

A FRAMEWORK FOR A MULTIFACETED ELECTRONIC VOTING SYSTEM

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ABSTRACT

The rapid advancement in information and communications technologies has given rise to new applications that were impossible just few years ago. One of these applications is e-voting. The term “e-voting” is defined as any voting method where the voter’s intention is expressed or collected by electronic means. This paper details the requirements, design and implementation of a generic and secure electronic voting system where voters can cast their votes anytime, anywhere and using a number of electronic devices including private computer networks, web and mobile phones.

Keywords: e-voting, three tier architecture, Short Message Service (SMS), Virtual Private Network (VPN), Proxy Server, Database Server and Internet.

1. INTRODUCTION

“While democracy must be more than elections, it is also true it cannot be less” former United Nations Secretary General, Kofi Annan once said (Annan, 2000). Democracy is a form of government in which the supreme power is vested in the people and exercised directly by them or by their elected agents under a free electoral system. Election on the other hand is a process in which voters choose their representatives and express their preferences for the way that they will be governed (Kohnno et al., 2003) and (Malkawi et al., 2009). Democracy and elections have more than 2500 years of tradition (Krimmer et al., 2007). However, technology has always influenced and shaped the ways elections are held (Held, 2006). In times past, different voting systems that are based on traditional paper ballots, mechanical devices, or electronic ballots were developed for elections (NSF, 2001) and (Malkawi et al., 2009). However, these voting systems have littered history with example of elections being manipulated in order to influence their outcome. Allegations of violence, intimidation, ballot stuffing, under-age and multiple voting, counting error, complicity of the security agencies and the absence or late arrival of election materials etc often trail elections conducted using these systems of voting (NSF, 2001), (Fischer, 2003), (Muir et al, 2005), (Boniface, 2008) and (Malkawi et al., 2009). In Africa, most elections are conducted using paper ballots. However, there have been countless reported cases of eligible voters being unable or prevented from exercising their right to vote as stated in the Universal Declaration of Human Rights of the United Nations (United Nations, 1948), sometimes due to violence and intimidation, lack of information on physical location of voting poll sites, social discrimination; and by other natural causes like advanced age, physiological disability, terrain, floods, and poor communication infrastructure (Boniface, 2008).

Therefore, there is the need of a significant alternative to this conventional system in the delivery of trusted elections. The advancement of information and telecommunications technologies has allow for a fully automated online computerised election process whereby electoral vote counts are done in real time that by the end of elections day, the results are automatically out (Rubin, 2002). This type of election process is referred to as electronic voting (e-voting). E-voting is any voting method whereby at least the voter’s intention is expressed or collected by electronic means (Buchsbaum, 2004), (Magi, 2007) and (Nestas, 2010). The term e-voting is being used from tabulating the votes by electronic means to integrated electronic systems of voters’ and candidates’ registration to the publication of election results (Buchsbaum, 2004). In general, two main types of e-voting can be identified: e-voting supervised by the physical presence of representatives of governmental or independent electoral authorities, e.g. electronic voting machines at poll sites popularly known as Direct Recording Electronics (DRE); and e-voting within the voter’s sole influence (remote e-voting), not physically supervised by representatives of governmental authorities, e.g. voting from one’s own or another person’s computer via the internet, by mobile phones (including Short Message Service, SMS), or via digital television (Buchsbaum, 2004).

The emergence of e-voting will undoubtedly enable voters to cast their vote from a place other than the poll site in their voting district, facilitate the casting of the vote by the voter, facilitate the participation in elections by those who are entitled to vote, widen access to the voting process for voters with disabilities or those having other difficulties in being physically present at a poll site, increased voter turnout by providing additional voting channels, reduce overtime, the overall cost to the electoral authorities of conducting an election, deliver voting results reliably and more quickly amongst many other benefits (Buchsbbaum, 2004). This paper details the requirements, design and implementation of a generic e-voting system, where voters can cast their votes anytime, anywhere and using a number of electronic devices including web and mobile phones. Section 2 details a high-level set of requirements that an e-voting system must satisfy. The architecture of an e-voting system that satisfies the stated requirements is presented in section 3. Section 4 and 5 outline description and the implementation of a prototype for the e-voting system. Finally, section 6 presents some concluding remarks.

