Election Workflow Automation - Canadian Experiences

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Abstract: Democratic parliamentary and presidential voting supported by election systems worldwide represents the essential idea behind any free society. In recent years, numerous challenges have been overcome to satisfy this fundamental principle. On one side we have low voter turnout and high electors migration, on the other, sometimes complex electoral systems such as preferential or transferable ballot voting. In addition, proliferation of modern computerized technologies is giving hope that with new automated processes and voting channels, the election process and democracy as a whole can be more accessible, secure and transparent. In this paper we are presenting the Democracy Suite as the field-proven solutions for full election automation workflow.

1 Introduction

Governments in Canada are organized in a range of geographical structures. The federal government uses a single member plurality system in 308 ridings, also known as electoral districts. Similar systems are used in each province but with lower numbers of ridings. Municipalities use more complex structures – typically electing a single mayor and multiple councilors or trustees using composite ballots with several plurality contests. To date, preferential or transferable ballots have not been widely used but successful pilot projects are contributing to serious consideration. Elections dates in Canada can be divided into two general categories – fixed and variable. Most municipal events are on fixed dates and several hundred towns and cities can have elections on the same day. In contrast, provincial and federal governments are modeled on a parliamentary system so governments can be defeated at any time during a 5-year term.

In Canada, paper ballots and in-person voting are predominantly used for all types of elections. In some cases vote-by-mail is used as well, but in essence this voting channel still uses paper ballots with central vote counting. For decades, the voting process was mostly performed manually – electors were recorded using a hard-copy voters list and ballots were tabulated by hand. This basic system was acceptable for simple elections, but recording inefficiencies cause long line-ups at voter registration and manual vote tabulation leads to inconsistencies and long delays in results reporting.

Automation of vote tabulation has started in mid 1990's and was predominantly used for decentralized and centralized paper ballot processing for local elections in large cities. These first generation systems from Diebold and ES&S, designed before introduction of Voting Systems Standards [FEC02] and HAVA standards [HAVA02], didn't provide accessible, secure and transparent election process as required by [EA05]. In addition, lack of integrated elector management system, standard-based data interchange schemas and alternative remote voting channels, made those systems inappropriate for Canadian elections. Since late 2002, Dominion has been developing an integrated and automated election system under the name of Democracy Suite. This set of software applications and hardware devices, coupled with variety of services, provides a complete set of solutions for traditional in-poll or remote paper-based voting, electronic remote voting (Internet), and elector management. In this paper we will provide a brief technical overview of the Democracy Suite as it was deployed in the variety of elections in the provinces of British Columbia, Alberta, Ontario, Quebec and Newfoundland.

2 Automated Election Workflow

The overall election process schedule is separated into *election event* and *election cycle* activities (Figure 1). Election events represent specific voting occurrences, with its date and the jurisdiction of the given electoral authority, plus a unique set of *election entities*, such as polling divisions, contests, candidates, ballot styles, voting channels, etc. The election cycle activities, on the other hand, include elector management activities for obtaining the complete and most up to date list of eligible voters.

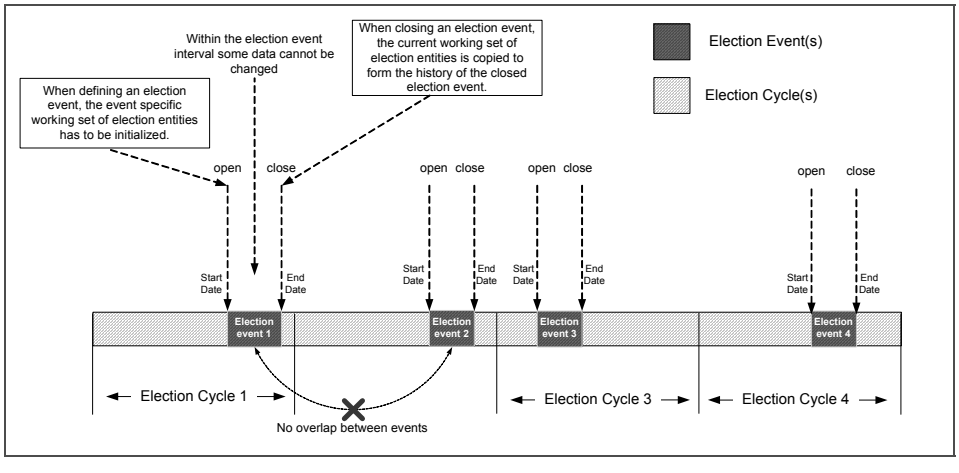

Figure 1: Relation between election events and election cycles.

