US 20180102013A1

(19) United States

(12) Patent Application Publication

Spanos et al.

(10) Pub. No.: US 2018/0102013 A1

(43) Pub. Date: Apr. 12, 2018

(54) **SYSTEM AND METHOD FOR SECURELY RECEIVING AND COUNTING VOTES IN AN ELECTION**

(71) Applicants: **Nikolaos Spanos**, New York, NY (US); **Andrew R. Martin**, New York, NY (US); **Eric T. Dixon**, North Bergen, NJ (US)

(72) Inventors: **Nikolaos Spanos**, New York, NY (US); **Andrew R. Martin**, New York, NY (US); **Eric T. Dixon**, North Bergen, NJ (US)

(73) Assignee: **Blockchain Technologies Corporation**, New York, NY (US)

(21) Appl. No.: **15/831,364**

(22) Filed: **Dec. 4, 2017**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/820,530, filed on Aug. 6, 2015, now Pat. No. 9,836,908, which is a continuation-in-part of application No. 14/809,062, filed on Jul. 24, 2015, now Pat. No. 9,608,829.

(60) Provisional application No. 62/029,409, filed on Jul. 25, 2014, provisional application No. 62/090,370, filed on Dec. 11, 2014, provisional application No. 62/112,130, filed on Feb. 4, 2015, provisional application No. 62/170,131, filed on Jun. 3, 2015, provisional application No. 62/185,613, filed on Jun. 27, 2015.

Publication Classification

(51) **Int. Cl.**

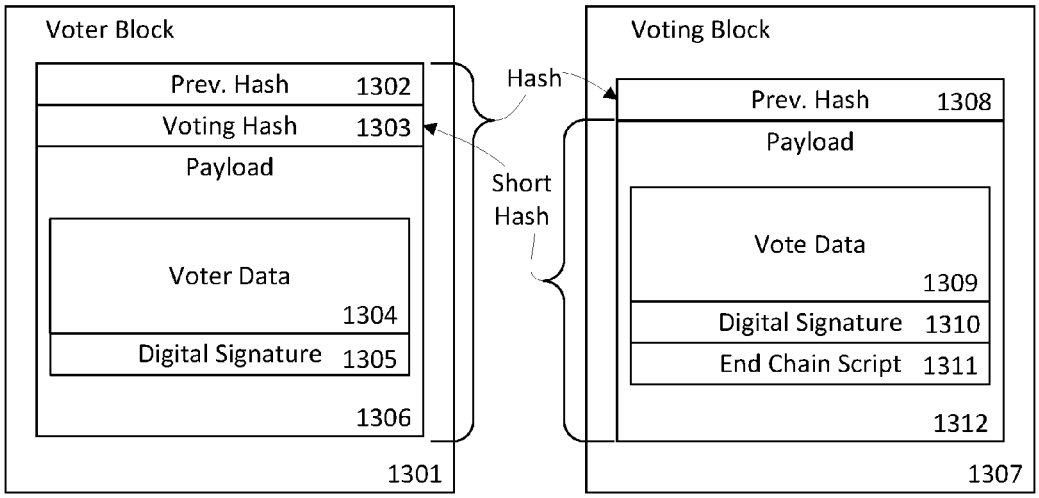
G07C 13/00	(2006.01)
H04L 9/06	(2006.01)
H04L 9/14	(2006.01)
H04L 9/30	(2006.01)
H04L 9/32	(2006.01)

(52) **U.S. Cl.**

CPC ***G07C 13/00*** (2013.01); ***H04L 9/0637*** (2013.01); *G06Q 2220/10* (2013.01); ***H04L 9/30*** (2013.01); ***H04L 9/3247*** (2013.01); ***H04L 9/14*** (2013.01)

(57) **ABSTRACT**

The present invention generally relates to blockchain technology. Specifically, this invention relates to adapting blockchain technology for the storage of voting data in an electronic voting system. The system includes a distributed network of voting machines in communication with each other. Each voting machine has a barcode scanner, a network communications device and a computer system running a voting client. Votes are received through the barcode scanner or a voter interface system and stored securely on a blockchain. The tally for various candidates in the election is updated and stored as each vote is received and counted. This creates an auditable trail of votes and the tally which can be used to detect, correct, and prevent fraud and error in the vote counting process.



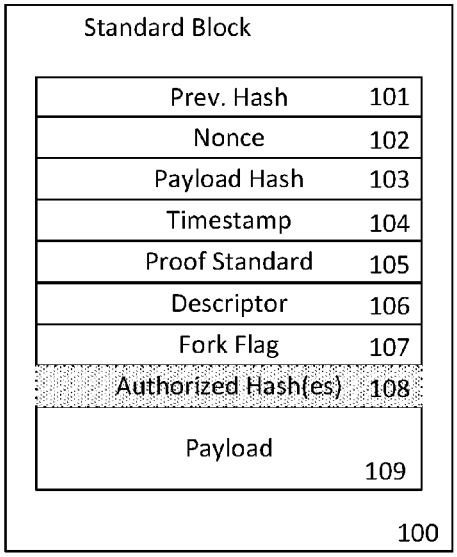

Standard Block
Prev. Hash 101
Nonce 102
Payload Hash 103
Timestamp 104
Proof Standard 105
Descriptor 106
Fork Flag 107
Authorized Hash(es) 108
Payload 109
100

Fig. 1

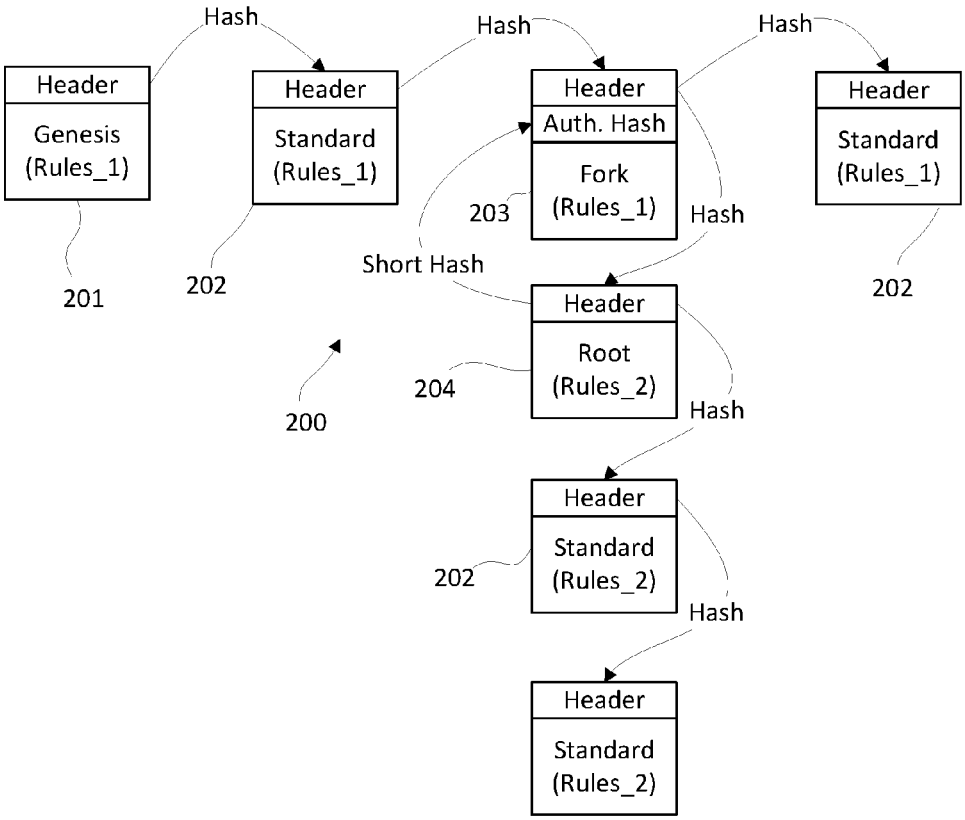

Hash
Hash
Hash
Header
Genesis
(Rules_1)
Header
Standard
(Rules_1)
Header
Auth. Hash
Fork
(Rules_1)
Header
Standard
(Rules_1)
203
Hash
Short Hash
201
202
202
Header
Root
(Rules_2)
204
200
Hash
Header
Standard
(Rules_2)
202
Hash
Header
Standard
(Rules_2)