2. REQUIREMENTS DEFINITION FOR THE E-VOTING SYSTEM

The design of any voting system, whether electronic or traditional paper ballots or mechanical voting system must satisfy a number of sometimes competing criteria (NSF, 2001) and (Nestas, 2010). These requirements are divided into two groups, namely, generic and system-specific. The system is to cater for the following generic requirements:

- i. *Privacy*: After casting a vote, no one should be able to link the voter to this vote;
- ii. *Authenticity*: Only eligible voters can cast their votes;
- iii. *Integrity/accuracy*: Once a voter cast a vote, no alternation to this vote is permitted. Moreover, All valid votes must be counted, whereas all invalid votes must not be discarded;
- iv. *Security*: Throughout the voting process, a vote can't be tampered with;
- v. *Democracy*: All eligible voters must be able to vote, one person - one vote and no one can vote more than once or vote for others.
- vi. *Verifiability*: Voters can independently verify that their votes have been counted correctly and are included in the final tally.

The system-specific requirements of the framework allow:

- i. *Multi-user*: A number of voters can vote simultaneously;
- ii. *Accessibility*: The system can be accessed by voters from any location using secure Internet and/or mobile devices;
- iii. *Availability*: The system must have high-availability during an election campaign.

3. ARCHITECTURE OF THE E-VOTING SYSTEM

To accommodate the requirements presented in section 2, an architecture presented in Figure 1 below, for the e-voting system was developed. The e-voting system was modeled around the three tier architecture: client tier, server tier and database tier.

3.1 Client tier

The client tier is made up of the following components:

- i. *Mobile terminal voters and the mobile network operator*: SMS voting is done through mobile terminals. Communication between the mobile terminals and the SMS server is through GPRS which is provided by the GSM network provider.
- ii. *Remote clients' computers*: Remote internet voting is done on the clients' computers (equipped with fingerprint reader) in locations outside the poll sites. The clients' computers connect to the web server to load the web application over the internet via HTTP. The e-vote is sent to the poll site server via TCP/IP (socket programming and .NET remoting). A RSA encryption algorithm was implemented to secure end to end messaging.
- iii. *Registration Centre and Poll Site Computers*: The Registration Centre/Poll Site Computers in practice should be special-purpose computers for voters' registration and poll site voting. Communication between the Registration Centre/Poll Site Computers and the Poll site server is by TCP/IP (socket programming and .NET remoting). A RSA encryption algorithm was implemented to secure end to end messaging.

3.2 Application server tier

The application server tier is made up of:

- i. The SMS sever which interacts with voters that use their mobile telephone set and the SMS messaging service to access the e-voting system. At the lowest level, the SMS server interfaces to GSM modem(s) that receive voters' SMS messages through a SMS service provider (mobile operator).
- ii. The web server which interfaces the e-voting system to web voters. In addition, it stores the different web page(s) containing the code required to interact with the user as well as the database system.
- iii. The poll site server which interfaces the e-voting system to the electorates during registration and poll site voting.

3.3 Database server tier

Database server is the core service for storing, processing and securing data. The database server provides controlled access and rapid transaction processing to meet the requirements of the client tier. The voters' records, candidates' record and election results database resides on this server. This server is also responsible for authenticating voters and administrators' authorisation.

4. EVOLVING THE OVERALL SYSTEM ARCHITECTURE

The system architecture defines the key components of the proposed system together with the interactions between these components. The overall functional structure of the framework is summarised as follows: an eligible electorate (18 years and above) registers with the electoral body at a gazette registration centre. The person identifies self by providing all the required biodata, phone number and the fingerprints of the person will be scanned and stored in the database. The registered electorate will be given a unique voter identification number and a unique voting code which he/she is expected to keep confidential. A remote internet voter (client) runs the Uniform Resource Locator (URL) for the e-voting system through a web browser. The web application prompts the voter to download the voting application package that should be installed on the voter's computer. The voting application runs remotely on the client's computer. Voting is done via the voting application installed on the client's computer by selecting the political party of choice and a fingerprint scan. A remote mobile terminal voter votes via SMS. Poll site voters cast their electronic ballots at designated Poll sites. The voter selects the political party he/she wants to vote for on the voting interface and scans a fingerprint to cast the vote.

