Handbook of Research on E-Services in the Public Sector:

E-Government Strategies and Advancements

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Information Science REFERENCE

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Hershey • New York

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Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Handbook of research on e-services in the public sector : e-government strategies and advancements / Abid Thyab Al Ajeeli and Yousif A. Latif Al-Bastaki, editors.
p. cm.
Includes bibliographical references and index.
Summary: "This book assists its readers in recommending formulation of ICT strategies for e-government implementation and maintenance from the perspective of acknowledging the importance of e-Governance for building institutions to achieve transparency and accountability, and eventually democratic governance"--Provided by publisher.
ISBN 978-1-61520-789-3 (hardcover) -- ISBN 978-1-61520-790-9 (ebook)
1. Internet in public administration. 2. Public administration--Information technology. 3. Communication in public administration--Technological innovations.
I. Al Ajeeli, Abid. II. Al-Bastaki, Yousif A. Latif.
JF1525.A8H36195 2010
352.3'802854678--dc22
2010000633

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Chapter 22
Developing a Secure Integrated E-Voting System

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ABSTRACT

The electoral system is paramount to the survival of democracy all over the world. Current happenings around the world, particularly in the developing world where poor conduct of elections had left a number of countries devastated are of great concern to world leaders. Therefore, efforts are ongoing to introduce a voting system that is transparent, convenient and reliable. This chapter presents an overview of an integrated electronic voting (e-Voting) system comprising: the electronic voting machine (EVM), Internet voting (i-Voting) and mobile voting (m-Voting). Similarly, issues of interoperability of the integrated system are discussed as well as the needed security measures. It is however recommended that emphasis be directed at EVM for use within the country while others are restricted to special cases of remote voting for citizens living abroad or living with certain deformities.

INTRODUCTION

In democratic societies, voting is a prominent tool for collecting and reflecting peoples' opinions. Traditionally, voting is conducted in centralized or distributed places called polling booths (Yang et al., 2006). Before the Election Day, the entire voting population is delineated into reasonable sizes of not more than 500 people per location and polling booths situated in each location across the country. At the booths, votes are cast by each eligible voter under the supervision of electoral officers with party representatives in attendance. At the close of the Election Day, votes are counted manually and the result taken to the collation centres where they are transferred to the state/regional headquarters for announcement. The rapid and extensive developments of Information and Communications Technologies (ICTs) have transformed the contemporary industrialized societies

DOI: 10.4018/978-1-61520-789-3.ch022

into a network of societies called Global village. With the increasing penetration of the society by ICTs, their applications in public administration (e-Government) and in democratic decision making process (e-Democracy) have brought about meaningful developments over the conventional systems (Ayo *et al*, 2007).

The term ICT embraces all electronic devices such as the wired and wireless networks including the Internet. Hence ICT offers various platforms of implementation like the Internet (i-Government, i-Business, i-Voting etc); the wireless or mobile platform (m-Government, m-Business, m-Voting etc); and the wired platform (e-Government, e-Business, e-Voting etc). However it must be noted that all the platforms are electronic in nature but for specificity, they can be so categorized (Pierre *et al*, 2006).

Electronic voting (e-Voting) is one of such areas where the impact of ICT is sought globally, particularly in the developing nations of the world, to help ameliorate some of the problems plaguing the electoral processes. Electronic voting refers to the use of electronic devices to vote in referendums and election. Traditional voting systems were developed to ensure strict compliance with the principles of democratic elections and referendums. These principles include (ACE Encyclopaedia, 2008):

1. Freedom to vote.
2. Secrecy of vote.
3. Non-modification of the votes cast.
4. Lack of intimidation during elections.

Therefore, a basic precondition for e-Election is the feasibility of implementing the voting system without undermining the basic principles as listed above. However, besides the needs for simplicity and ease of use of e-Voting systems, they must demonstrate at least some measure of security offered by the traditional voting systems.

Consequently, the following issues are considered as the minimum requirements for e-Voting systems. Any e-Voting system must ensure that (ACE Encyclopaedia, 2008):

1. Only eligible voters have the right to vote.
2. Every vote cast is counted but once.
3. Every voter is free to make his/her decisions without intimidation or coercion.
4. The secrecy of vote is maintained throughout the voting process.
5. Every eligible voter has access to vote without prejudice to educational level, location and disability.
6. The entire voting process is very transparent.

EVOLUTION OF E-VOTING

The history of the voting techniques is dated back as far as the 19th century. The various systems are arranged as follows.

