Design Imperatives for E-voting as a Sociotechnical System

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Abstract— ***There are a number of past and ongoing research efforts on the development of e-voting systems. These works largely focus on requirements, technical specification and implementation technologies to support different aspects of the elections from registration and verification through balloting to counting and result. A major shortcoming of these studies is their sole focus on technical aspect of e-voting solution without significant attention paid to human and environment factors that arguably determine the successful adoption of such e-voting solutions. This paper addresses this design gap in three steps. First, it provides a conceptualization of e-voting system as a socio-technical system. Second, it elaborates a set of principles to guide a sociotechnical design for e-voting. Third, it provides concrete implications of these principles. The paper concludes on the pragmatics of this approach to e-voting adoption particularly in environment such as Nigeria.***

Keywords*— e-voting, sociotechnical System, human and environmental factors,** ***2011 Nigerian General Elections, Electronic Voting Machines.

I. INTRODUCTION

E-voting constitutes a very important aspect of ICT-enabled democratic governance [1]. E-Voting solutions generally aim at increasing participation, improving the outcomes elections by addressing challenges associated with traditional voting practices. The notion of e-voting in this paper refers to the use of technology to support one or more of the major phases of the electoral process – from registration stage in the pre-voting phase to voting/balloting and verification to counting or tallying after voting [2], [3]. Although, the term is often associated with the use of electronic channels like the Electronic Voting machines or the internet for casting votes, its use for ICT-enabled voter enrollment or registration is gaining popularity particularly in the developing world.

Generally, there are mixed sentiments regarding e-voting adoption, particularly in the aspects of vote casting. For example a number of countries like Netherlands, Germany and Ireland moved away from the use of e-voting for balloting after initial adoption [1]. E-Voting using Electronic Voting Machines (EVM) have also remained controversial in the United States. While e-voting is generally perceived as generally risky [4], there is some consensus that the benefits of e-voting outweigh the actual risks.

In this light, developing countries have shown significant interest towards the adoption of e-voting. Given that elections in developing countries attract significant controversies and are fraught with several challenges, the idea of trying any credible alternative is a plausible strategy.

While not completely oblivious of the risks involved in e-voting, research contributions on e-voting in Africa such as [5] and [6] have largely focused on technological design of e-voting systems. However, designs espoused in these works largely ignore: the social context in which the e-voting systems will enacted, peculiar needs of different users (e.g. voters) and the organizational context of the Electoral Authority. Direct experiences of the authors based on adoption and implementation of e-voting solution in Nigeria show that these shortcomings significantly impact the effectiveness of the solution and could potentially compromise the outcome of the elections.

A way to address this problem is to adopt a Socio-technical System (STS) design framework for e-Voting systems. Socio-technical systems approaches advocates a human-centric analysis which considers the impact of the technical or computing sub-system on people and how technology can be designed more effectively for people [7]. The goal of an STS system is to collectively optimize the technical, social and environment subsystems [8].

We consider in this paper the design of e-Voting systems as a socio-technical system. Our goal is to augment existing knowledge about requirements and design of e-Voting systems by the specific design principles that must underpin any e-voting solution when considered more holistically as a socio-technical system. For illustration, we highlight implications of these principles for e-Voting solution in the Nigerian context.

II. E-VOTING AS A SOCIO-TECHNICAL SYSTEM

A. Core Concepts

E-voting is usually associated with the use of electronic devices such as Electronic Voting Machine (EVM) and channels (like the Internet) for casting votes or balloting [9], [3]. E-voting is considered in [10] as digitization efforts related to e-government and e-democracy. In this line of thinking, e-voting will aim at digitizing the different stages of

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the electoral process including registration, balloting, verification and counting.

According to Chung et al. [10], the possibility to vote remotely is one of the greatest benefits from e-voting since it potentially raises participation in the voting exercise. Qadah et al. [11] supports this assertion claiming that e-voting permits voters to cast their votes at any time from any location and using a variety of electronic devices. In addition, they believe that e-voting generally automates and simplifies the election process, increases participation rates, reduces counting mistakes and minimizes the time it takes to announce voting results.

Different e-voting systems have been proposed and adopted to support voting process. This includes Computer counting, Direct Recording Electronic voting machine (DRE), Online Voting, Poll-site e-voting, Kiosk e-voting and remote e-voting [11], [2].