Every election event begins by collection of election entity data. This election event definition phase primarily involves accumulation of contest and candidate names as well as all additional geographical and administrative information needed (polls, polling districts, polling locations, polling stations, etc.).

This data usually comes directly from electoral authorities responsible for event organization and enters our system in an XML defined schema for election entity information exchange, similar to EML [EML05]. After importing this data into our election event data model, the system proceeds with automated creation of ballot styles, voting information files needed for programming of voting channel devices, and election results reporting XML schemas.

All voting channels utilize a common set of configuration files (channel configuration and voting information files) which contain directives for the system operational and election rules (Figure 2). For data protection and performance issues, these files are encrypted and in binary format. Using this approach, complete and seamless integration of all system components is achieved - unifying diverse entities with clear technical separations (i.e. paper versus electronic ballots). Simply stated, the system provides a) only one point of definition for all relevant election data and b) only one point of tabulation from different voting channels. Figure 2 also shows different voting channels supported by our automated election workflow:

a) Decentralized poll-based voting using paper ballots and polling station tabulators (CF200 series)
b) Centralized voting using paper ballots and central count tabulators (CF500 Series)
c) Electronic remote voting using electronic ballots and Internet (e-Voting)
d) Fax-back remote voting using paper ballots and fax services
e) Vote-by-mail remote voting using paper ballots and regular postal services

Ballots cast, using any of the voting channels, are collected using the same central platform which performs a variety of tasks such as vote tallying, verification, auditing and publishing.

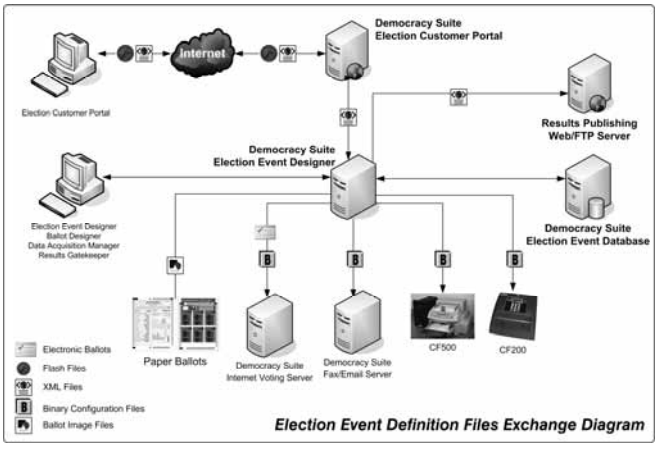

Figure 2: Election event definition files exchange diagram.

In addition, for full support of a variety of voting channels, Democracy Suite includes elector management support for registration and tracking of electors. This support includes day-to-day elector management (add, modify, delete), address management, and

administrative areas management tasks. For real-time voter tracking during election events, Democracy Suite creates an electronic poll-book list of electors which is synchronized with central elector register using GPRS/EDGE or regular Internet connectivity. Finally, the system provides full support for remote voting registration, such as vote-by-mail and Internet voting. Figure 3 presents an elector management deployment scenario.