Paper Ballots

This is the foremost method of voting and it is still in use in virtually all nations of the world. Voters mark boxes next to the names of candidates or next to the party logos, and place them in a ballot box. The ballots are counted manually. Their drawback is that counting is laborious and subject to human errors (Jan, 2001).

Mechanical Lever Machines

This system offers a way of reducing ballot tampering by eliminating document ballots. That became possible with the introduction of the lever voting machine in 1892 (Eric, 2003). Voters cast ballots by pulling down levers that correspond to each candidate. The machines prevent voting for more than one candidate (David, et al, 2003).

Punch Cards

Punch cards offer voters the opportunity to punch holes on computer readable ballot cards to indicate a choice in an election. Some systems use mechanical hole-punching devices for punching the holes while others provide the voter with pins to punch out the holes. The latter has led to incomplete punches, resulting in more errors in reading the cards (California Internet Voting Task Force, 2002).

The Optically Scanned Ballot

This is also called mark-sense or Bubble Ballot Paper. It contains the offices and the names of the candidates with a small circle (radio button) by its side. Voting is done by shading the small circle against the preferred candidate and counting is done via an optical scanner. That is, the papers are all scanned into a machine for automatic counting.

Direct Recording Electronic (DRE)

This is an electronic version of the lever machine. It offers electronic and automated casting, counting and tallying of total votes. The system displays electronic ballot on a screen for a voter to thumbprint against a preferred candidate after which the vote is cast and summaries produced. The issue against this method is lack of audit trial but can be catered for with minimum effort.

There are a variety of e-voting setups:

1. **PollingPlace e-Voting:** This involves casting of votes through an electronic means (voting machines) within a polling booth or station.
2. **Remote e-Voting:** This involves casting votes anywhere outside the polling station through an electronic means and transference of the votes through the Internet or telephone to designated locations.

The DRE equipment is situated at the polling station with which voters cast their votes usually through a touch screen mechanism. However, with the remote e-Voting, the system allows voting at remote locations without a physical presence at the booth. Voting can be done at home and computer kiosk, through the use of PCs and cell phones.

THE MERITS AND DEMERITS OF E-VOTING

The Merits

E-Voting offers:

a. Reduced common mistakes with the use of touch screen monitor.
b. Immediate feed-back on votes cast for urgent error correction.
c. Reduced multiple voting tendencies.
d. Convenience of voting.
e. Reduced ballot paper usage.
f. Enhanced speedy processing of results.
g. Backup of votes for audit trail.
h. Enhanced confidentiality, transparency, security and trust.
i. Reduced chances of bribery and intimidation.
j. Good voting platform for the handicapped, particularly the sight impaired through headphones and Braille keypad.

The Demerits

The demerits to watch out for include:

a. Over-voting/under-voting.
b. Broadcast storm arising from simultaneous transmission of results from polling booths to headquarters.
c. Equipment malfunctions in the course of election.
d. Proprietary source code could be a source of fraud (open source may be adopted).

e. Poorly implemented security measures may result to backdoors for hackers.
f. Most touch-screen systems run Windows CE which may require security upgrades to prevent virus and worms when connected to the Internet.
g. Election rigging through code manipulation by software developer.
h. Wire tapping by hackers during vote transmission.

SOME E-VOTING PROJECTS IN THE WORLD

Various e-Voting projects had been developed in a number of countries in the world. The procedures employed involved seeking legislative backing; contracting the projects; and conducting trials or tests in public areas to the satisfaction of the generality of the populace. In some countries, the project did not go beyond the trial phase because of some negative reports noted. The negative reports notwithstanding, e-Voting has a lot of merits. Table 1 are some of the countries where e-Voting had been experimented, tried and/or adopted.

Some Documented Problems on E-Voting Systems

Below are some problems associated with the adoption of e-Voting systems (Wikipedia, 2008):

1. **Denial of Service (DoS) Attack:** In Fairfax County, Virginia, during the 2003 election, it was observed that about 953 voting machines tried to forward results simultaneously at the same time. This led to traffic jam that delayed posting of results for a day because of the number of systems involved. Therefore, for a successful adoption of e-Voting system, the issue of traffic management must be looked into.
2. **Non-functional Voter Card Encoders:** Some voters were disenfranchised in Alameda and Sandiego in 2004 California