Fig. 2

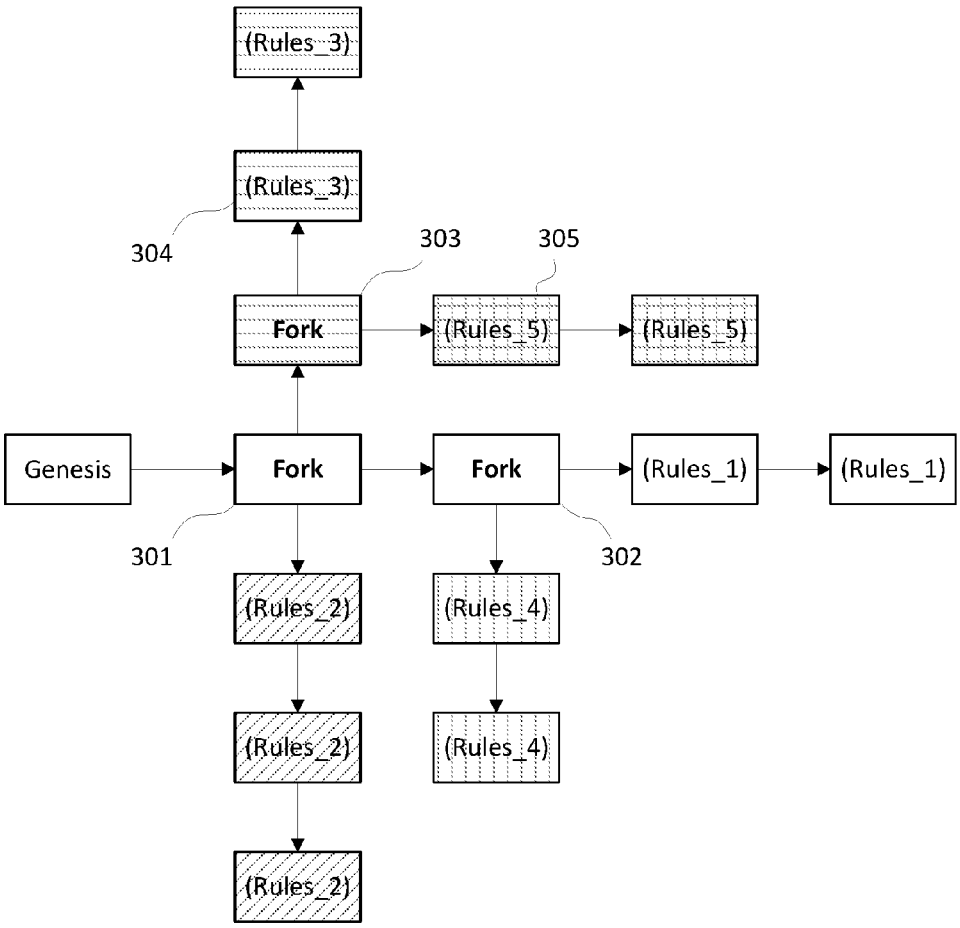

(Rules_3)
(Rules_3)
304
303
305
Fork
(Rules_5)
(Rules_5)
Genesis
Fork
Fork
(Rules_1)
(Rules_1)
301
302
(Rules_2)
(Rules_4)
(Rules_2)
(Rules_4)
(Rules_2)

Fig. 3

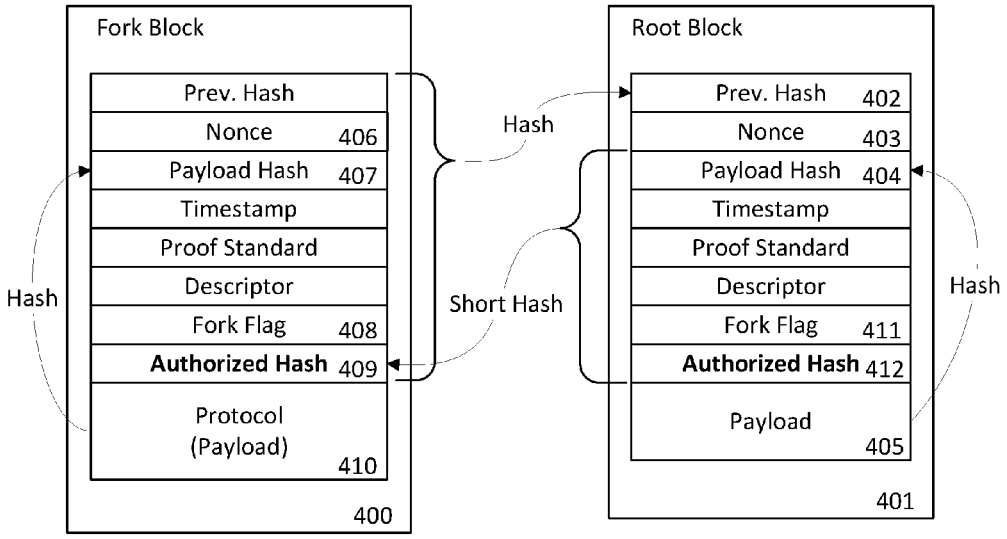

Fork Block
Prev. Hash
Nonce 406
Payload Hash 407
Timestamp
Proof Standard
Descriptor
Fork Flag 408
Authorized Hash 409
Protocol (Payload) 410
400
Hash
Short Hash
Hash
Root Block
Prev. Hash 402
Nonce 403
Payload Hash 404
Timestamp
Proof Standard
Descriptor
Fork Flag 411
Authorized Hash 412
Payload 405
401
Hash

Fig. 4

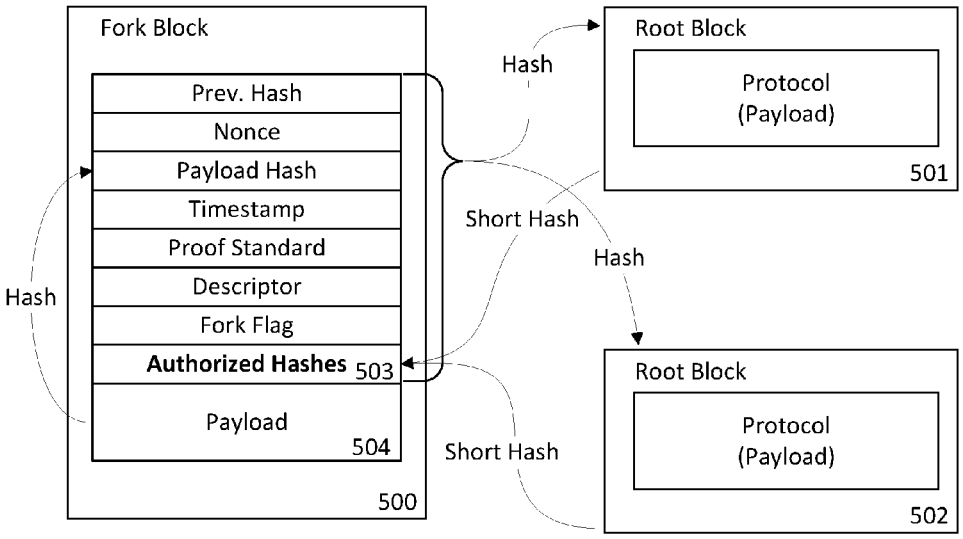

Fork Block
Prev. Hash
Nonce
Payload Hash
Timestamp
Proof Standard
Descriptor
Fork Flag
Authorized Hashes 503
Payload 504
500
Hash
Short Hash
Hash
Root Block
Protocol (Payload)
501
Hash
Root Block
Protocol (Payload)
502
Short Hash