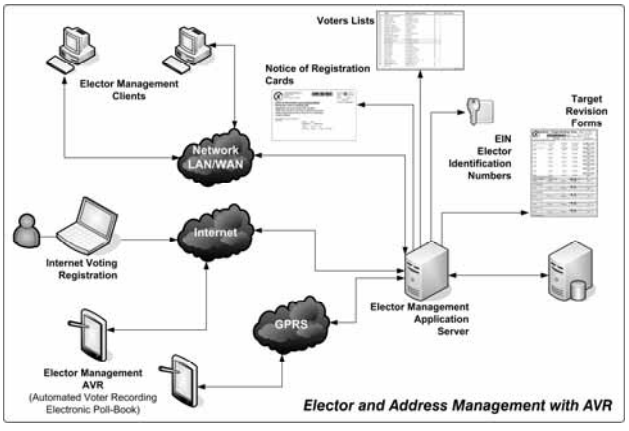

Figure 3: Elector and address management.

3 Data Model

The data model for our automated election services is structured around three databases: *elector management*, *election event*, *security* database. Each of the databases model the real election related entities and their relationships. Electors and their addresses, as well as related administrative data are stored in *elector management* database, together with the voting channel type and elector status (voted, not-voted). The *election event* database contains data related to particular election event such as contests and candidates. This database also stores voting results for a given election event. Finally, the *security* database models electoral organization roles, permissions and retains a log of all activities performed by the users of the system.

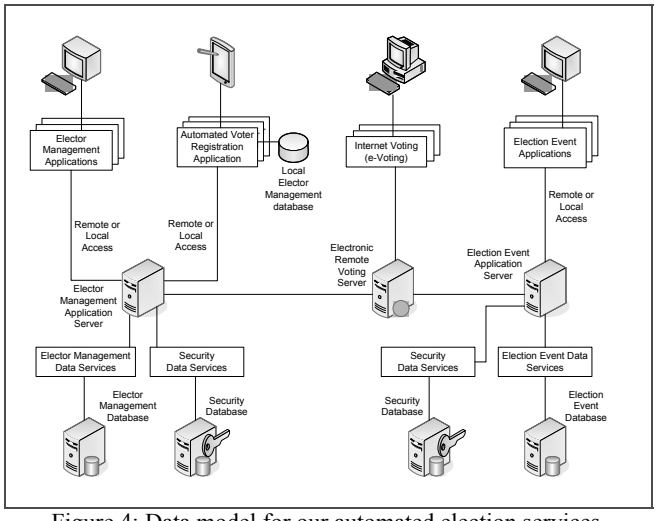

Figure 4: Data model for our automated election services.

The data in the Elector Management database model can be classified into the following categories in relation to an election event and election cycle:

a) Logically detached from election event
b) Logically attached to election event
c) Logically semi-detached from election event

The data in Election Event database has validity only during a particular election event for which they are defined – i.e. list of contest and candidates will change between different election events.

All the tables in our data models can be divided into four categories: *Entity*, *Type*, *Log* and *Mapping* tables. Examples of Entity tables are *Person*, *Poll*, *Candidate*, etc. These tables always use GUIDs as primary keys and contain primary election entities. Examples of Type tables are *LocationType*, *VotingChannelType*, etc. These tables always use integers as primary keys and define election entity or action types as enumeration values expressed in different languages. Examples of Log tables are *VotingLog*, *AdvancedVotingLog*, etc. These tables record all election cycle and election event related activities such as time and place where someone has been voting. Finally, Mapping tables provide support for various levels of relationships between different entities. Examples of these tables are *LocationHandlesPoll*, or *PollUsesBallot*, etc.

From software architecture point of view, both Election Event and Elector Management Application Servers, as guardians of database access and management, implement optimized and concurrency safe data access layers. These software components are not only responsible for direct database access, but also for Object to Relational Mapping (ORM) between database tables and their relationship on one side, and domain objects on the other. This architecture provides robust election specific domain access and clear view toward the election data models.

