

Blockchain Based Voting Systems

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Abstract: Voting is an essential tool for any democratic government. It is the most important factor that makes the government for the people, by the people. It is surprising that many countries in the world haven't moved on from traditional paper ballot system of voting. There are some countries that have taken a forward step by using Electronic voting machines. As simple as it may sound, there are a lot of issues with these systems. Between having to physically go to the venues and standing in long queue at the polling station to counting the vote by hand the entire process is time consuming at the same time expensive. Malicious actors have many avenues to influence paper ballot based elections using intimidation at the polling booth by capturing the ballot box or stuffing the box by fake votes. Similarly, in Electronic voting machines, a highly motivated group can get hold of the machine and change the chip so whichever button is pressed, all the votes go to one political party. Another issue is it whether it is impossible to keep track of the votes. How can we be sure that our vote was counted or perhaps in case of ballot paper, not thrown away? The present article discusses ways of bringing voting systems into the 21st century by using the Blockchain Technology.

Keywords: Cyber Security; System on Chip; Microcontroller Security; Hardware Security.

1. Introduction

Today the world around us is rapidly changing. Artificial Intelligence have been making huge waves in today's industries. It has forced people to realign their priority. At the core of all of this buzz, there is data on which all the sophisticated algorithms train on. Since the advancement in AI, Data has become the new oil. Companies that consume public data like Facebook, Instagram, Twitter, Snapchat or e-commerce sites like Amazon, Flipkart and Alibaba control enough of market capital to influence the outcome of any event or perhaps shape people's opinion. There are several cases where the data centers of these social media giants were breached and profile details of the millions of users were leaked Maglaras et al. (2018). Voting systems around the world have come under scrutiny where there are several cases of fraud reported. Because of this people tend to lose faith in Electoral Process. Violence, corruption, riots are often things that go hand in hand during Election process. Due to this, there is a social imbalance amongst society.

For decades we have been elected our leader by participating in the democratic festival of voting. Each country has their own way of electing member of their parliament. Elections are held after gap of every 4 or 5 years. In countries like United States, Germany, Spain, Japan and Israel elections are held every four years while in some democracies like United Kingdom, India, South Korea, Canada and Ireland there is a five-year term for the elected leaders. Various voting methods are deployed around the world. Some of the most common systems are,

- First Past the Post System
- Instant Run-off Method
- Two Round Run-off
- Proportional Representation

Every system has certain advantages and disadvantages attached to it. We will discuss all the systems in depth and try to figure out which system should be preferred for a blockchain based Voting system Hj'almarrsson et al. (2018). We will discuss all the systems in depth and try to figure out which system should be preferred for our blockchain based Voting system. Before we dwell into these systems let's assume that there was an election in our local constituency and after counting the votes, our four candidates,

- Mary got 35
- Bob got 16
- Jane got 15
- Danny got 34

We will discuss each system and see how the elected candidates vary as we change the way leaders are elected.

1.1. First Past the Post System

In this system, the candidate that has received the most votes amongst all the candidates is declared winner. There is no minimum cut-off that needs to be breached in order to be declared the winner. So, as per our example, Mary will be elected the leader of our constituency. However, this system is at times not fair to the people who voted in the process. In 2015 Indian General Elections, the winning party got 31% percent votes. Similarly, in 2016 United States Presidential Election, Donald Trump received 3 million less votes than his opponent Hillary Clinton. One can wonder how this system is fair if majority of the people did not vote for the elected person. In our example, 65% people did not have Mary as their first choice but now she is going to be their leader.

Another disadvantage of this system is that people would generally vote for the candidate that seems to be winning and not the candidate who they think deserve to win. The reason behind this is extensive media coverage, print interviews that everyone thinks that apart from top two or three candidates, voting for any other would not make a difference and thus, be a waste of a vote. This discourages independent voters, democratic voice within the societies to gain strength. There are people who want to improve the condition around them, but as they are not affiliated with the major parties, they get crushed due to the popularity of their rival. Moreover, voter's also vote not thinking at a candidate should win rather a candidate should not win. This can also be termed as negative voting. In our example, let's assume that supporters of Jane dislike Danny. So, to stop Danny from winning, seeing that Jane does not have clear chance of winning, they might instead vote for Mary cause her chances of winning are more and thus forsake their choice. This can be termed as voting of lesser of the two evil. Apart from the winning candidate, there are other candidates who came at third or later position whose votes didn't make a major difference. All those votes casted were in a way wasted.