Fig. 5

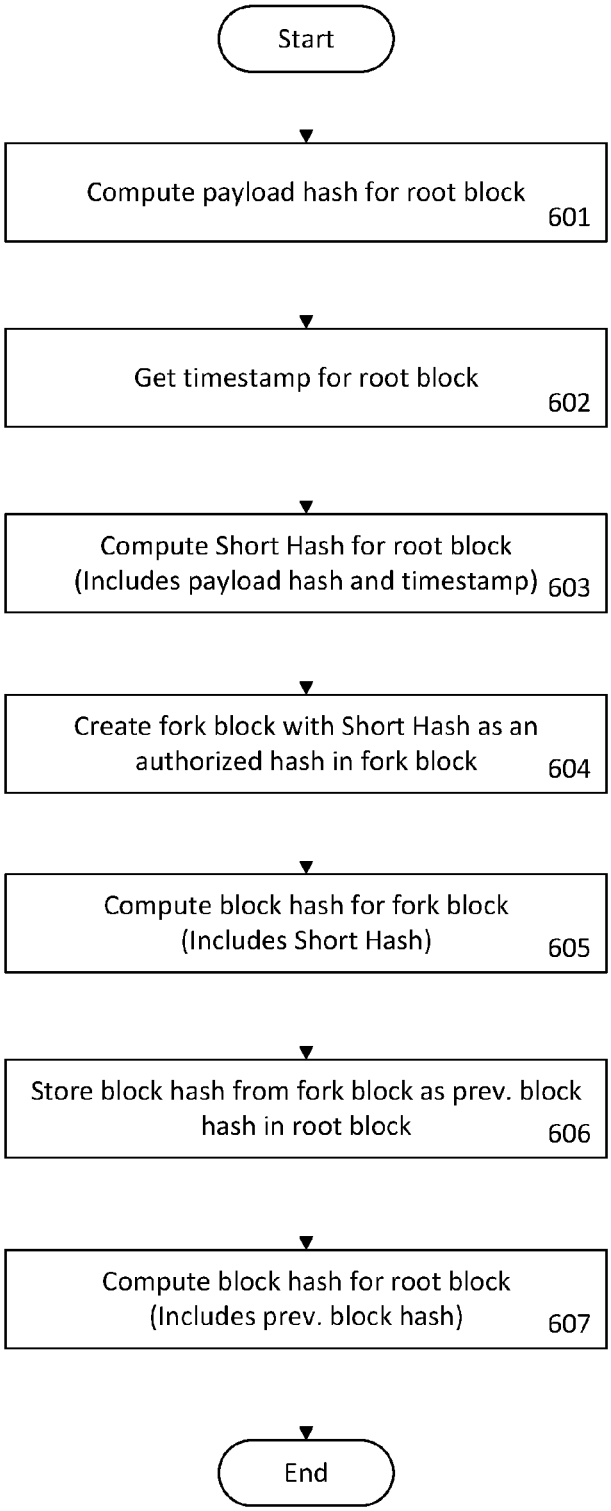

Start
Compute payload hash for root block
601
Get timestamp for root block
602
Compute Short Hash for root block
(Includes payload hash and timestamp)
603
Create fork block with Short Hash as an
authorized hash in fork block
604
Compute block hash for fork block
(Includes Short Hash)
605
Store block hash from fork block as prev. block
hash in root block
606
Compute block hash for root block
(Includes prev. block hash)
607
End

Fig. 6

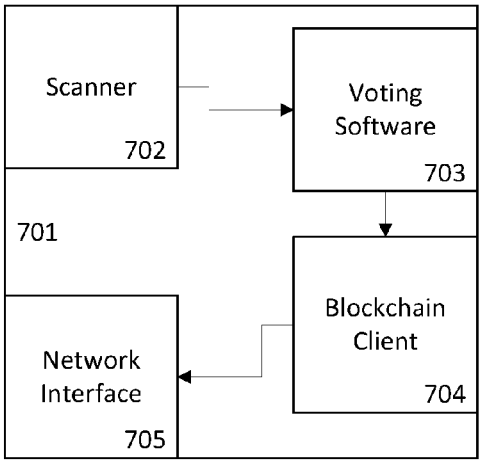

Scanner
702
Voting
Software
703
701
Blockchain
Client
704
Network
Interface
705

Fig. 7

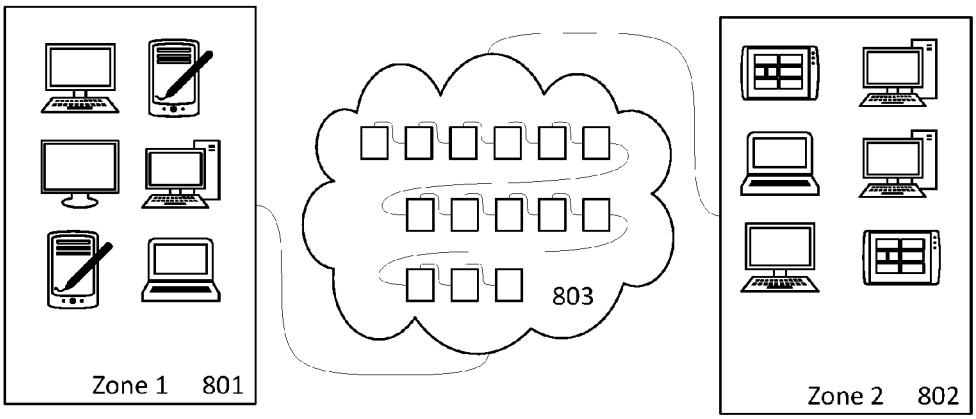

Zone 1 801
803
Zone 2 802

Fig. 8

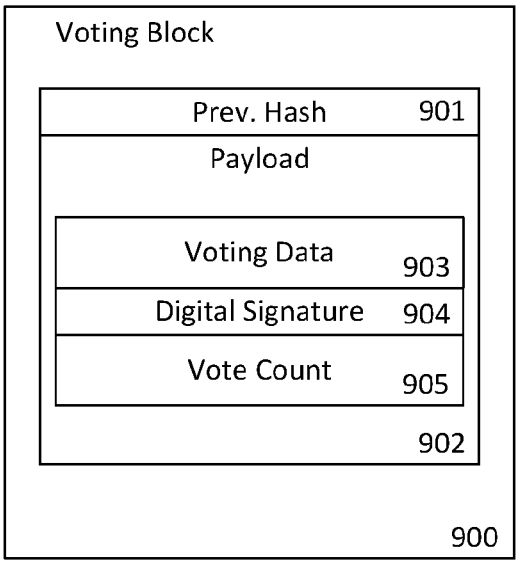

Voting Block
Prev. Hash
901
Payload
Voting Data
903
Digital Signature
904
Vote Count
905
902
900

