steps: (1) authenticity of the SA ID number, which can also be verified through the following algorithm: i. from the rightmost digit of the SA

ID number, double every second digit; ii. sums up the digits of this result (doubling of the digits); iii. add the resultant digits together, with the remaining (odd) digits of the SA ID number; and iv. if this sum is divisible by 10 (without remainder), it means that the SA ID number is valid; (2) eligibility of the voter. Citizens under 18 years of age, and those with permanent residence (PR) status are not eligible to vote in the South African elections; and (3) the SA ID is mapped against mobile phone number and physical residence address as stored in RICA.

These, as explained above, are complicated processes, and if not architected, can result in derailment. The TAF enables the creation of a unified database, through real-time synchronization and integration of the databases. The TAF is a prevailing paradigm, which questions the goals, scope, processes and roles that are considered during technology deployment, and introduction of new technology infrastructure potentialities (Iyamu 2012).

Security and clustering theorem

The clustering theorem is used to ensure tighter security. It is a procedure that requires users to provide answers to security questions during the registration process. The security answers are stored using symmetric key algorithms in one of the databases in the data layer. Entities in the technology layer are used to define the availability, status, and access to both application and databases through the security modes. Access to the database is granted only for election purposes.

An algorithm based on a clustering theorem is used for partitioning and defining criteria for users' security access. There is a plethora of clustering algorithms, such as partitioning methods, hierarchical clustering, fuzzy clustering, density-based clustering, and model-based clustering. Some of these technologies overlap, and others are very much related to each other. The process should not allow any unauthorized proxy as guided by the TAF, which defines the standard use of the technologies, the principles approach of implementation of the clustering, and policies of partitioning of each of the selected clustering. The use of clustering ensures anonymity (privacy), which prevents votes being linked to voters, or altered for any purposes. This also addresses problems in understanding the relationship between touchscreen button manipulation and interactive response from the RP³ (Kascak et al. 2015).

Computational abilities

Mobile devices have different capacities. Some have limited computational abilities, which makes it difficult to employ schemes with large computational features as defined by both the technology and data layers of the TAF (Figure 1). Some devices have usability challenges such as data entry, slower network speeds, and a lack of optimized mobile content. Another significant challenges, which cannot be ignored, are low battery life and wireless network reliability, particularly in developing countries. These two factors can prevent user from voting, or cause a disruption in the process of casting a vote.

These challenges can make it impractical to employ the m-voting application (Kumar et al. 2008).since if the

application or database server signs blank votes before a user casts his or her vote, it may cause unwarranted multi voting. Further, if a user votes before the signing of a server, voting information can be leaked to the server, and may be compromised. Therefore, mechanisms such as digital signatures, blind signatures, and bit-commitment mechanisms need to be carefully addressed, which require the definition and standardization provided by the TAF. This is primarily because the mechanisms are considered primitive cryptographic elements (Chiou, Wang, and Chen 2017).

Analysis and discussion of findings

Mobile application for an intensive process such as voting cannot be made static; it therefore requires change, which can only flexibly occur through the TAF. Iyamu (2012, 192) argues that the technical architecture framework focuses on *managing technology, change from system to system, implement new technology, maintain compatibility with existing technologies, and change from one business process to another*. One of the significant aspects of an architecture framework is that it can be used to trace, track, and detect components and structures, and dynamically refactor disconnecting aspects (Mei and Lü 2016).

Security – privacy and integrity

The election system (or commission) principle is built on one-voter to one-vote, which prevents individuals from voting more than once as did indeed happen in South Africa in the 2019 general election, and has happened in many other countries. There were two notable cases of security breaches during the South African general election of 2019. One was the claims of multiple voting at some polling stations (EWN 2019). The second security challenge was the use of deceased persons' names to cast votes (Hunter and Umraw 2019). According to a report by EWN (2019), there were at least 20 people who were arrested for allegedly trying to cast votes in more than one polling stations. It was of great concern to still be experiencing such challenges after 25 years of democracy and five general elections (Hunter and Umraw 2019). It is therefore of paramount importance to develop a mobile voting system, which can be used to address issues of secret, single, and safe voting for the electoral system of South Africa. From similar perspectives, a voter and a police officer shared their views as follows:

Our electoral system is not secured enough, and the IEC is not tapping on technology advancement. They should embrace technology to improve the security of the process. (VOE07)

It is a challenging situation. I hope the authority will not expect us to overly carry out policing on voters during voting because that will infringe on their privacy and right to secret vote. (POE03)

M-vote application relies on multi-level security, user-name and password, national ID, and a dedicated security algorithm (Khelifi et al. 2013), which require facilitation by an architecture. The challenges of privacy can be addressed through digital signatures by using public-key cryptography (Chiou, Wang, and Chen 2017). M-voting

application enacts privacy, which means discrete use of voters' information (Marky et al. 2019).