However, as we only must count the votes one and get with them, often it is seemed that the results are declared quickly in this process. There are more chances of a single party forming a government rather multiple parties forming coalition government. In terms of Economic strength, a government with full majority is considered much more stable rather than a coalition government. This method is used in major Democracies like United States, United Kingdom, India, etc.

1.2. Instant Run-off Method

In this method, instead of voting for their favorite candidate, the voters rank their candidates in terms of preference. This way the candidates the voters instead of popularity voting, can vote for the leader they believe in. After counting, if no candidate gets more than 50 % voting, then the candidate who got least number of votes, all the voters whose first choice was that candidate, now their votes are redistributed keeping their second preference in mind. In our example, we can see nobody got more than half of the votes. So, in this scenario, Jane's votes will be redistributed in amongst the rest of the candidates based on voters second preference and see if anyone has breached the half mark. If not, we repeated the process until someone does. This method has higher correlation with the sentiment of people and outcome of the Electoral process. The minimum barrier for a candidate to cross in order to be declared as a winner is decided depending on the size of constituency and eligible voters. From the countries perspective, the benefits of this system are that there will be less chances of negative voting. If we see from voter's perspective, then they don't have to vote in desperation rather vote the candidate whose ideology you believe in. In a scenario where you want a third candidate to lose, you can just put him down your ranking order. So, this way the disadvantages of First-Past-The-Post system are eliminated. This type of voting system is used in many countries for electing leader of their country like Australia, Sri Lanka, India (Election of President, where only the members of parliament vote), etc.

Many countries have modified this method to suite their system. In Sri Lanka, The President is elected through a variation of Instant Run-Off Method called Contingent Voting. The voters only select their top three or top four candidates from the list. The winner is decided amongst those three or four candidates. Interesting even in the most popular Hollywood Awards, The Academy Awards, the winner is decided through the Instant Run-Off Voting method.

1.3. Two Round Voting System

In most of the Presidential Countries like Russia, France and South American Countries they employ a system called Two Round Voting System. As the name suggest, the Electoral voting process is divided into two rounds, if in the first round the candidate with majority vote has not crossed halfway mark. Then, upon completion of first round of voting, the top two candidates are pitched against each other in the next round, which decides the eventual winner. This system often shares all the disadvantages of the First-Past-The-Post system. In fact, in some countries, only two candidates are selected from a constituency so to avoid going to the next round of voting. So, the regional parties, or new parties are often crushed by the heavyweight National Parties. They never get to reach the top or provide a different, fresh narrative to the Nation. In the end the voters find themselves voting for the candidate whose chances of winning are more. This way it encourages use Parties to spend a lot of money marketing, advertising their candidate to popularize their candidate. This is often linked to parties receiving money from illicit sources and encourage corrupting in the process.

So, in our example, After the first round of voting, no candidate has received more than 50 percent of votes. The election goes to second round for that constituency where people now only have two candidates to choose from, Mary and Danny. This way the Electoral process can go over several weeks.

1.4. Proportional Representation

In an ideal democracy, the percentage of votes a party gets should equate to the number of seats it wins in the parliament. This method is called Proportional Representation System. It is a common system in National Legislation of around 80 countries. Belgium was the first country where this system was first implemented in 1900 General Elections. There are multiple ways of implementing this system. The most common two are,

- Pure Proportional Representation.
- Open and Closed List System

In countries like Israel and Netherlands, the entire country is one constituency and not split into different constituencies. People cast votes keeping Political parties in mind and the vote percentage it receive, gets proportionally converted to the number of seats in the Parliament. This called Pure Proportional Representation. In some countries, the parties publish list of candidates and people cast their vote based on this candidate. This is closed list system. Contrary to this, in some countries when the parties publish the list, people also rank these candidates and which type of list is published and what percentage of votes should be given to what candidate on the list. This is called open list system. So, in earlier example where in 2015 Indian General Election, The Bharatiya Janta Party won 31% votes and formed the government by winning 336 seats out of 545 seats in parliament, by using First-Past-The-Post system, they would have only won 169 seats if Proportional Representation system was considered instead.

It's not like there are no disadvantages of this system. The critiques of this system say that the people lost connection from their leaders on the local level. When having a broader view from National Perspective, it looks good, but from the ground level, people fail to associate with their local representatives. Further, as the seats are distributed as per vote percentage, there are very high chances of Coalition Government formation. This is not encouraged and often leads to ending the term of the government before it should have. Keeping all this in mind, in country like Germany, instead of using any one system, they have implemented a mixture of the above methods. They use a combination of First-Past-The-Post system and Proportional Representation. In their National Legislation, 50 percent seats have Proportional Representational and rest have First-Past-The-Post system. This way the advantages of both the side is balanced perfectly. Any country is free to adjust the system as per their needs. For example, In Greece, the party that wins majority, is awarded 50 additional seats just because they won the majority.