4 Democracy Suite Software Components

The two core software components of Democracy Suite are Election Event and Elector Management application server. These two server components implement automated election workflow intelligence and communicate with corresponding data models. These application server modules are deployed utilizing encrypted binary transport channels and a variety of client applications and dedicated task-oriented services:

a) Election Event Definition – set of pre-voting modules for defining election events, programming of the voting channels and creation of ballots, either paper of electronic.
b) Results Tally and Reporting – set of post-voting modules for acquisition of election results from the voting channels, manual data entry, results verification, tally and publishing. In addition, auditing of the overall voting process is integrated in this module.
c) Elector Management – responsible for the importing, cleansing, maintenance and real-time tracking and registration of electors. In addition to importing elector data from a variety of data sources, this system creates:
    i. Notice of Registration Cards (NRCs), or invitation to participate (vote) in a given election event.
    ii. Electronic and paper poll-book lists that can be used in combination with the our Automated Voter Recording system and the CF105 electronic poll-book platform,
    iii. Elector Identification Numbers (EINs) used as secure PINs for remote electronic voting (e-Voting), and
    iv. A list of voters and addresses for a subsequent target revision process which should provide a clean and up to date list of electors for the next election event.
d) Remote Electronic Voting – includes a support for Internet voting, which basically includes Registration Server, Electronic Ballot Issuing Server, Internet Voting Server and Electronic Ballots. All these components work in harmony with Election Event and Elector Management subsystems.

5 Automation of Paper Ballot Voting

A majority of the elections in Canada, and also in other parts of the world, remain based on a paper ballot system and in-poll voting. We can expect that this traditional voting channel will be in use for some time as a result of cost, accessibility, and permanent audit record considerations. Therefore, one of the primary goals of our strategy was to automate that process as much as possible using a specialized set of software and hardware solutions.

From a hardware point of view, we have designed an electronic voting box (CF200) in the form of optical ballot tabulator (Figure 5) with integrated audio vote capabilities and variety of communication options.

This device, especially designed for decentralized deployments (for in-person voting), deploys a reliable two-sided high-resolution digital scanning mechanism with on-board advanced image processing algorithms for optical mark recognition. Every ballot scanned is saved and permanently imprinted with the results of the vote determination algorithm. This patented feature provides a fully auditable paper and electronic trail. Also supporting special requirements for people with disabilities, the CF200 deploys audio ballot feature for greater accessibility. Visually impaired and other people with disabilities can use this feature to cast their votes.

Figure 5: The CF200 electronic voting box in the form of optical poll-level tabulator.

For all central count applications reliable high-speed scanning hardware has been integrated with high-performance and accurate image processing algorithms. Depending on the scanning performance, ballot size and layout requirements, appropriate central count solutions from CF500 series can be selected. The CF500 is the most suited for high-turnout elections with scan rate of 6000 ballots per hour and ballot size of up to A3 format, while the CF520/40 models are designed for mid-turnout elections with scan rate of up to 2500 ballots per hour and ballot size of up to A4.

The image processing module within Democracy Suite leverages the binary nature of the scanned ballot images and provides high speed tabulation utilizing a two-dimensional signal correlation algorithm for tracking form landmarks. Prior to this approach, the optical tabulation platforms used a rudimentary bounding box technique together with a straightforward pixel counting method for detecting form answer fields. Although this technique was extremely fast, it was highly susceptible to printing inconsistencies, scanning noise and image skewing. Furthermore, the decision process for any given voting field (i.e. detection of mark or no mark for a given candidate) employed fixed rotation bounding boxes that did not accommodate for even minor image skews.

In order to speed up processing, the new algorithm uses an iterative search space which converges on the location of the desired ballot marking field by varying the search space extent and resolution until a specified threshold is reached. This use of pattern matching is superior to a simple bounding box technique because it is able to filter noise more effectively as well as account for some variations in skew as the most likely result is used in the analysis of voting boxes. The new technique has been able to successfully detect votes that have been inadvertently cut off during scanning, markers obscured by printing or scan head artefacts, as well as markers that have been tampered with (e.g. written on). In addition, form skew is taken into consideration, allowing the bounding box of the answer area to be rotated appropriately, and thus provide more accurate pixel counts.