There are a number of key entities involved in any form of voting including e-voting. These entities include: Voter, Authority, Candidate and Adversary [3]. These entities could be very useful in developing voting model that may underpin an e-voting system. Voters are those eligible to vote by choosing among the Candidates. Candidates are usually pre-specified and often chosen by Voters in a private manner. In addition, final count has to be reliable and verifiable. Authorities are government agencies and offices responsible for conducting the election. An adversary is any malicious entity that attempts to manipulate the voting and tally. Sampigethaya et al. [3] further explains that External Adversary may coerce a voter or buy votes or passively breach privacy of voters. Internal Adversary on the other may try to breach privacy, modify or reveal the partial tally or corrupt the Authority. Designs of e-voting system must preserve important rights of voters and concomitantly prevent malicious activities.

There are strict requirements for any e-voting system [10], [11][3], including: (1) *Eligibility*: ensure that only valid voters meeting pre-determined criteria are eligible to vote or take part in the election; (ii) *Privacy and Anonymity*: Ensure that no one can connect a ballot to its voter; (iii) Fa*irness*: Ensure that votes obtained by each candidate cannot be known before the announcement of the election result, (iv) Verifiability: A voter should be able to verify if its vote was correctly recorded and accounted for in the final vote tally; (v) *Uniqueness*: must ensure that eligible voter can cast a vote only once in each election; (vi) *Dispute-freeness*: must provide a mechanism to resolve all disputes in any stage.

B. Socio-technical System Perspective

Socio-technical systems focus on the impact of computer systems (technical system) on people and considers ways in which technology can be designed more effectively for people [7] in an organization. While there are many models describing the elements of a Socio-technical system, for instance see [8], three core elements socio-technical systems standout. These core elements include: Technical, Social and the Environmental subsystems. The technical subsystem comprises the devices, tools, and techniques needed to transform inputs into outputs towards the main objective of the system. The social element comprises the employees, knowledge, skills, attitudes, values and needs they bring to work environment as well as the reward system and authority structures of the organization. The Environment subsystem includes external entities, rules and regulations, which governs the relationship between the organization and the society at large[1].

Carayon[8] identified three critical phases for sociotechnical systems – design, implementation and operation of STS. However, the design of STS extends over time, continuing beyond implementation and throughout use. In addition, Clegg [12] prescribes a detailed set of 19 principles to underpin design of any STS.

In the considering e-Voting as an STS, *the goal is thus to explicitly address human, organizational and environmental factors that are rarely considered in designing e-voting system, particularly in conditions where e-voting solutions are acquired and deployed without any form pilot or experimental activities*. Our goal in this paper is to offer a set design principles based on Clegg's STS Design principles to guide the design, implementation and operationalization of e-voting solutions.

III. STS DESIGN PARADIGM FOR E-VOTING

Clegg[12] identified three categories of principles for grounding STS design and related them to original work of Cherns in [13]. The category of principles include: Meta-principles, Content principles and process principles. These principles are listed in Table 1 and explained in the context of e-voting, where possible concrete examples from the case of the Nigeria e-voting environment based on the information contained in the electoral act document [14]and cognate

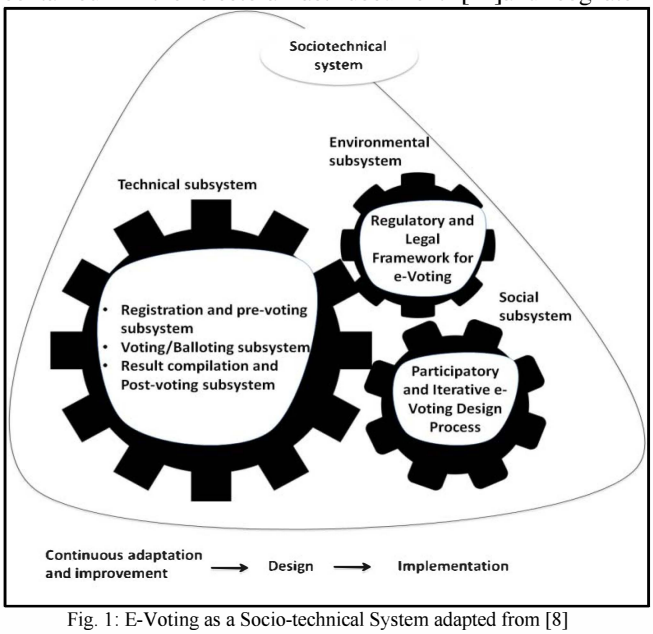

Fig. 1: E-Voting as a Socio-technical System adapted from [8]