So, in conclusion, we can see that for different systems, the elected leader varies. Some systems have their advantages while they have little correlation to people's sentiment on ground, while other have better

connection to Electorate but the process could be really long. However, with Blockchain voting, we can digitalize the entire Electoral Process and thus can opt for longer election process as less effort will go for voters to cast their vote again and at the same time we can have a mandate the maximum people agree with cause in the end, Democracy is of the people, by the people!

2. Voting Methods

There are numerous ways in which a person can vote in a democracy. Over the years, many countries have upgraded from simple ballot paper-based elections to electronic machines to elect their representatives. The most common used methods are as follows,

- Ballot Paper
- Electronic voting Machine
- Vote over Internet
- Biometric voting Machine

2.1. Ballot Paper

One of the simplest forms of election mechanism is writing your preference on a piece of paper and submitting. This is called voting by Ballot Paper. It has a table to first column containing the name of the Party contesting the election and name of the candidate and another column which is kept blank for voter to mark their choices. The rules are pretty simple. You can put a cross in front of any candidate of your choice and fold your paper and submit it into Ballot Box. The Election Authority in charge of the overseeing the election must take care of the Ballot Box and see that it isn't tampered with. The Advantages of using a Ballot are as follows.

- It is one of the oldest forms of voting. Takes very little effort to explain to people how to cast their vote and easy to understand. There are many people in rural areas who are not connected with technology advancement in the world. For them even understanding basic electronic device might be difficult and thus, prone to mistakes. Thus, keeping it simple pen and paper-based voting will be easy to explain and at the same time the entire process is quick.
- The voter can have full faith that his vote is listed correctly as there is no scope to correct the vote once crossed.
- Once the vote is casted, it stays in the ballot box for as long as kept safe. Unlike software-based voting where it might lose data if there is a power loss. In many countries Electoral processes are held in summer period. Electronic machines can lose more power as they heat up fast and might malfunction at times. So the risk of data is high.
- There is little to no automation while counting the ballot paper votes, thus it can create employment opportunity for short term for many people in the voting constituency.

As much as the Ballot Paper are praised for its merits, there are certain limitations to this system as well. Few of the most common ones are,

- As there is little to no scope of automation, it might take hours to get a result out. There has to be a human to verify the votes at the end.
- In a country where the Electoral Authority is not independent and Strong, there are chances that someone can tamper with the ballot box by inserting bogus votes in the box. No way of knowing whether the votes were casted by a real person or not.
- As they are piece of paper, it is not environment friendly to have so many papers with little use to be implemented.
- Paper is at the end of the day, flammable and thus can be subject to fire which might risk losing entire votes in the box. Moreover, guarding paper ballots is cumbersome as they can be easily stolen away.

2.2. Electronic Voting Machines

Citing all the negative reviews from ballot paper, many countries upgraded their voting mechanism with advancement in embedded technology with machines

called Electronics Voting Machines.

Structure

EVMs are electronics device which are programmed only once when it is manufactured. The chip is loaded with the software and then it can't be reprogrammed. EVMs consist of two units. There is a control unit where the voter is presented with options of all the candidates to for. There is a button corresponding to the name of the candidate. Connected to this device, by a 5-meter cable, is another embedded device that collects all the electronic votes is Electronic Balloting Unit. EVMs don't require external power supply as it run on a standalone battery. They are light in weight, potable and easy to setup in any condition.

Working

The Electoral Authority in charge of the overseeing the election, presses the Ballot button on the control unit which initialize the EVMs. Then, voter pressing any button corresponding to the candidate he wants to vote for, the machine will light a LED light corresponding choice for voter to be assured that the machine has recorded the vote correctly. Subsequently, the machine locks itself. Now it can only be unlocked by a new ballot number which the person in charge will press again when new person goes to vote. This will ensure that there are not multiple votes from one person.

Advantages

- Lightweight, portable and runs on 6 volt alkaline battery. So it can be taken to place where there is no electricity supplies.
- The votes are stored electronically, so no wastage of paper which eventually becomes waste after the elections.
- Votes are stored in the Electronic Balloting unit, which means it will help speed up the counting process.
- Illiterate people find easy to press a button corresponding their choice rather than using pen and paper.