The developed e-voting system was designed to allow many voters to voting simultaneously while ensuring highly availability during the electioneering process. Authentication into the voting system is either by biometrics or voter identification number (voter ID) and voting code generated for each voter after registration. Poll site voting and internet voting requires a fingerprint scan for ballot casting while SMS voting requires combination of mobile number (SIM) of the electorate, the generated voter ID and voting code, which are unique for voter. A voter ID and voting code sent to a particular SIM after registration cannot be used on another SIM for voting. The security considerations of the system were based on a RSA encryption algorithm which was implemented to secure end to end messaging, the Transport Layer Security (SSL/TLS) which is a VPNs' cryptographic tunneling protocol and firewalls in form of proxy servers. Furthermore, the web server only hosts the web page of the e-voting system. Actual ballots casted by web voters are sent to the Poll site server which is on a VPN. Ballot casted are record in the data tables at the backend of the database as binary templates.

The system ensures only one-person, one-vote (democracy) property of voting systems. The voter's fingerprint, voter's SIM, voting ID and voting codes of a voter intending to cast his/her ballot are matched at every voting attempt to prevent multiple voting. During registration, fingerprints of new electorate about to be registered are matched against exiting fingerprints in the database to prevent multiple registrations. The overall system was developed base on the derived system requirements and on the .NET framework using Visual C#, GrFinger SDK (version 4.2) and Ozeki message server (version 6). Web applications were developed using ASP. NET while the data tables at the backend in the database server were developed using MS SQL Server 2008.

5. E-VOTING SYSTEM IMPLEMENTATION

Following the architecture presented in section 3, a prototype for the e-voting system was developed. The system is divided into the client systems and the Application server system.

5.1 Client Systems

The developed client-side systems are the subsystems for registration, poll site voting and internet voting. The client-side subsystems interface the electorates to the e-voting system during the registration and voting processes.

5.1.1 Registration Centre Subsystem

Figure 2 depicts the voters' Registration Centre subsystem. The Register Voter module allows voters' information to be stored in the system. During the registration process, the picture of each voter is stored against his/her biodata (which must include mobile phone number) and the fingerprints of the voter are scanned into the system. A SMS containing voter identification number (voters ID) and a voting code is sent immediately after registration to voters as receipt acknowledging their registration. Figure 3 shows the Register Voter module of the Registration Centre subsystem.

5.1.2 Poll Site Voting Subsystem

The poll site voting subsystem is a client-side application system which electorates use to vote under the supervision of the electoral body or other relevant government agencies on Election Day. This subsystem can be viewed as the electronic version of the conventional tradition paper ballot casting. However unlike traditional paper ballots which restrict ballot casting to electorate's ward/precinct (or point of registration) the poll site subsystem allows ballot casting at any poll site. Figure 4 depicts the poll site voting subsystem.

5.1.3 Internet Voting Subsystem

The internet voting subsystem is a client-side application system which electorates can use to cast their ballots outside the poll site anywhere and at anytime (though within the voting period timeframe) on election day. Figure 5 depicts the web page of the developed e-voting system.

5.2 Application Server

The developed application server is a software framework dedicated to the efficient execution of procedures (programs, routines, scripts) for supporting the construction of applications. The sever has five menu options, namely New Contestant (use to register new contestants), Voter's List (use to view list of registered electorates), Registered Party (use to register new political parties), Election Process (use to initiate and terminate a particular election) and Election Result (use to view the result of a particular election). The developed e-voting system requires that the Application Sever must be running before any client action could take place. Figures 6 – 8 depict the some menu options that make up the application server menu.