Table 1. List of countries with e-voting projects by type

Country	Type	Date
Australia	Polling Place e-Voting	First in 2001
Austria	Remote e-Voting	First in 2003
Belgium	Polling Place e-Voting	First in 1999
Brazil	Polling Place e-Voting	First in 1996
Canada	Remote e-Voting (Internet/Telephone)	First in 2003
Estonia	Remote e-Voting	First in 2004
France	Polling Place e-Voting & Remote e-Voting	First in 2003
Germany	Remote e-Voting	First tested in 1999
India	Polling Place e-Voting	First in 2003
Portugal	Polling Place e-Voting	First in 2004
Spain	Remote e-Voting	First in 2003
Switzerland	Remote e-Voting	First in 2004
The Netherlands	Polling Place e-Voting &Remote Place e-Voting	First in 2004
UK	Polling Place e-Voting & Remote e-Voting	First in 2002
USA	Polling Place e-Voting & Remote e-Voting	First in 2000

[Source: ACE Encyclopaedia, 2008]

primaries arising from faulty card readers. There was a law suit against the machine developers (Diebold), which was settled by paying about $2.6 million. Therefore, equipment malfunctioning is an issue to be given serious attention.

3. **Improper Calibration of Marksense Scanner:** In Napa County, California in 2004 elections, the system overlooked about 6,692 absentee ballot votes because of improper calibration. Similarly, during the early voting in 2006 and 2008, votes meant for particular candidates were swapped due to calibration errors. Calibration error at design time should be given due consideration.
4. **Possible Eavesdropping:** The Dutch Minister of Home Affairs in 2006 withdrew the license of 10% of the voting machines manufacturers; Sdu NV because it was proven that one could eavesdrop on voting from about 40 meters using Van Eck phreaking.
5. **Systemic Failure:** The New York University Law School released a report with more than 60 examples of e-Voting machines failures in 26 states in 2004 and 2006 elections.

INTEGRATED VOTING SYSTEM

The proposed integrated voting system is composed of three major platforms: an e-Voting machine (EVM); wired Internet; and mobile Internet. The traditional paper-based ballot is not considered. An e-Ballot reduces the chances of multiple voting arising from multiple thumb-printing that may result during folding of the paper or erroneous thumb-printing. With a manual ballot, voters are only entitled to one ballot and once marred, there is no replacement. However, with an e-Ballot, voters have the chances of correcting mistakes before submitting the ballots (Giampiero, 2008).

Electronic Voting Machines (EVMs)

These are basically polling site e-Voting system. Their configurations showed low-end processors: Diebold-400MHz Intel PXA-255; ES&S IVOTRONIC- 25MHz Intel 386; SEQUOIA VS-300 MHz; Urna (BVM)-386 IBM compatible, etc. The machines run on a variety of proprietary operating systems: VirtusOS, Windows CE and Linux. They equally have a variety of other peripheral devices: screens (touch and non-touch), flash memory, backup battery and PCMCIA – smart card removable memory (Boutin, 2004; Jason, 2003; Whitney, 2000).

The advantages of these configurations include the fact that the machines can be networked to interoperate with other ones; they can transmit data from one node to another; and can be designed and customized to meet the local/cultural needs of the various countries.

Internet Voting (I-Voting)

This refers to voting over the Internet through a PC with Internet connection to cast a vote and transmit same to another remote computer/server. Personal Digital Assistants (PDAs), Telephone or mobile phones can be used for this purpose (Kelvin, 2002).

The proponents of i-Voting suggest that it could increase turnout, particularly among younger voters who are familiar with Internet technology. I-voting has a lot of benefits but its security is in doubt because of its public nature, however, there are concerted efforts geared toward securing this medium.

Types of i-Voting

1. **Polling Station i-Voting:** PCs with Internet connections are provided at a location for all to use. There are electoral officers at each location to authenticate voters before voting.
2. **Remote i-Voting:** Voters cast their votes at remote locations through personal computers

using electronic authentication and computer security technologies.

Mobile Voting (M-Voting)

The provision of computing power on wireless devices opens an avenue for mobile transactions, particularly as mobile devices (smart phones, PDAs, cell phones and notebooks) are equipped with browsers (Gonzalez, 2003). Currently, about two-third of the world population has access to mobile devices. Thus, for enhanced participation in elections, it offers a good platform for voting anywhere, anytime, and at one's convenience (Dennis, 2002).

However, there are significant difference between developing applications for the wired Internet and the mobile Internet. The wired Internet applications are based on hypertext transfer protocol (HTTP) and the Internet markup language called hypertext markup language (HTML). Thus, the platform assumes that all devices have similar display sizes, memory and software capabilities, hence they are considered to be relatively static (Duford, 2002).