Disadvantages

- In ballot paper, the most criminal thing that can happen is that entire ballot box is captured. Those votes are anyway wasted. This can be easily be tackled with. However in case of EVMs, if anyone can get his hand on the device, he can manipulate with the machine by replacing the chip and commit a higher degree of sophisticated crime which might not even be detected.
- As the votes are electronically stored, if anything is to happen to the balloting unit then all those votes could be in danger. There are many ways where the embedded device memory can be corrupted with.

2.3. Vote over Internet

In 2005, Estonia pilot voting via internet in local elections. During those days, the citizen had a national ID card with was embedded with a special chip and pin which concealed the details of the voters. The voters login to the website using National ID and cast his votes from anywhere in the world. To keep government from knowing who voted for which candidate, when the voting data is stored in database, the identity of the voter is sealed and thus anonymity of the voter is fully taken care of.

Such a system provides voting hassle free and in the comfort of our house. However, unlike any internet based service, even this platform has severe critique to point our discrepancy in its working. The government has called team of cybersecurity experts from all over the world to test its voting platform time and time again. Often the team conducting tests have come to the conclusion that not only they can change the vote tally but also remove any trace of them being there. No digital fingerprint will be left in the system that can be traced back to them. This is caused a lot of rift within the people. The founding idea of democracy was justice for all and Voting is one of the key festivals of the democracy. So, it is governments job to ensure that the citizen have full trust in the system and if any issue arise, they are taken care of.

2.4. BiometricVoting

There are often cases where a lot of bogus votes have been cast. This is because once the votes got through, to keep the identity of voters private, data of voter is removed. Instead, some African Countries tried a different way of tackling this problem of bogus voting Yinyeh&Gbolagade (2013). They introduced finger- print based voting system where there is biometric machine which helps identify the person. In many studies it is proved that a person's fingerprint is unique. This can be used to identify the person at the time of voting. The whole process gets over quickly with less hassle. The government has to set up a national voting registration program where they register everyone with their fingerprints and make a final list of all the legible voters.

The advantages of such systems are:

- Quick and hassle-free voting
- Can help reduce illicit voting Disadvantages
- As all of this machines will use enormous electricity to run continuous, it will be difficult to use in rural areas.

In Conclusion, while developing an Blockchain based system, we might come across similar problem of authentication as the voters can vote from anywhere in the world. Thus, we may use of Biometric sensors or even Face Recognition software to ensure the voters that cast their votes are genuine. Moreover, In online based system there are often chances that the hacker might perform the cult so professionally that it won't be easy to easily trace it back to the original culprit. Thus, all of these things need to be kept in mind while developing a blockchain voting system. Even though blockchain is a distributed system, we can't let even one of our nodes be under attack as it might let people question the entire process and in democracy such speculation shouldn't be there.

3 Blockchain Voting System

To have a voting system based on blockchain, there needs to be certain do's and don'ts that needs to be considered Kshetri&Voas (2018). After evaluating the online voting system in general, following consideration needs to be considered.

- Voter's identity, in any circumstances, should not be traced back from the votes. The system should provide a robust and secure way of only voters to check whether their correct votes have been registered or not.
- There should be complete transparency in the voting process. Any voter should be able to check for authenticity of the entire process without risking everyone's privacy.
- Stakeholder's who will form the nodes in the system, their sizes in terms of capital, needs to be restricted so vote tampering is avoided. This way, big conglomerates, corporations, business are not able to influence the results.
- System should make sure only eligible voters vote in the electoral process. System should consider that a voter registered in one constituency is not able to vote in multiple constituency. Otherwise, duplication of votes will result in inaccurate results.
- There needs to be an Authority formed within the stakeholders that oversees any disputes that might result during the Electoral process. The final decision of the authority should be taken as ultimate verdict and should be respected by all.

3.1 Voting System Flow and Voting Machinery

The voter's, on successful registration, will login to the system to cast their votes. They will use the vote token generated at the time of registration for verification at the time of voting. As they have enough network currency to vote only once, they will go to their respective constituency and cast their vote. To do so, they can use Computers, Mobile Phones, or Government approved devices. Once their votes are validated, their votes are added to the blockchain in form a new block. Upon successful casting the vote, the system generates a transaction ID to the voter which can be used to tally his vote anytime as long as the network is active.