6. CONCLUSION

Elections allow the populace to choose their representatives and express their preferences for how they will be governed. Naturally, the integrity of the election process is fundamental to the integrity of democracy itself. The election system must be sufficiently robust to withstand a variety of fraudulent behaviors and must be sufficiently transparent and comprehensible that voters and candidates can accept the results of an election. However, this cannot be said for conventional voting systems. Electronic voting is emerging as significant alternative to these conventional systems in the delivery of reliable and trusted elections. This paper details the requirements, design and implementation of a generic e-voting system, where voters can cast their votes anytime, anywhere and using a number of electronic devices including private computer networks, web and mobile phones.

7. REFERENCES

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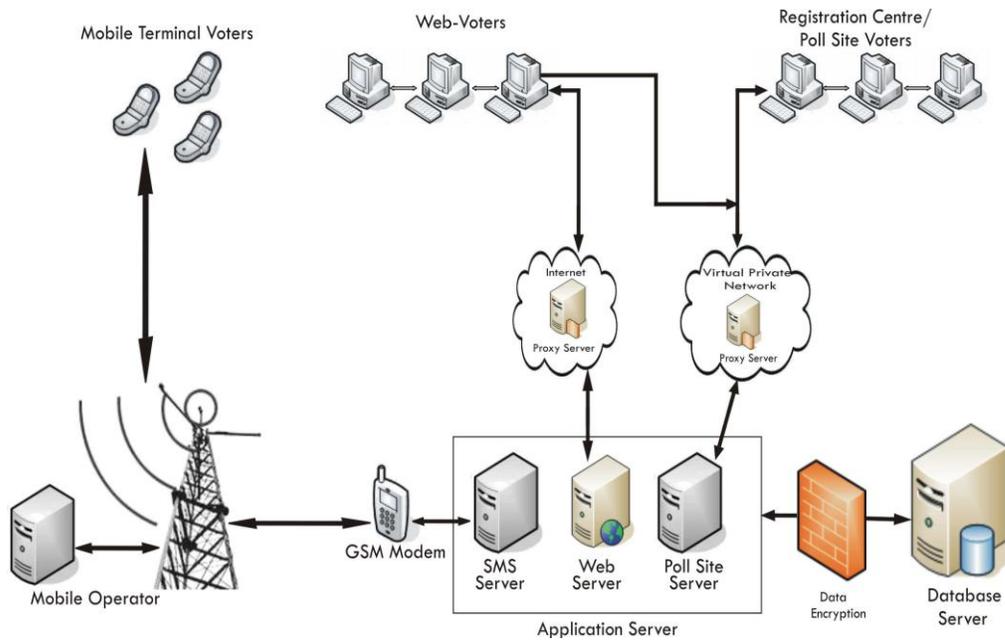