Mobile applications on the other hand are based on wireless application protocol (WAP) and wireless markup language (WML). This is because of the inherent nature of mobile devices such as: small screen format with limited display and navigation capabilities; low computation capability; limited data-entry capability due to the size of the key-pad; low bandwidth and high cost of data transmission; and network latency and other delays. Thus the HTTP/HTML features will not work well on WAP/WML devices (Duford, 2002).

Therefore, deploying applications to the mobile devices calls for simplicity, usability and user-friendliness, and consideration for end-users.

ARCHITECTURAL FRAMEWORK FOR E-VOTING SYSTEM

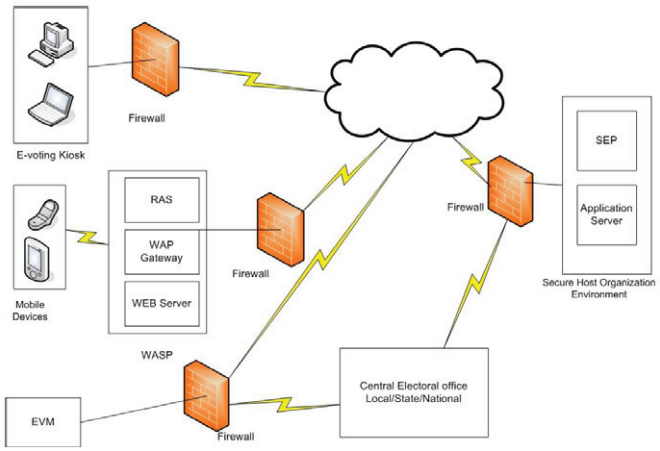
The proposed framework is composed of five (5) basic components as shown in Figure 1:

i. The wireless devices and providers
ii. The host organization and environment
iii. The e-Voting kiosk
iv. The e-Voting machine
v. The central electoral office.

The Wireless Devices and Providers

This sector comprises of the wireless devices: WAP cell phones and other mobile devices that are under the control of the Wireless Application

Figure 1. Deployment architecture



Service Provider (WASP). The WASP environment is composed of:

a. Remote Access Servers (RASs): Servers that establish connections between mobile devices, the wireless providers, and the wired Internet.
b. Web Servers (WSs): Servers that manage the various web applications such as mails, applications etc.
c. WAP Gateway: This is the major link between the WASP and the wired Internet. The function of the gateway among others include: decrypting secure socket layer (SSL) encrypted traffic and re-encrypting it with wireless transport layer security (WTLS) meant for the wireless devices and vice-versa; and basically providing Internet access to its subscribers (Dennis, 2002).

The security features governing transmissions from the mobile devices and WASP is WTLS. The encrypted message is further routed through a firewall for enhanced security. The security measures are further fortified using the public-key cryptography, digital signature and digital certificate (Tallinn, 2005).

The Host Organization and Environment

This environment offers a secured wired environment through a 1024-bit SSL encryption, which is stronger than the WTLS encryption offered by WASP. This environment is composed of:

a. Secure Enterprise Proxy (SEP) that performs the SSL/WTLS translation within the secure environment rather than being done on the WAP gateway within the WASP environment to prevent the "Gap in WAP" situation.
b. Application Server that is the repository of the e-Voting applications.

The "Gap in WAP" syndrome describes a situation where there is security breach during the process of SSL/WTL conversion.

E-Voting Kiosk

This section represents the environment or public locations where e-Voting facilities are made available for public use. The locations are equipped with PCs, EVM, and Internet facilities among others.

E-Voting Machine (EVM)

The machines could be customized e-Voting systems, PCs or a special purpose computing system. The existing configurations include:

i. Premier Election Solutions (Formerly DIEBOLD ACCUVOTE-TS).
ii. Elections Systems and software (ES&S IVOTRONIC).
iii. Sequoia Voting System.
vi. Hart InterCivic.
v. URNA Eletrônica

These systems run on either Windows CE or a proprietary Operating System with compact flash for storage of votes and a backup battery that can last the period of the election (Boutin, 2004). Thus, to prevent multiple voting, the machine should offer Internet access through a micro browser to update voters register. The voters' registers are localized into the area of registration and voting for easy reference.

Central Electoral Office

This is the central, local, state and national electoral office that is responsible for collating and declaring local or regional results to the party agents to ensure transparency. Having declared the result at the polling booth, the flash storage is forwarded to the central office where the results of the e-Voting machines are added to the result

on the Application server. The system has provisions for audit trail through the flash disks and the results in the application server.