Fig. 9

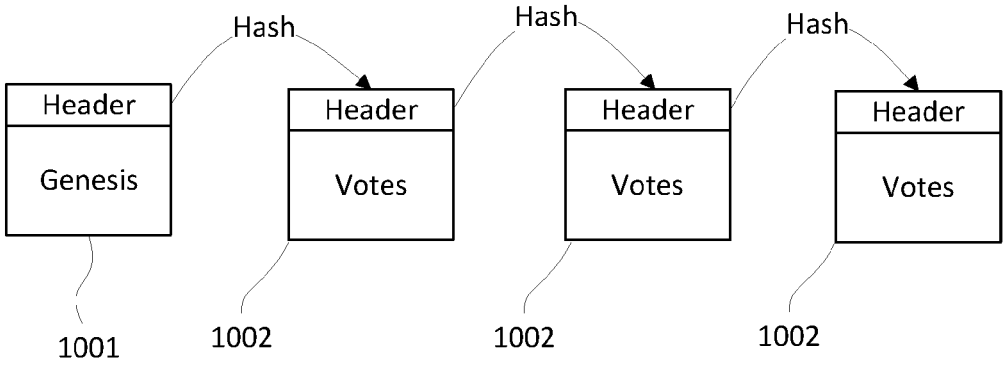

Hash
Hash
Hash
Header
Genesis
Header
Votes
Header
Votes
Header
Votes
1001
1002
1002
1002

Fig. 10

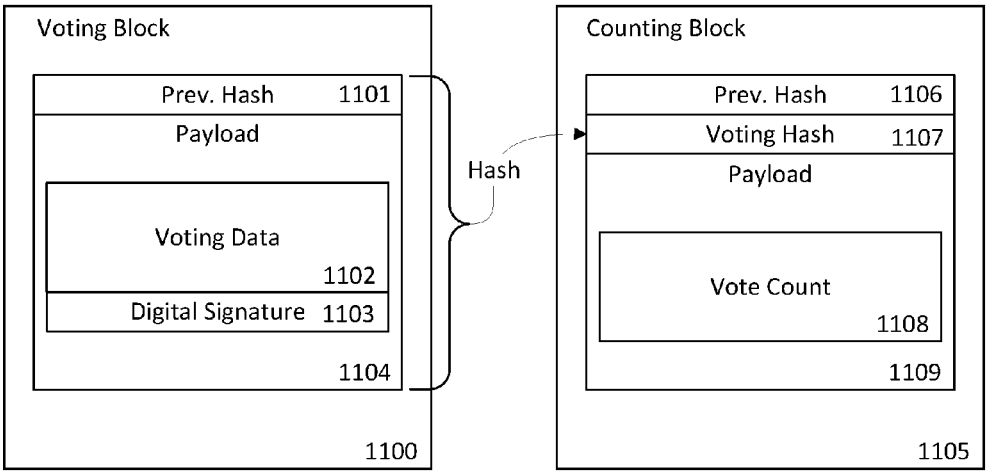

Voting Block
Prev. Hash 1101
Payload
Voting Data
1102
Digital Signature 1103
1104
1100
Hash
Counting Block
Prev. Hash 1106
Voting Hash 1107
Payload
Vote Count
1108
1109
1105

Fig. 11

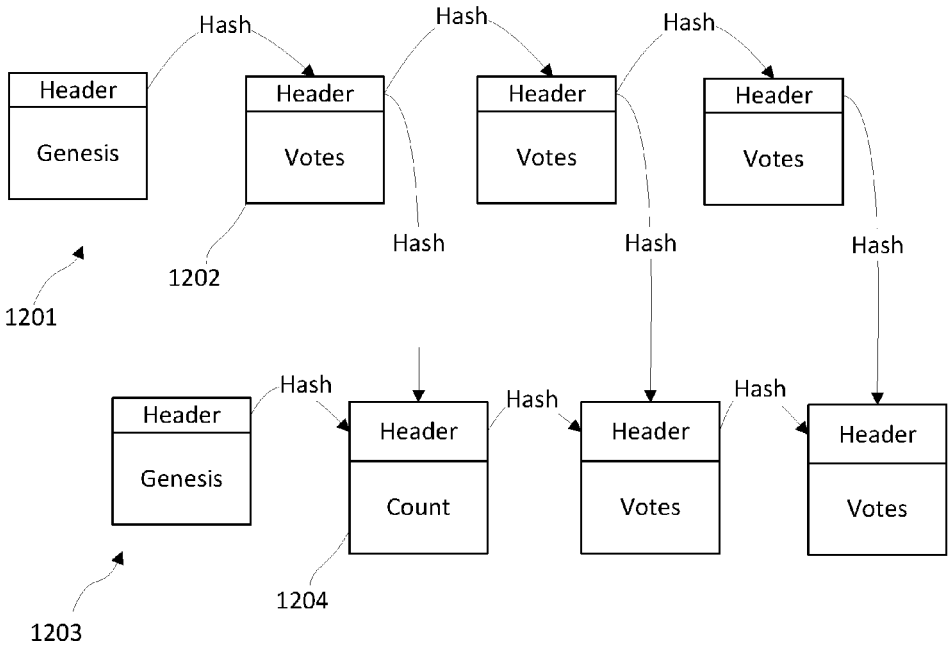

Hash
Header
Genesis
Header
Votes
Header
Votes
Header
Votes
1201
1202
Header
Genesis
Header
Count
Header
Votes
Header
Votes
1203
1204

Fig. 12

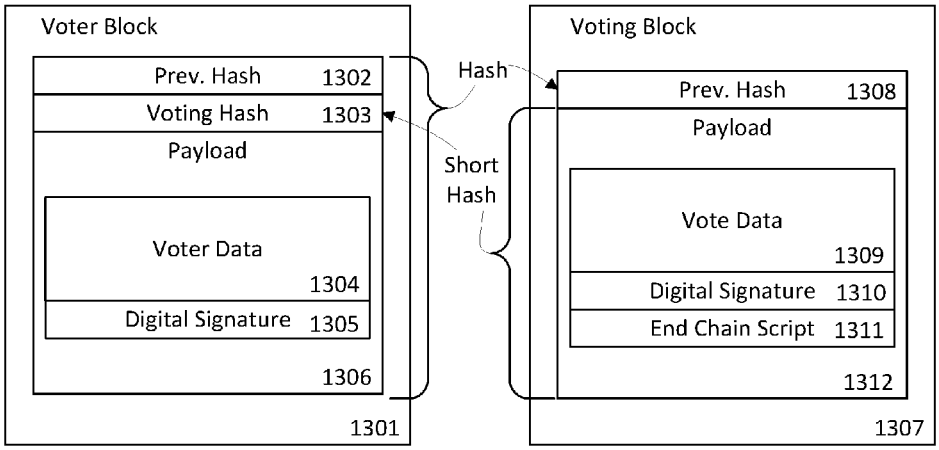

Voter Block
Prev. Hash 1302
Voting Hash 1303
Payload
Voter Data
1304
Digital Signature 1305
1306
1301
Hash
Short Hash
Voting Block
Prev. Hash 1308
Payload
Vote Data
1309
Digital Signature 1310
End Chain Script 1311
1312
1307

Fig. 13

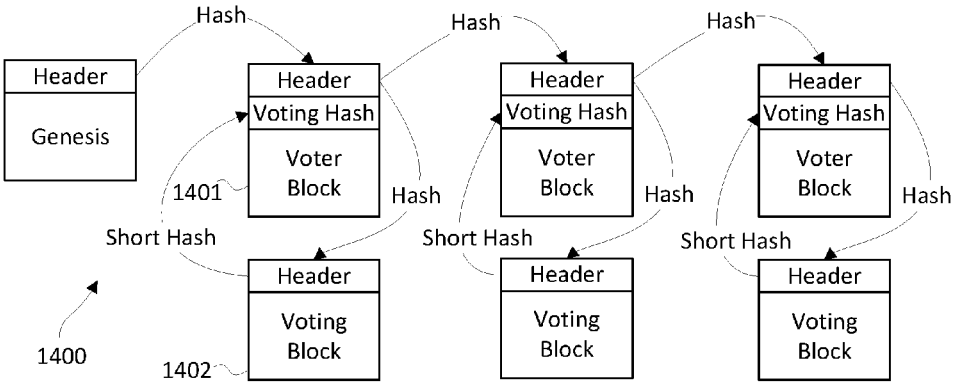

Header
Genesis
Hash
Header
Voting Hash
Voter Block
1401
Short Hash
Header
Voting Block
1402
1400
Hash
Header
Voting Hash
Voter Block
Short Hash
Header
Voting Block
Hash
Header
Voting Hash
Voter Block
Short Hash
Header
Voting Block
Hash