Both the compression algorithms used to save ballot images and the file formats are different for the poll level (CF200 series) and central count (CF500 series) tabulators. On the CF200 series tabulators, the images of all scanned ballots are compressed using run length encoding (RLE) and stored as a BMP files. Since the images are binary (black and white), RLE is very efficient in compressing the images up to 15 times. On the CF500 series tabulators, TIFF LZW (Lempel Ziv Welch) is used for image compression to save all scanned ballots. TIFF LZW is the de-facto standard for lossless image storage. LZW is the most popular compression for black and white and grayscale images. This algorithm compresses and decompresses without any information loss, achieving compression ratios up to 5:1.

From a software point of view, Democracy Suite includes several software modules for automation of paper-based voting. Election Event Definition modules include Election Event Designer and Ballot Designer features. While first one is used for collection of contest and candidate names, as well as administrative electoral divisions, the second one creates ballot styles and layouts using predefined ballot templates. This complete set of information is used for creation of binary voting configuration files for programming of voting channels. Another set of software automation tools are used for result tallying and reporting. These modules are responsible for election results acquisition from various voting channels, manual results data entry, results tallying, verification, auditing and reporting. Each voting channel produces the results information file in a common binary format. After importing these result files into the Results Tally and Reporting module, votes cast are stored in a temporary database giving the electoral officers the opportunity to perform results verification before making results public. This verification can be selectively performed either for all contests or just for contests flagged as critical. Finally, in an auditing process using a random algorithm, electoral officers and scrutineers can select ballots for inspection and compare images of scanned ballots with system recordings. Using this approach, a very high level of acceptance is achieved in the overall tabulation validity.

6 Electronic Remote Voting

Electronic Remote Voting (Internet voting) has some unique requirements that differentiate this method from traditional paper-based voting processes. In recognition of these unique requirements, a 5-step process was defined as shown in the following diagrams.

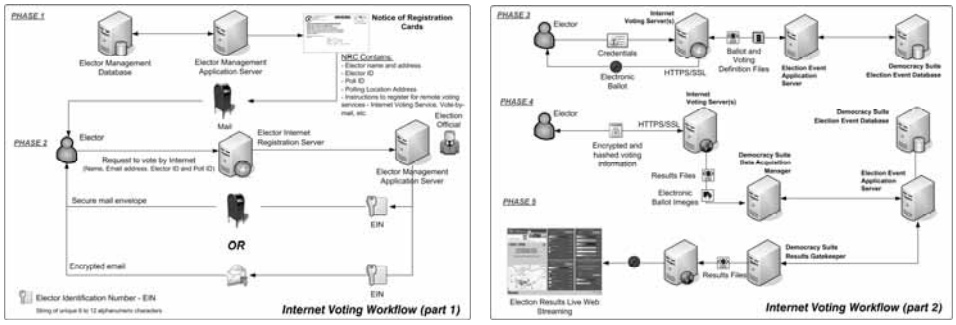

Figure 6: Internet voting five step process.

Phase 1 – Elector Management - This phase is common for any type of election, regardless of the voting method(s) being employed. At the end of the elector management process, the system generates the invitation to vote (NRC) cards to be mailed to eligible voters. Each NRC card contains information about the voter including name and address, unique elector identifier (Elector ID), etc.

Phase 2 – e-Voting Registration - Upon receipt of their NRC cards, voters can choose to vote using a traditional paper ballot at the polling location, or to register to vote using the Internet voting. If an elector chooses to vote via the Internet, they must first register at the designated Internet site (Internet Registration Server). Based on this information, the system generates a unique Election Identification Number (EIN) for that elector. This EIN serves a similar purpose to that of the PIN numbers commonly used in Internet banking. This number is communicated to elector using the secure mail service.

Phase 3 – Electronic Ballot Download - On the Election Day(s), electors who received EIN codes can access the Internet Ballot Issuing Server and proceed with voting by downloading an electronic ballot. Every electronic ballot is generated dynamically by mapping elector information with content in Election Event database. In addition, each ballot contains a randomly generated Ballot Activation Code (BAC), which is embedded into the ballot in the form of 2D barcode matrix. This code ensures that one ballot is issued and cast only once.