Cost to human lives

There were challenges, which according to Dlulane (2019), the Chief Electoral Commissioner of the IEC conceded, that there was room for improvement in the aftermath of the 2019 general election. Some of the challenges were the cost to human lives. This included the deaths of two older voters in two different provinces. Grobler (2019) reports that a 67-year-old man died outside the Westview voting station in Elandspoort, Tshwane, and in a separate incident, a 79-year-old woman died moments before she could cast her vote in Bophelong, Vanderbijlpark. According to a report by Dlulane (2019), in confirmation of the deaths, the State President sent condolences to the families of two elderly voters. The cause of the deaths was associated with exhaustion, which could have been avoided had they cast their votes from home. According to one of the participants:

If technology was used for this election process, our work would have been made simpler and easier. This is because the problems such as long queues and double casting of votes, that we encountered during the election process started at the registration stage. (POE02)

The adoption of m-voting allows voters to have the option of casting their votes from anywhere (including their homes), and at their convenience. Such a method decreases the length of voting periods, reduces vulnerability, and decreases long queues at polling stations during voting (Krimmer et al. 2018).

Flexibility – vote from any location

There were 26.7 million registered voters for the general election of 2019. Retief and Tonisi (2019) report a voter shared her frustration as saying, 'the last time I voted I waited two hours before I could cast my vote'. In the general election of 2019, there were about 1161 voting stations across the country (Donovan 2019). Weather was another factor that possibly made voters stay away from voting. For example, it rains in the Cape region during that period and there is usually strong wind (Retief and Tonisi 2019). Also, voting stations closed at the 21h00. Owing to long queues, many voters were denied the opportunity to vote. According to Kotze (2019), about 9 million registered voters did not vote, and more than 250,000 spoiled their votes for various reasons. The outcome could have been different if there had been an alternative, such as the option of m-voting. Some of the voters that were interviewed furiously expressed themselves:

Many members of my family and friends did not vote because of one reason or the other, which include long queue and bad weather condition. We wished we could vote at our convenience. (VOE02)

I heard many countries have electronic voting, why can't we do the same thing? We shop and do many others via online, why can't we do the same? (VOE11)

An alternative such as m-voting is more cost effective to the voters and electoral commission than the traditional

method, which is the physical presence of polling stations (Krimmer et al. 2018). Alternate voting methods have been experimented with in some part of Europe (Alvarez, Hall, and Trechsel 2009). A TAF can be applied to guide any system because of its premise to provide a more solid foundation, enhanced support, and improved management approach of the voting method (Chen, Zhang, and He 2017).

Data analytics

Ease of analytics is significant for future purposes. Based on the challenges as described above, it is critical to adopt m-voting system to strengthen the future of the electoral process in South Africa. One of the challenges in managing change towards the future is gaining an accurate view of the current state. This includes facilitating assessment of the impact of the challenges that were encountered during the election. This entails technology (m-voting) involvement for change of the current method, and the conception of strategic alternatives for consideration. Some of the voters expressed themselves as follows:

Sometimes, I wonder how the IEC analyze the voters' participation, is it through the approach of using MS Excel? I don't know. I keep asking this question because they make the same mistakes in every election. (VOE02)

Does the IEC even have a detailed analysis of the voters across the provinces, gender, and age groups? (VOE07)

Failure to identify and neutralize uncertainty result in unreliable operationalization of technology components, and therefore require the use of analytics (Liao et al. 2015). The analytics approach helps to simulate capabilities of technology components and techniques, and their integration (Chou et al. 2014). This include consequently, unreliable weather predictions, which can affect telecommunication infrastructure. The architecture framework (Figure 1) is designed to enable and support an interactive process and real-time analysis to circumvent the problems. Therefore, components and techniques must be prescriptive, descriptive, and predictive. Data analytics can be employed in the review of the application which the TAF helps dictate. Alvarez, Hall, and Trechsel (2009) highlighted some of the areas of analysis as: (1) internet penetration, (2) structure of internet voting issues, (3) identification and digital authentication, and (4) a political culture that is supportive of internet voting.

Conclusion

This paper proposes a technical architecture framework (TAF) to provide clarity and an understanding of the entities, elements, and components that are involved in the design, development, and implementation of a mobile application for voting purposes. The TAF is a critical aspect that has been missing in the deployment of m-voting or e-voting applications. Using the TAF, this paper provides guidelines related to the technical challenges and overall protocol design of the software development cycle for a voting application. Very importantly, the TAF makes complementarity possible for both manual (traditional) and mobile voting systems in an electoral process. This is of interest and benefit to South Africa

in advancing and solidifying its electoral process by providing a secure, flexible optional method for voters.

The TAF enables a log of procedures and technological activities for review and to detect deficiencies, which are crucial in ensuring credibility and reliability, in advancing the electoral process of the country. South Africa is a greenfield, in that neither e-voting nor m-voting has been tried or applied in its 25 years of democracy. Thus, it is necessary to begin with an architecture framework, to attain a more concrete foundation for technology adoption.

The outcome of this research contributes to defining and developing an application that is more effective and secure for mobile voting. The study shows that determining the effectiveness of verification constitutes a challenge and must be considered from the early stage in planning and design. Some of the benefits of the TAF are that it facilitates design, development, and implementation of an m-voting application, in achieving: (i) accuracy – a vote cannot be manipulated or altered; (ii) voters may cast their votes from any geographical location; (iii) only eligible voters can participate in a voting process; and (iv) it allows eligible voters to vote only once.

This study should be of interest to the South African IEC, political parties, and the general populace. The paper can be used as developmental material by academics in the areas of information systems, software development, and social sciences. Even though the study is comprehensive, there are limitations, particularly on two fronts, which leave room for further studies. First, the study is silent on the implementation of the TAF. Second, it does not provide a method through which the TAF can be assessed.

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