Fig. 14

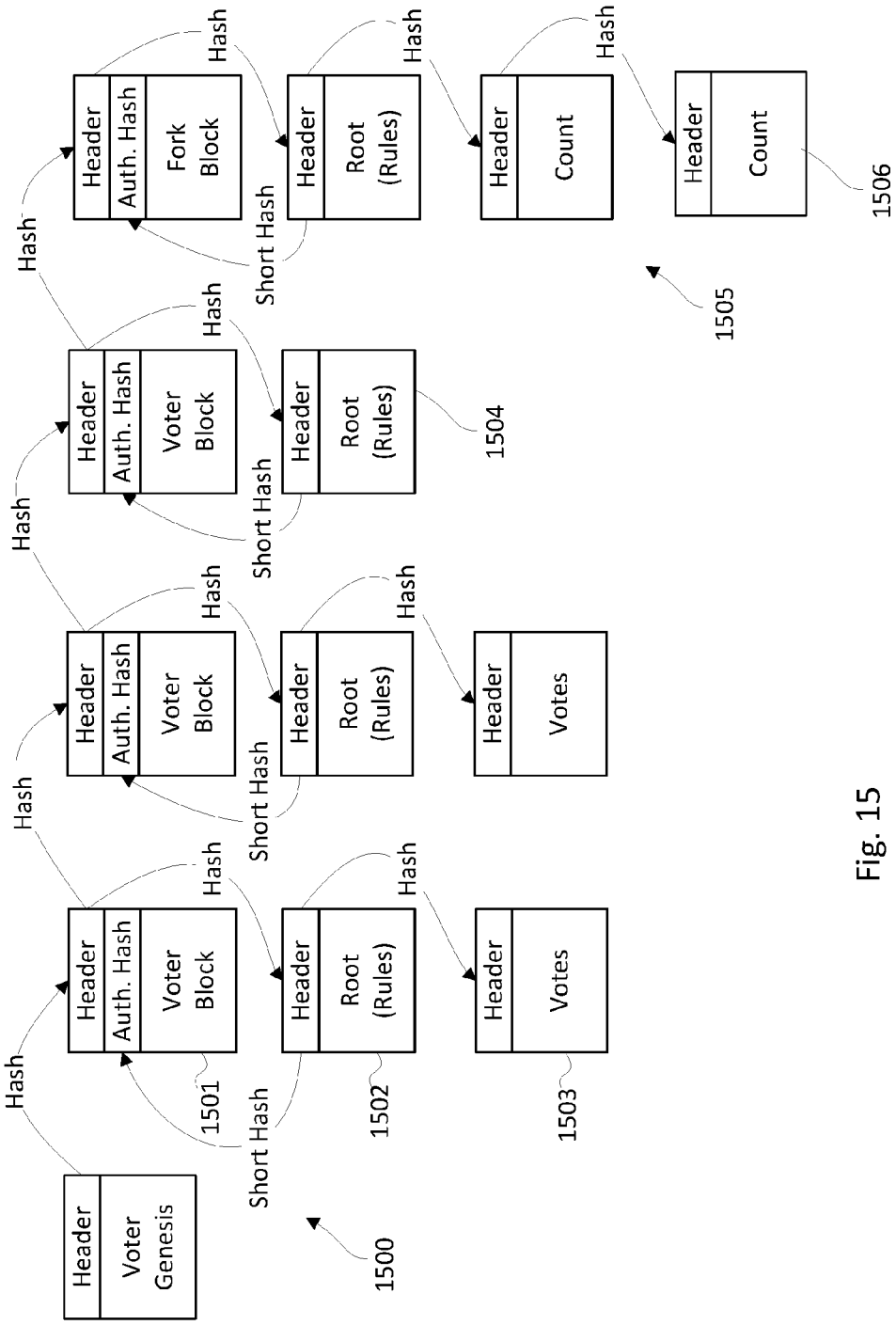

Header
Voter Genesis
Hash
Header
Auth. Hash
Voter Block
1501
Short Hash
Header
Root (Rules)
1502
Hash
Header
Votes
1503
Header
Auth. Hash
Voter Block
Short Hash
Header
Root (Rules)
Hash
Header
Votes
Header
Auth. Hash
Voter Block
Short Hash
Header
Root (Rules)
1504
Header
Auth. Hash
Fork Block
Short Hash
Header
Root (Rules)
Header
Count
Header
Count
1506
1500
1505

Fig. 15

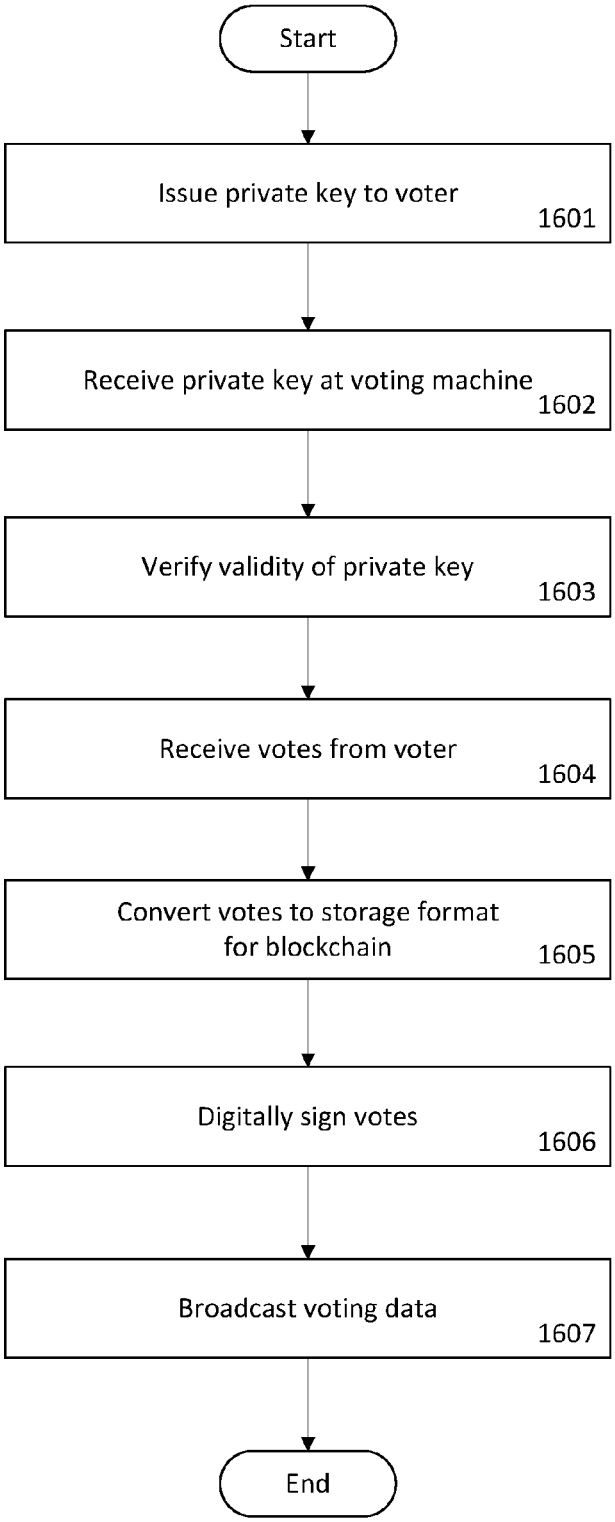

Start
Issue private key to voter
1601
Receive private key at voting machine
1602
Verify validity of private key
1603
Receive votes from voter
1604
Convert votes to storage format for blockchain
1605
Digitally sign votes
1606
Broadcast voting data
1607
End