Figure 1: Architecture of the Developed E-voting System

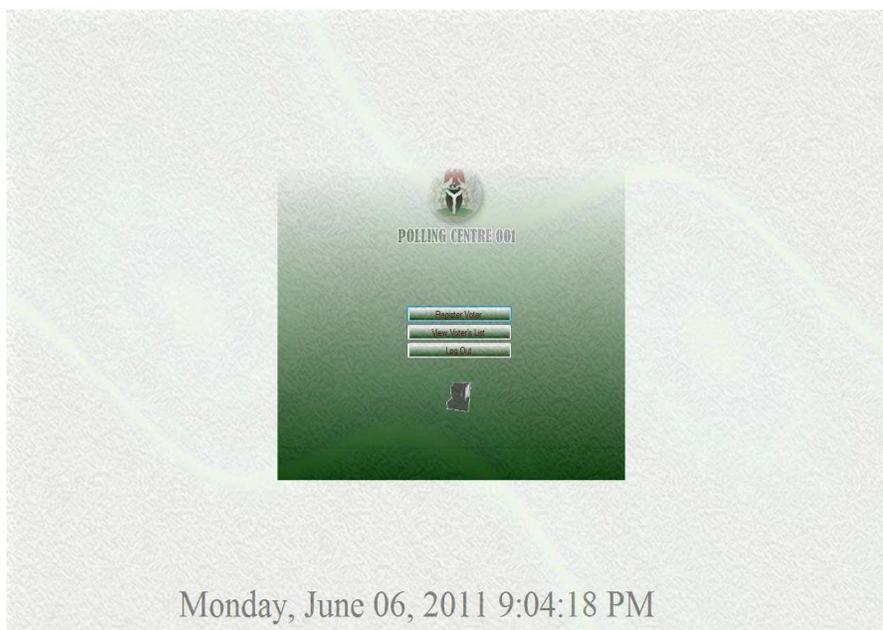


Figure 2: Registration Centre Subsystem of the Developed E-voting System

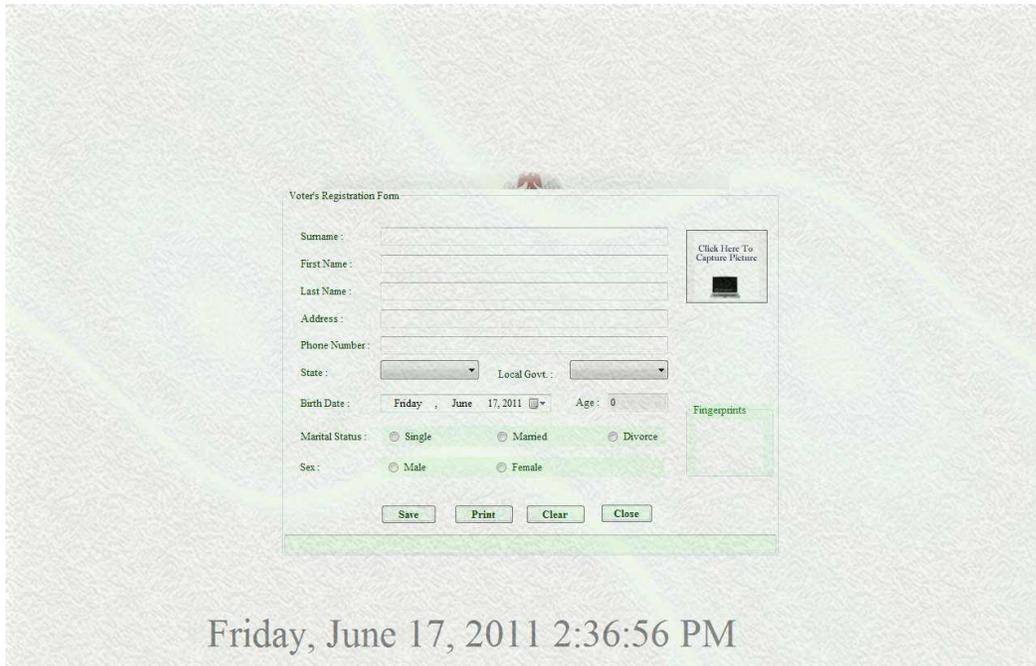


Figure 3: Registration Voter Module of the Registration Centre Subsystem

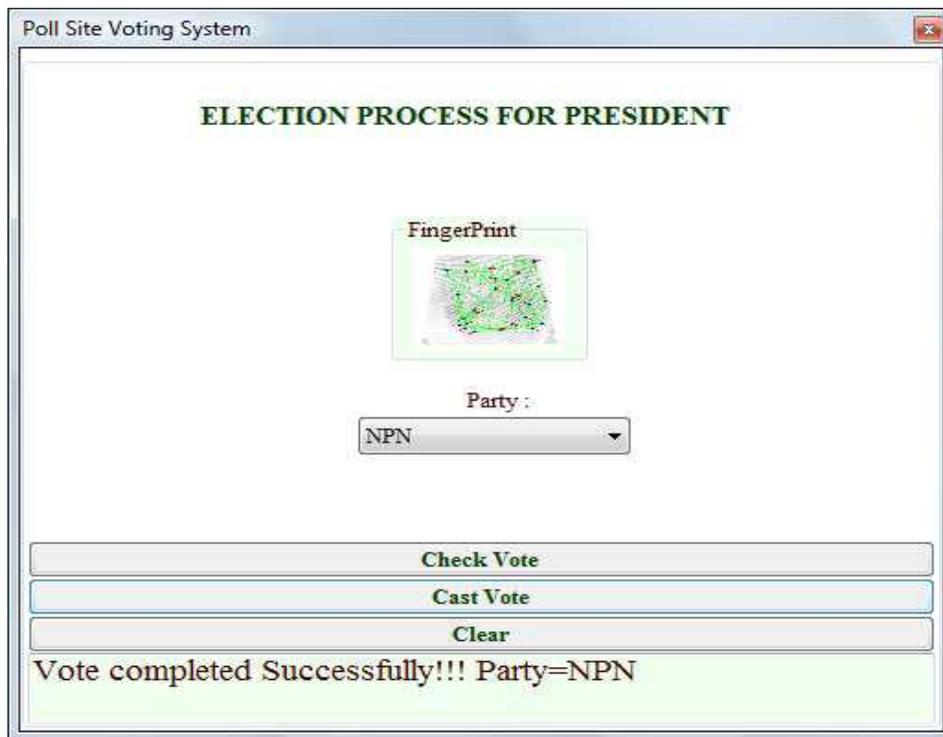


Figure 4: Poll Site Voting Subsystem

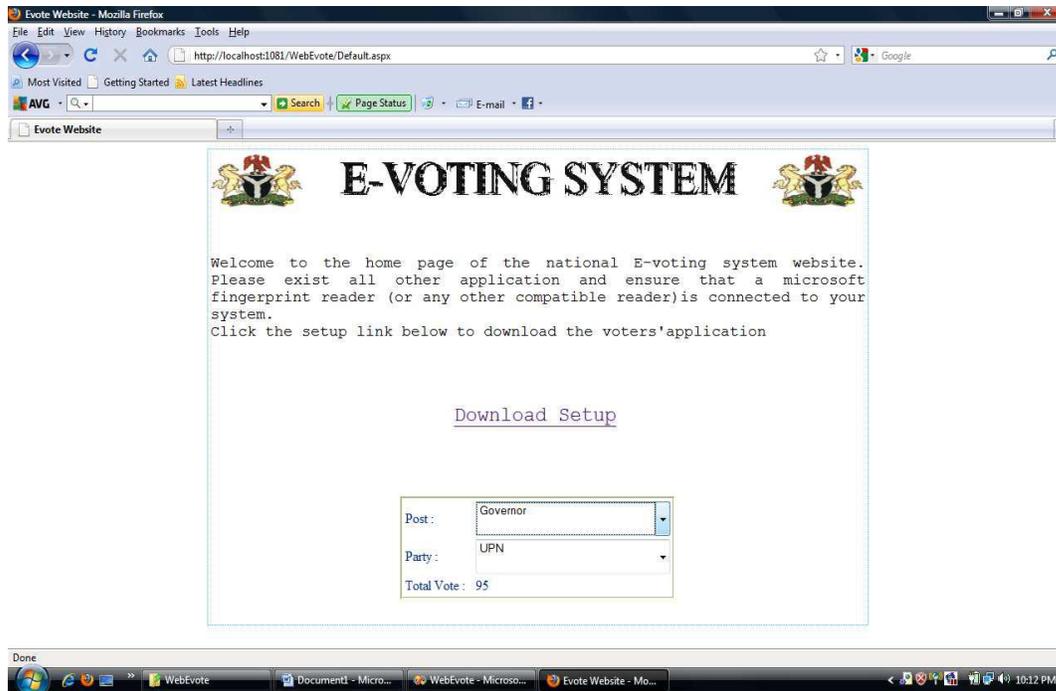


Figure 5: Web Page of the Internet Voting Subsystem

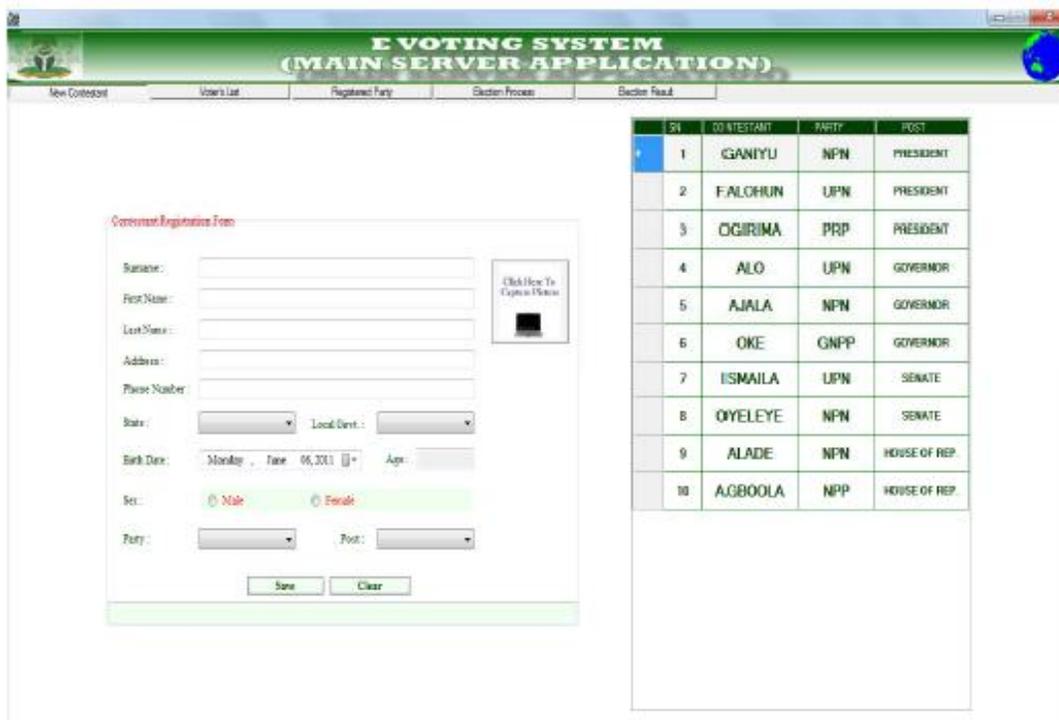


Figure 6: New Contestant Menu of Application Server

**E VOTING SYSTEM
(MAIN SERVER APPLICATION)**

New Contestant Voters List Registered Party Election Process Election Result

SN	ID	SURNAME	FIRST NAME	LAST NAME	ADDRESS	PHONE	LOCAL GOVT.	STATE	BIRTH DATE	AGE	MARITAL STATUS	SEX
1	1084	AKINKUNAN	ADEWOLE	OLAKUNLE	BEHIND OPADAYIMI V.I.	+234803012608	Ogwoho South	Oyo	Tuesday, August 30		MARRIED	MALE
2	1085	AKERELE	DAMOLA	ROSE	ADIBI HOUSE KIBETI...	+234805271648	Ogwoho South	Oyo	Sunday, July 21...	26	MARRIED	FEMALE
3	1087	ONEDIRAN	OLADIPU	OLAREWANJU	OPP BLIND CENTRE	+234809887457	Ogwoho South	Oyo	Wednesday, Aug 19		SINGLE	MALE