Phase 4 – E-Voting – A sample electronic ballot is presented in Figure 7. Electronic ballots can have animated help, configurable marking options (square, oval, circle, arrow, x, check mark, etc.), audio capabilities, magnification features, etc. This is especially important for visually impaired people who can vote using these special features. The voting process itself is identical to marking a paper ballot. After making a selection, the elector presses a Submit button which is followed by a confirmation screen. Depending on configuration settings, this system can prompt an elector to correct his selection if the ballot is blank, overvoted or undervoted. After elector acknowledgement, votes are extracted from the ballot and serialized to the Internet Voting Server over the secure communication link. At this point, the used EIN code is destroyed and the elector voting state is appropriately changed. For each electronic ballot cast, electronic image of the ballot is created. Using this approach, even electronic voting can have auditing trail (images can be printed and used as the paper ballots) and in case of a recount, the electronic voting process does not have to be repeated (generated images can be scanned using optical tabulators together with other paper ballots).

Phase 5 – Results Tally and Reporting - The results processing and reporting phase is the same for all methods of voting, including Internet voting and traditional paper ballot voting. The Internet Voting Server produces results files in the same format as those produced by the paper ballot tabulator devices.

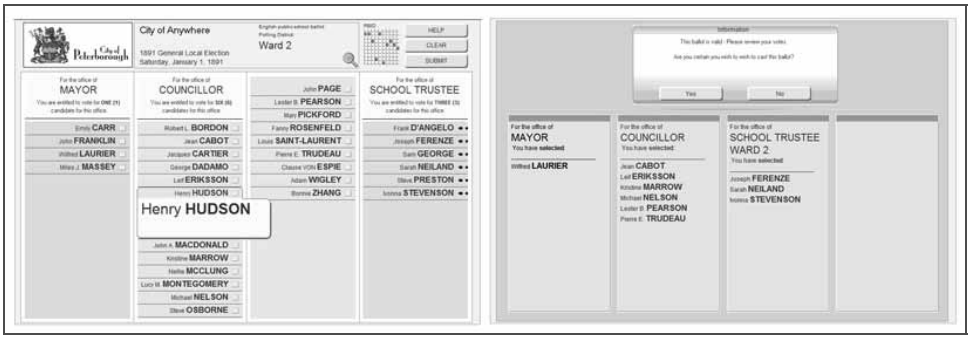

Figure 7: Sample electronic ballot with zooming feature.

7 Reporting

All reports can be divided into the following groups:

a) Election Event Definition reports provide information about the structure of the defined election event, with all of their election entities and their relations.

b) Elector Management reports include all of the information about the list of eligible electors, issued and mailed NRCs, status of electors (list of voters who voted at advanced polls and regular election days), list of issued certificates to vote, list of issued proxies, etc. The system keeps track of all electors who have registered to vote by Internet, along with their voting status.

c) Internet Voting Services status reports provide information about electronic ballots issued, along with the status of the Internet servers and connections, alarms (if any), etc.

d) Election Results Tally and Reporting module produces up-to-date PDF/Excel/XML reports in addition to the live web streaming reports, based on rich-content data representation (maps, tickers, charts, grids). Live web reports are fully customizable in terms of content and layout (Figure 8, left), providing interactive and dynamic results representation format at the election night (Figure 8, right).

Figure 8: Live web streaming election results presentations.

8 Conclusions

In this paper we have presented automated election workflow based on Democracy Suite line of software and hardware products. Democracy Suite has a range of features to handle contemporary election issues. Computer technologies are utilized in order to provide ballots in a greater variety of formats to reach a larger percentage of electors. High migration is handled more effectively with database tools for elector list management. Automation is introduced into the poll to provide assistance to electors and also to support more complicated ballot styles. All security concerns for both internet ballots and election management have been addressed to ensure system integrity. Full attention is granted to election event and election cycle entities to minimize the required time required to stage an election. Our current work includes additional system improvements for making the Democracy Suite fully compliant with [FEC05] specifications.

Literature

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