Fig. 16

SYSTEM AND METHOD FOR SECURELY RECEIVING AND COUNTING VOTES IN AN ELECTION

RELATED APPLICATIONS

[0001] The present application is a continuation of and claims priority to non-provisional U.S. patent application Ser. No. 15/676,959, entitled, "System and Method for Securely Receiving and Counting Votes in an Election", filed Aug. 14, 2017, which is a continuation in part of U.S. patent application Ser. No. 14/820,530, entitled, "System and Method for Securely Receiving and Counting Votes in an Election", filed Aug. 6, 2015, which is a continuation in part of U.S. patent application Ser. No. 14/809,062 entitled "System and Method for Creating a Multi-Branched Blockchain with Configurable Protocol Rules" filed Jul. 24, 2015 and which, in turn, claims priority from provisional application No. 62/029,409 entitled "System And Method For Database For Self-Actuating Contracts And Other Data" filed Jul. 25, 2014, provisional application No. 62/090,370 entitled "Use of Blockchain Database To Enhance Security of Support Secure Electronic Voting and Election Result Tabulation" filed Aug. 6, 2014, provisional application No. 62/112,130 entitled "System And Method For Blockchain-Type-Based Search Engine Database Within An Internet Browser Supporting A User Affinity Program" filed Feb. 4, 2015, provisional application No. 62/170,131 entitled "Retailer-Captive Blockchain-Derivative System For Hosting Secure and Non-Counterfeit Transactions Within A Retailer's Customer Affinity Program" filed Jun. 3, 2015, and provisional application No. 62/185,613 entitled "System And Method For Blockchain-Inspired Database Allowing Remote Access To Medical Records" filed Jun. 27, 2015, the contents of which are incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

[0002] The present invention generally relates to blockchain technology. Specifically, this invention relates to adapting blockchain technology for the storage of voting data in an electronic voting system. The system includes a distributed network of voting machines in communication with each other. Each voting machine has a barcode scanner, a network communications device and a computer system running a voting client. Votes are received through the barcode scanner or a voter interface system and stored securely on a blockchain. The tally for various candidates in the election is updated and stored as each vote is received and counted. This creates an auditable trail of votes and the tally which can be used to detect, correct, and prevent fraud and error in the vote counting process.

BACKGROUND OF THE INVENTION

[0003] Blockchain technology is most widely known as the technology behind the popular cryptocurrency, Bitcoin. A blockchain creates a history of data deposits, messages, or transactions in a series of blocks where each block contains a mathematical summary, called a hash, of the previous block. This creates a chain where any changes made to a block will change that block's hash, which must be recomputed and stored in the next block. This changes the hash of the next block, which must also be recomputed and so on until the end of the chain.

[0004] Although the hash, or mathematical summary, is simple to compute, there are rules imposed which require the value of the hash to be below a certain threshold value. In addition, the hash is based on a special type of mathematical function that is not reversible; you cannot predict what input can be used to produce the desired output. A valid hash is found by repeatedly adjusting a changeable value in the block, and recalculating the hash until it meets the validity requirements. The freely changeable value is called the nonce. The unpredictable nature of the hash considerably increases the difficulty of finding a nonce that produces a valid hash of the block. Typically, trillions of different nonces must be tried before a valid hash is found. Therefore, changing the value of previously stored data in the blockchain is computationally expensive, although not impossible.

[0005] The security of a blockchain is further increased by implementing it on a distributed network. This means a large number of users all have access to the blockchain and are all attempting to add blocks to the end of the chain by finding a nonce that produces a valid hash for a given block of data. When two blocks are found that both claim to reference the same previous block, a fork in the chain is created. Some users in the network will attempt to find the next block on one end of the fork while other users will work from the other end of the fork. Eventually one of the forks will surpass the other in length, and the longest chain is accepted by consensus as the valid chain. Therefore, anyone who attempts to change a block must not only re-find a valid hash for each subsequent block, but must do it faster than everyone else working on the currently accepted chain. Thus, after a certain number of blocks have been chained onto a particular block, it becomes prohibitively costly to try to change that block.

[0006] Blockchains on a distributed network with sufficiently restrictive rules for creating valid blocks are fairly secure against unauthorized changes to the data stored in them. This makes blockchains particularly useful for recording financial transactions. However, the blockchain has not been properly adapted for use in a voting system, and a voting system has not yet been created which leverages the advantages of blockchain within a larger electronic voting system to solve traditional problems related to fraud in voting systems.

[0007] Therefore, there is a need in the art for a system and method for a voting system that prevents fraud in the counting process by leveraging and adapting blockchain technology to a distributed voting system.

SUMMARY OF THE INVENTION

[0008] Accordingly, it is an object of the present invention to provide a system and method for securely receiving and counting votes in an election.

[0009] According to an embodiment of the present invention, a voting system comprises: one or more voting machines connected to each other by network connections to form a distributed network; wherein each of said one or more voting machines comprises: a computer processor; a non-volatile computer-readable memory; a scanner configured to read data from barcodes and/or voting ballots; and a network interface; wherein the non-volatile computer-readable memory is configured with computer instructions configured to: receive a private key and public key pair from a voter, receive voting data comprising one or more votes for

one or more candidates in an election, use said private key to digitally sign said voting data to produce signed voting data, and broadcast said signed voting data with said public key to a distributed network, store said signed voting data with said public key on a blockchain database managed by the one or more voting machines forming said distributed network.

[0010] According to an embodiment of the present invention, said computer instructions are further configured to: store voting data with said public key in a voting block on a voting blockchain; update a voting count according to said voting data; store said voting count in a counting block on a counting blockchain, wherein each counting block also stores a hash of the voting block storing the voting data which was used to update the voting count, the result of which is stored in the counting block.

[0011] According to an embodiment of the present invention, said computer instructions are further configured to: store, in a voter block which is a fork block of a slidechain, voter data identifying the voter and elections in which said voter is allowed to cast votes, store voting data from said voter in a voting block which is a slidechain root block storing a voter hash of said voter block, wherein said voter block also stores a voting hash computed from data in said voting block, accept the longest chain on said slidechain as a valid chain and accept as valid a chain where any voter block stores a voting hash of a voting block which, in turn, stores a voter hash of said any voter block.

[0012] According to an embodiment of the present invention, said computer instructions are further configured to: update a voting count according to said voting data; store said voting count in a counting block on a counting chain which is a fork chain of said slidechain, wherein each counting block in said counting chain also stores a hash of an immediately preceding counting block.

[0013] According to an embodiment of the present invention, said computer instructions are further configured to: store, in a voter block which is a fork block of a slidechain, voter data identifying the voter and elections in which said voter is allowed to cast votes, create a slidechain root block storing a voter hash of said voter block, store, in said voter block, a root hash computed from data in said root block, store said voting data in a voting block, store said root hash in said voting block, and accept the longest chain on said slidechain as a valid chain and accept, as valid, a chain where any voter block stores a root hash of a root block which, in turn, stores a voter hash of said any voter block.

[0014] According to an embodiment of the present invention, said computer instructions are further configured to: update a voting count according to said voting data; store said voting count in a counting block on a counting chain which is a fork chain of said slidechain, and wherein each counting block in said counting chain also stores a hash of an immediately preceding counting block.