4	1088	BAMUS	TAOFEEK	ALABI	Laybiki Villa, Behind...	+234805704151	Ogwoho South	Oyo	Sunday, May 05...	26	SINGLE	MALE
5	1089	OYEKAN	ERUNDAYO	PERU	Oyekar House, Off Oyo...	+234803463772	Ogwoho South	Oyo	Wednesday, Sep 28		SINGLE	MALE
6	1090	ADIGUN	ADESI	ABIMBOLA	Patrol PL, Off Akeria...	+2348030770116	Isedai	Oun	Thursday, Nov...	38	MARRIED	FEMALE
7	1279	ONEDIRAN	OLADOTUN	OLUSOLA	Opp. Blind Centre, Rai...	+234803448236	Ogwoho South	Oyo	Monday, Novem...	33	MARRIED	MALE
8	1092	GANIYU	RIFU	ADESPA	Dept. of Computer Sci...	+234802016330	Ogwoho South	Oyo	Wednesday, Dec 12		MARRIED	MALE
9	1093	ONEDORA	ELIJAH	OLUSOYO	Dept. of computer sci...	+2348030772446	Ife East	Oun	Friday, May 23 1...	42	MARRIED	MALE
10	1095	ONIDYSHO	RUTH	OMOLOLA	Peace and Love Head...	+2348030778878	jejo	Bit	Wednesday, Feb 25		SINGLE	FEMALE
11	1097	ABDULRAHMAN	SHARAFUDEEN	A.	Stadium Area, Ogbooso	+2347033677705	Ede South	Oun	Saturday, Febru...	36	SINGLE	MALE
12	1099	DUD	WALE	DAMURE	AKRAU ADAGG ADISTE...	+234807782408	Ikealan	Oun	Sunday, Octobr...	24	SINGLE	MALE