One of the key points of Blockchain based voting is that the tallying of votes is done at the time when the votes are cast Shahzad & Crowcroft (2019). As the entire process is digital, the votes are added to the respective candidates tally as they are casted, Unlike in the conventional voting system where the counting of votes take several days. On the other hand, when having to count the votes physically, the Election

Commission need to setup a team, provide security to the ballots and to establish dedicated personnel at the counting of votes Ferrag et al. (2018). All of this can be avoided and the capital can be invested in developing the network and protocols Kumar (2018).

3.2 Security concerns

Any human made system is prone to errors and in a situation where thousands of people are coming out to vote, some issues are bound to arise. In such a scenario, all the stakeholders in the system form a committee amongst themselves to address such concerns. The Election Commission can introduce few nodes in the network whose sole purpose is to oversee the whole transaction validating process. They have the right to read the ledger but not write to it. This team can be formed from within the stakeholders or it can be a set of individuals who have no connection from the stakeholders. This way they will not be influenced to overlook any error. In spite of being a robust system, there are other several problems that might arise during voting.

Double Spending

In digital world, it is easy to duplicate anything. It's as easy as pressing two buttons at a time. So when it comes to currency, one of the concerns were what if the same thing happens. In real world, we have physical cash, so when we hand it to the vendor, it is physically transferred. In digital world, it is just bits that are being transferred. So, it can be copied and rebroadcasted. This can be avoided by a procedure where we wait for a certain time before adding a block to the blockchain. In such a case when a sender tries to send the same coin to two different addresses, both transactions will be sent for verification, the one where the nodes verify the transaction first will go through and the other transaction will be termed invalid. Same things can be used in a system where before adding a block to the final chain we wait around 10 mins.

51 % Attack

One of the main reasons why blockchain is trending recently is due to its nature. It is distributed and decentralized. So, every node in the network is independent from each other. If one of the nodes goes down, it will still perform. All the records in the blockchain are immutable as to add an incorrect record to the blockchain the hacker would need control over half the nodes in the network to have consensus over the phony transaction. This in the practical world is nearly impossible. No single entity has enough computational power to pull this off. So, keeping this in mind, it is in our benefit to have as many stakeholders in our system as possible so to keep the network from coming under attack.

Authentication Flaw

As the elections are happening digitally, the voters can vote from anywhere. Be it from their comfort of their homes, or at a polling booth organized by one of the stakeholders. One issue that might arise and needs to be taken seriously in rural areas with people less connected with the technology, they can be influenced by rigging the voting process. People can vote on their behalf once they have authenticated themselves. This needs to be taken into consideration by all the stakeholders and Election Authority and identify areas where something like this is likely to happen.

4 Discussion and Conclusions

Various conventional voting systems around the world were studied. Most countries have common voting systems, like First-Past-The-Post system, Proportional Representation, Instant-Runoff or Two round voting system Wu & Yang (2018). Every country modifies the base system as per their needs Carr III et al. (2018). Many researchers have been asking the question whether Blockchain can provide an answer to the challenges typically in areas which have suffered due to lack of efficient technologies for modern voting systems around the world. This article addresses this in three distinct phases.

There is a phase before voting where keeping track of who is registered and where who is allowed to vote is harder than it should have been. We have a lot of examples where the voter showed up on the day of the polling booth only to find out their names were missing from the list. A lot of paperwork goes missing, people get removed from voting roles, etc. A Public ledger that tracks who is registered to vote and legitimate voters can register from their home machine and confirm that before they showed up at the pole would help a lot in

reestablishing trust in the system and validating that whoever is eligible to vote is allowed to vote by providing independent verification of that.

The Second phase is to actually vote. Now there is always an issue with digitizing government process. We have come across stories where databases were compromised and private information were leaked or changed. This can be very challenging when it comes to voting, especially voting for the leader of the country. By introducing Blockchain framework, not only we can reduce corruption in the Electoral process but actually help researchers, scientists, teachers empower so they can help bring net generation up to the challenges of the emerging world. We keep them as nodes in the network that will verify all the transactions. This way voters can trust the outcome of the result more and system will be more transparent Zhang et al. (2018).

The Final phase is Counting the Votes. The Election authority has taken the total that are coming from all the different sources like, postal ballots, vote by mail and the actual machines. There we have to keep faith in the system to count all the votes correctly, and report it nationally with accuracy. In many countries, the bases of this trust are violated. There is not a lot of confidence that total from a polling place is accurately summed up. So, using a distributed ledger, not to track the individual votes but to track the totals from each of the polling places will reassure the voter that the local polling didn't over count the votes. The voter can verify his votes from the transaction ID provided by the system to actually check whether his votes were counted correctly or not.

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