[0015] According to an embodiment of the present invention, a method of securing voting data comprises the steps of: receiving voting data produced by a voter; receiving a private key and public key corresponding to said voter; signing the voting data with said private key to produce signed voting data; storing the signed voting data in a voting block on a voting blockchain; updating a voting count based on said voting data; storing said voting count in counting block of a counting blockchain, wherein the counting block a has of an immediately preceding block in the counting blockchain and stores a voting hash of the voting block containing the voting data used to update the voting count stored in the counting block.

[0016] The foregoing summary of the present invention with the preferred embodiments should not be construed to limit the scope of the invention. It should be understood and obvious to one skilled in the art that the embodiments of the invention thus described may be further modified without departing from the spirit and scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a diagram of a standard block in a slidechain according to an embodiment of the present invention.

[0018] FIG. **2** is a diagram of a slidechain with a forked chain that has a different set of rules applied to it than the original blockchain according to an embodiment of the present invention.

[0019] FIG. **3** is a diagram of a slidechain with multiple forks where each new chain has a different protocol or set of rules that apply according to an embodiment of the present invention.

[0020] FIG. **4** is a diagram illustrating how a fork block interconnects with the root block of a forked chain according to one embodiment of the present invention.

[0021] FIG. **5** is a diagram illustrating how a standard block becomes a fork block and interconnects with the multiple root blocks of forked chains according to one embodiment of the present invention.

[0022] FIG. **6** is a flowchart showing the process for creating a fork in the slidechain according to an embodiment of the present invention.

[0023] FIG. **7** is a block diagram of a voting machine according to an embodiment of the present invention.

[0024] FIG. **8** is a network diagram of the distributed network of voting machines according to an embodiment of the present invention.

[0025] FIG. **9** is a diagram of a voting block of a blockchain according to an embodiment of the present invention.

[0026] FIG. **10** is a diagram of a blockchain for storing voting data according to an embodiment of the present invention.

[0027] FIG. **11** is a diagram of the connection between a voting block and a counting block where a separate blockchain is used to count votes according to an embodiment of the present invention.

[0028] FIG. **12** is a diagram of a voting blockchain and counting blockchain interconnected according to an embodiment of the present invention.

[0029] FIG. **13** is a diagram of a voter block and voting block implemented using a slidechain according to an embodiment of the present invention.

[0030] FIG. **14** is a diagram of a slidechain used to store voter and voting data according to an embodiment of the present invention.

[0031] FIG. **15** is a diagram of a slidechain implementation of the voting system according to an alternate embodiment of the present invention.

[0032] FIG. **16** is a flowchart of a voting process according to an embodiment of the present invention.

DETAILED SPECIFICATION

[0033] The present invention generally relates to blockchain technology. Specifically, this invention relates to adapting blockchain technology for the storage of voting data in an electronic voting system. The system includes a distributed network of voting machines in communication with each other. Each voting machine has a barcode scanner, a network communications device and a computer system running a voting client. Votes are received through the barcode scanner or a voter interface system and stored securely on a blockchain. The tally for various candidates in the election is updated and stored as each vote is received and counted. This creates an auditable trail of votes and the tally which can be used to detect, correct, and prevent fraud and error in the vote counting process. It should be understood that embodiments of the voting system detailed herein could be utilized for any type of election, whether related to the election of public officials, elections conducted for electing board members to a company, elections for voting on referendums, bills, propositions, voting done in person or by proxy, or any combination thereof. One of ordinary skill in the art would appreciate that the systems and methods detailed herein could be utilized for any type of voting, and embodiments of the present invention are contemplated for use with any type of voting.

[0034] The voting system described herein is designed to prevent fraud and error in the vote counting process and assumes all inputs to the system are valid. The voting system does not attempt to guarantee that each human voter is assigned only one voter ID in the system and does not attempt to guarantee that the voter ID used to cast a vote actually belongs to the person using it, nor that the voter ID used to cast a vote actually belongs to an existing human voter at all. The voting system relies on whatever identity verification system is used for the state, district, or municipality where the voting system is used. Once votes are entered into the voting system described herein, they are stored securely and irreversibly to guarantee that votes can be quickly and accurately verified and counted. Rather than waiting until the election is over to count votes, the voting system allows votes to be counted in real time as the election is ongoing. According to to one embodiment of the present invention, a customized blockchain called a slidechain is used to store votes and count data. The slidechain is described in the parent application (U.S. patent application Ser. No. 14/809,062) and the relevant parts are included below for convenience.

[0035] According to an embodiment of the present invention, FIG. **1** shows the data structure for a standard block of data in the slidechain. Previous hash **101** is the result of a non-reversible mathematical computation using data from the previous block as the input. According to one embodiment the computation used is a SHA256 hash function. One of ordinary skill in the art would recognize that any suitable hash function could be used without departing from the spirit and scope of the present invention. The hash function is designed so that any change to the data in the previous block results in an unpredictable change in the hash of that block. Previous hash **101** is what creates the link between blocks, chaining them together to form the slidechain.

[0036] When calculating the hash **101** for the previous block, it must meet certain criteria defined by data stored as the proof standard **105**. In one embodiment, this proof standard **105** is simply a number that the calculated hash must be less than. However, because the output of the hashing function is unpredictable, it cannot be determined, before the hash is calculated, what input will result in an output that is less than the proof standard **105**. The nonce **102** is used to vary the data content of the block, allowing for a large number of different outputs to be produced by the hash function in pursuit of an output that meets the proof standard **105**. This makes it computationally expensive to produce a valid block with a nonce **101** that produces a hash value meeting the criteria of the proof standard **105**.

[0037] The payload hash **103** is a simple hash of the data in the payload **109** and does not have to meet any proof standard. However, the payload hash is included as part of the input when the hash is calculated for the purpose of storing as the previous hash **101** of the next block. The timestamp **104** tells what time the block was created within a certain range of error. According to one embodiment of the present invention, the distributed network of users checks the timestamp **104** against their own known time and will reject any block that seems to have a bogus timestamp **104**. The descriptor **106** describes the size and/or data structure of the payload **109**. For a variable size payload **109**, the descriptor **106** may indicate the index of the first byte in the payload **109** and the size of the payload **109**. The descriptor **106** may also store other information relevant to the interpretation of the payload **109**.

[0038] The fork flag **107** is an indicator used to determine whether a fork is allowed from this block. The authorized hashes **108** indicate which blocks, identified by a hash, are allowed to chain off of this block. According to one embodiment, the authorized hashes **108** are only stored as part of the block if the fork flag **107** is set. In another embodiment, a single authorized hash **108** is present regardless of whether the fork flag **107** is set, but the authorized hash **108** data may be zeroed out or ignored when the fork flag **107** is not set. According to another embodiment, the number of hashes stored as authorized hashes **108** is flexible. The number of authorized hashes **108** stored may be tracked in the descriptor **106**, or a flexible data structure for storing authorized hashes **108** may be used to store a variable number of authorized hashes **108**.

[0039] The payload **109** is the data stored in the block, which may relate to voting, transactions, ownership, data access records, document versioning, or any kind of data that can be stored. The payload **109** may be a fixed size or a flexible size, and provides the input for the hash that produces the payload hash.

[0040] One of ordinary skill in the art would recognize there are a variety of different proof standards that could be used. The proof standard could be based on proof of work, such as hash value requirements, proof of stake, such as a key or other indicator of consensus, or any other kind or proof of consensus. The proof standard may be applied as a rule that requires a hash value to be less than the proof standard, more than the proof standard, or have a required bit sequence or a required number of leading or trailing zeroes. Any proof standard may be used without departing from the spirit and scope of the present invention.

[0041] The hash algorithms used for the previous hash **101**, the payload hash **103**, or the authorized hash may be all of the same type or of different types. Hash functions that could be used include MD5, SHA-1, SHA-224, SHA-256, SHA-384, SHA-512, SHA-512/224, SHA-512/256, SHA-3 or any suitable hash function resistant to pre-image attacks.