13	562	GBENKINDSI	GRACE	OLATEMI	Dairi Compound, Pako...	+2348077817668	Hejn	Oyo	Friday, January 2...	32	SINGLE	FEMALE
14	569	ABDUL	TAWAKULT	TOYIN	Id. Igb. area, Iba...	+2348077788292	Ojo-east	Oyo	Friday, November 22		SINGLE	FEMALE
15	578	BRAMON	KAYIBOLA	SAMUEL	Opp. Bgan compound...	+2348094718778	Ife Central	Oun	Friday, August 17...	27	SINGLE	MALE
16	587	AYIBA	JMDA	KAYODE	Behind Club 12, Owo...	+234805020200	Sandee	Oyo	Wednesday, Mar 22		SINGLE	MALE
17	596	OYEWUMI	ABOSEDE	OMOLARA	15, Isokun, Isok Owi...	+234809496754	Idoro	Oyo	Monday, Octobr...	23	SINGLE	FEMALE
18	598	WAHAB	RUNYAT	AJOKI	Agriculture compound, O...	+234809809962	Saki West	Oyo	Friday, July 28 1...	23	SINGLE	FEMALE
19	596	AKERELE	MORFINKELI	OLUSOLA	GHQ Head off Obank...	+234809029449	Saki East	Oyo	Tuesday, Decem...	22	SINGLE	FEMALE
20	597	BELLO	KAFAYAT	ABIDUN	Opp. Obabi House, Isok...	+234807389808	Ojo East	Oyo	Monday, March 2...	22	SINGLE	FEMALE
21	598	IDRIS	LUKMAN	OLADIPU	Opp. Heaven of Peace...	+234809877333	Ojo	Oyo	Sunday, Octobr...	21	SINGLE	MALE