[1]http://istheory.byu.edu/wiki/Socio-technical_theory

TABLE I
ELABORATION OF RELEVANT CLEGG'S STS DESIGN PRINCIPLES FOR E-VOTING SYSTEMS

No	Socio-technical System Principles	Principles for E-Voting Design	Exemplar implications
Meta Principles			
1	Design is Systemic	The design of e-voting system must be holistic in perspective even when only one element of the technical subsystem is being considered	Consideration of an e-registration or e-balloting system must still consider all attendants the social and environmental issues.
2	Values and mindsets are central design	The values and mindsets of voters, politicians, officials of the electoral authority must be considered when designing e-voting system	E-Voting will be implemented in an environment where most politicians perceive rigging as the only way to win elections.
3	Design involves making choices	Design options must be provided to participants of the participatory design process for e-voting	The goal of voters and other stakeholders participating in the design process is not to validate the design but to offer possible suggestions for improvement.
4	Design should reflect the needs of the business, its users and their managers	An "inclusive" user-centered approach should be adopted in designing e-Voting system	Blind and incapacitated voters should be accommodated as provided in the act, e.g. through the use of Braille, large embossed prints etc.
5	Design is an extended social process	The activity for designing e-voting system should be given sufficient time to enable different user categories understand and gain confidence in the emerging design.	This process will involve various stakeholders including representatives of: State Constituency; Federal Constituency Collation Centre; Senatorial District Collation Centre, etc.
6	Design is socially shaped	The resulting e-voting system must be a product of the inputs from all major actors over a period of time	The resulting e-voting system if not owned by voters, politicians etc., must be accepted by all major stakeholders
7	Design is contingent	E-Voting design is contingent on local realities	The prevalent social and environmental factors must shape the implementation of any e-voting solution
Content Principles			
8	Core processes should be integrated	All core voting processes across pre, voting and post-voting activities must be integrated	Registration, Authenticating, Balloting and Result processing solutions must be integrated
9	Design entails multiple task allocations between and among humans and machines	Detailed job design and work organization must be provided for the e-voting system	There should be clear criteria and principles for work to be done by human agents and teams in the e-voting system
10	Systems should be simple in design and make problem visible	E-Voting design should be simple to promote ease of use by different user categories	For voters and other categories of stakeholders to participate in E-Voting design, it must be simple
11	The means of undertaking tasks should be flexibly specified	E-Voting System design should not be overs-specified	Too detailed specification of e-Voting system design reduces the options available to participants of the design process
Process Principles			
12	Systems and their designs should be owned by their managers and users	E-Voting design should be owned by users and stakeholders	Voters and other categories of stakeholders should own e-voting design
13	Design involves multidisciplinary education	e-Voting Design requires more than technical knowledge	There is a need to engage a multi-disciplinary team in addition to ICT experts in the design of e-voting system
14	System design involves political process	The design of e-voting system happens is embedded within a political space and thus shaped indirectly by it	Political considerations and factors will play a role in the resulting e-voting system design and implementation, thus the need to understand and leverage these factors for success

experience of one of the authors as lead ICT officer in charge of implementing e-voting solution in Nigeria in the 2011 General Elections

The e-Voting STS depicted in Figure 1 is comprises three core subsystems that must be aligned for effective functioning of the whole e-voting system. The technical subsystem is modelled to include three major elements associated with the pre-voting, voting and post-voting phases of any election. The social subsystem aims at providing a participatory and iterative design activity involving potential voters and representatives of all major stakeholders. The aim of this is subsystem is to ensure that peculiar needs and concerns of the various user groups are considered in features of the respective elements of the technical subsystems. The environment subsystem stipulates rules and regulations (such as those specified in the Electoral Act) to ensure that the implementation of the technical subsystem is legally valid. It also ensures that the operation of the technical subsystem does not conflict with the values of the electorates, which varies with geographical locations in the case of Nigeria.
Table I shows how these Clegg's 19 principles elaborated in [12] affect the major e-Voting STS subsystems. Given the space limitation, more relevant principles were considered.

IV. CONCLUSION

The notion of e-Voting as an STS makes its inherent complexity more apparent. For instance, the need to operate e-voting system across different boundaries such as geographical, cultural and temporal boundaries, characteristic of complex systems [8] are not discussed in technical designs of e-voting. These principles make them explicit, for instance see principle #2 in Table 1 above. Omission in this respect creates potential source of failure for e-voting system. Congruent with the principles elaborated here, Chevallier et al [15] identified three core success factors for the Geneva's e-voting project – the role of politics, organization of trials involving voters and other stakeholders and having an interdisciplinary team comprising Legal experts, security CERN, sociologist and political scientists.

However, along the clear benefits for the adoption of a STS approach to e-voting design, we must point out some inherent challenges in operationalizing such approach, particularly in the developing country context. For instance, the classical STS approach requires iteration between design implementation and operation to enable continuous improvement and shaping of solution. The practicality of this in terms of participation of stakeholders and resource implication may be limited. Thus, there will be the need to carefully identify principles that could be supported in different context and under the prevailing temporal constraints for the overall election process.

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