Interoperability Issues

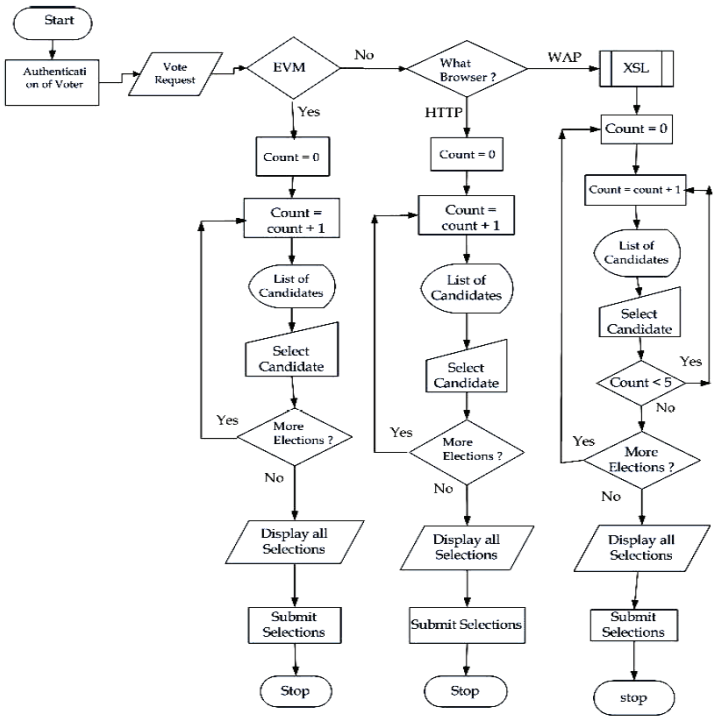
Interoperability between the wired and wireless Internet can be achieved in two ways (Ayo, West):

i. Using extensible markup language (XML) and extensible style sheet language (XSL) to target multiple devices. That is, rather than creating multiple sites for the various devices, data can be extracted as XML and XSL templates can be used to generate HTML and WML documents for the various devices.
ii. The use of Aether systems' Scoutweb to WAP-enabled devices is a web-based application. It offers interfaces for websites and mobile devices. Scoutweb supports over 30 different devices and helps translate HTML to mobile content on the fly given a set of rules.

PROPOSED SYSTEM IMPLEMENTATION

The overall objective of this chapter is to present a framework for an integrated voting system. That is, an efficient and effective system that satisfies the desires of the electorates by offering several platform of operation as presented in Figure 2. An electorate can vote through any of the three options: EVM; i-Voting; or m-Voting. The EVM is an example of a polling station e-Voting, that displays the e-Ballot and electorates go through the user-friendly procedures to cast their votes. Similarly for i-Voting or m-Voting. Once the medium of voting is ascertained, the appropriate format is displayed on the respective devices. For

Figure 2. Integrated voting system



i-Voting, the HTML equivalent of the e-Ballot is displayed for the electorates. However, for mobile devices, the WML format is displayed, which is a function of the size of the screen. In some, it could be the five candidates per screen for Palm devices or a single candidate per display screen depending on the size of display.

The major design considerations of the system include: (i) Provision of Voter Verifiable Audit Trail; (ii) Prevention of Multiple Voting; (iii). Prevention of Over-Voting/Rigging; (iv) Provision of avenue for Disabled Voters; and v. Provision of Adequate Security Measures.

PROPOSALS AND CONCLUDING REMARKS

i. We propose five (5) candidates (parties) for each election. The candidates can be displayed at once on the PC and EVM, but displayed one candidate per screen, or all candidate(s) per screen, depending on the mobile device.
ii. Multiple elections (presidential, gubernatorial, etc) can be conducted a day. After each election, the next elective office and candidates are displayed for selection/voting until all elections for the day are concluded in one stream.
iii. There is much flexibility in the system as voters are availed the opportunity of perusing their selections before they are submitted to the server.
iv. A biometric smart card-based voters cards proposed foe enhanced security and integrity.
v. After each election, the voter's card is blocked to prevent further use on the day of the election, nor can it be used through another medium to vote. Thus over-voting is prevented.

In conclusion, this paper presented the different flavours of e-Voting systems: the polling station e-Voting and remote e-Voting. The integrated and deployment architectural frameworks were presented.

While the various components of the system would function as a separate entity, it is however recommended that i-Voting be reserved for remote voters living abroad and m-Voting for persons living with certain forms of disability. Security issues were discussed through the deployment architecture showing the various devices required to safeguard the integrity of the votes cast.

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