22	599	SHAFI	MORISAT	OLABI	Behind BACOTHU, Isok...	+234809808618	Off Ife	Oyo	Friday, January 2...	21	SINGLE	FEMALE
23	610	ADIGUN	EDWARD	ADEKUNO	Off Olanika Road, Isok...	+234809829903	Orebae	Oyo	Thursday, Januar...	20	SINGLE	MALE
24	611	AMBAU	SENU	OLUPEMI	Behind Wogbesin Road...	+234807367693	Ojo Are	Oyo	Saturday, Decem...	21	SINGLE	MALE
25	612	ADEKIRE	GABRIEL	SUNDAY	Behind Alka Univ. Off S...	+234809462612	Oloko	Oyo	Sunday, Decem...	22	SINGLE	MALE
26	613	ADEKUNYA	OLUFUMILAYO	ELIZABETH	Behind Sabon Gps. Saki...	+2348072938196	Oluwasejo	Oyo	Tuesday, Januar...	21	SINGLE	FEMALE
27	621	ONISLE	ADEBAYO	PATRICK	Behind Lakun Pst. I...	+2348089496714	Off Ife	Oyo	Saturday, Septe...	21	SINGLE	MALE
28	632	DARAMOLA	JOSEPHINE	KOEDLA	Behind Dicoa house, Isok...	+234809803038	Orebae	Oyo	Sunday, June 24...	21	SINGLE	FEMALE

Figure7: Voter’s List Menu of the Application Server

**E VOTING SYSTEM
(MAIN SERVER APPLICATION)**

New Contestant Voters List Registered Party Election Process Election Result

Post : PRESIDENT

CONTESTANT	PARTY	NOTE
GANIYU	NPN	155
FALCHUN	UPN	193
OGIRIMA	PPP	117

Figure 8: Election Result Menu of the Application Server