There is also no requirement that a hash be computed only once. The results of a hash function may be reused as inputs into another or the same hash function again multiple times in order to produce a final result. One of ordinary skill in the art would recognize that any hash function could be used to compute the required hashing without departing from the spirit and scope of the present invention.

[0042] FIG. **2** shows a simple diagram illustrating a slidechain **200** with a single fork. The genesis block **201** is a special block that begins the slidechain **200**; it is different from the other blocks because it is the first block in the chain, and thus cannot include a hash of a previous block. The genesis block **201** marks the beginning of the genesis chain. The protocol, that governs how the genesis chain grows, what data it stores, how forks are created, and how block and chain validity are verified is indicated by the Rules_**1** label inside each block in the genesis chain. The Rules_**1** protocol is the default set of rules that allows for the creation of forks and the modification of rules in those forks. Notice that the Rules_**1** protocol still applies to blocks in the genesis chain even after a fork block **203** creates a fork chain where the Rules_**2** protocol applies.

[0043] The fork block **203** allows the chain to be forked such that both the genesis chain and the fork chain are considered valid chains. Normally, in a blockchain, all forks are eventually ignored and considered invalid except the one representing the longest chain. The fork block **203** is special because it works like a standard block, but additionally includes a reference identifying the first block, or root block **204**, in the valid fork. In one embodiment of the present invention, the new protocol, Rules_**2**, is stored as the payload of the fork block and applied to the root block **204** and each subsequent standard block that chains from the root block **204**. In another embodiment, the new Rules_**2** protocol is stored in the payload of the root block **204** itself, and is applied to each standard block that chains from the root block **204**. In either case, any subsequent block that is chained from either the genesis chain, where Rules_**1** applies, or the fork chain, where Rules_**2** applies, can be another fork block creating yet another valid chain fork.

[0044] The Rules_**1**, Rules_**2**, and other protocols are not defined by this specification, but defined by users of the system at runtime. These protocols are customizable based on a scripting, or programming language. According to one embodiment, a new protocol can only be defined for a forked chain and the original protocol remains fixed and applied to the genesis chain. In another embodiment, the genesis chain protocol itself can be modified or updated and applied to every future standard block that chains off the genesis chain. This new base protocol would ideally be backwards compatible with the original genesis chain protocol so that all previous data is not rendered obsolete. The ability to update the protocol and create new protocols gives slidechain the flexibility to adapt to any future technological need where a blockchain is useful.

[0045] According to an embodiment of the present invention shown in FIG. **3**, the slidechain can have multiple forks. Each forked chain is pattern coded in FIG. **3** to visually indicate that the same protocol rules apply to blocks with the same pattern fill. The genesis chain, including the genesis block is filled with plain white. Two consecutive fork blocks, **301** and **302**, are shown on the genesis chain. The first fork block **301** begins a forked chain that applies the Rules_**2** protocol. The second fork block **302** immediately following the first fork block creates a new forked chain that applies a different Rules_**4** protocol. There is no limit to the number of fork blocks or the frequency of fork blocks in the genesis chain. According to one embodiment of the present invention, every block in the genesis chain could conceivably be a fork block. However, it is possible for the protocol of a forked chain to impose its own rules for the creation of additional fork blocks on that forked chain. If a chain that does not recognize the validity of multiple branches is required for a particular application, a customized protocol that disallows forking can be created.

[0046] According to an embodiment of the present invention, a forked block may allow for more than one fork to chain from it. The first fork block **301** illustrates this with a fork chain applying Rules_**2** attached beneath it and the fork chain applying Rules_**3** chaining above it. In order for a fork block to allow for multiple forks, it must store a reference to the root block for each chain that chains from it. This requires a section in the block for authorized hashes that can store more than one authorized has corresponding to a root block. According to one embodiment of the present invention, the protocol rules for each chain are stored in the root block of each forked chain, and not the fork block itself In another embodiment, the protocol rules for multiple forks are stored in the fork block itself, with an identifier that references the root block to which the protocol rules apply.

[0047] According to an embodiment of the present invention, the first block in a forked chain may also be a fork block itself. This is illustrated in FIG. **3** by the third fork block **303**. The first fork block **301** creates a forked chain with a Rules_**3** protocol and the third fork block **301**, which is the first block in the Rules_**3** chain, is also a fork block creating a forked chain to the right with a Rules_**5** protocol. According to one embodiment of the present invention, the chain rule set for each chain is stored in the first block of the chain fork. Therefore, the Rules_**3** protocol would be stored in the third fork block **303** and the Rules_**5** protocol is stored in the root block **305**. According to another embodiment of the present invention, the fork block stores the protocol rules for the forked chain. In this embodiment, the first fork block **301** would store the Rules_**3** protocol and the thirds fork block **303** stores the Rules_**5** protocol.

[0048] The language used for defining the protocol rules for a forked chain at runtime can be a known computer programming or scripting language, such as, Python, Ruby, Perl, JavaScript, PHP, Scheme, VBScript, Java, Microsoft .Net, C++, C#, C, or a custom-created language for defining the protocol rules. One of ordinary skill in the art would recognize that any suitable language can be used for defining runtime protocols for forked chains without departing from the spirit and scope of the present invention.

[0049] Under normal circumstances, blockchains naturally fork from time to time. However, only one branch of the chain in a standard blockchain can be considered valid. Consensus on which chain is valid is achieved by choosing the longest chain, which represents the chain with the most work put into completing it. In order to allow for forked chains without allowing accidental forks in the chain, there must be some mechanism by which valid forks can be verified, and invalid forks can be ignored.

[0050] FIG. **4** illustrates how the fork block **400** is interconnected with the first block in an intentional fork to create a valid fork chain. Each block in the blockchain contains a hash of the immediately preceding block stored in the

previous hash **402**. This creates a link going back through the chain from each block and is a key component to making it prohibitively difficult to modify the chain. The first block in a valid intentional fork is called the root block **401**. Therefore the root block **401** naturally contains in its previous hash **402** a link to the fork block **400**. In order to distinguish valid intentional forks from invalid unintentional forks, a hash representing the root block **401** is also stored in the fork block **400**. This creates a two way link where the fork block **400** and the root block **401** each contain a hash reference to the other.

[0051] According to an embodiment of the present invention, the root block **401** is partially created before the fork block **400** is created. The previous hash **402**, which will come from the fork block **400**, and the nonce **403** are left unspecified at this point. A payload hash **404** is created from the data stored in the payload **405**. The payload hash **404** and all the data of the root block **401**, except the previous hash **402** and the nonce **403**, are used to compute a short hash, which is stored as the authorized hash **409** of the fork block **400**. Excluding the previous hash **402** from the short hash prevents the situation of having mutually dependent hashes with no known way to find a solution. Excluding the nonce **403** is required because the nonce **403** will later be changed in determining a valid hash for the root block **401** after the previous hash **402** is determined from the fork block **400**, which does not yet exist at this point.

[0052] According to one embodiment of the present invention, the protocol **410** rules that apply to the fork chain beginning with the root block **401** are stored in the fork block payload. A hash is then computed based on the payload and stored as the payload hash **407**. The fork flag **408** is set in the fork block to indicate a valid fork branching from the fork block **400**. The authorized hash **409**, which represents the root block **401**, is included along with the payload hash **407** and the rest of the fork block data in computing a valid hash for the fork block **400**. This is done by repeatedly adjusting the fork block nonce **406** until the resulting hash meets the required proof standard.

[0053] Once the fork block hash is computed and stored as the previous hash **402** of the root block, a valid root block hash can then be computed by repeatedly adjusting the root block nonce **403** until a hash is produced that meets the required proof standard. Because the previous hash **402** and the nonce **403** of the root block are not included in the short hash, they can safely be modified without changing the authorized hash **409** in the fork block **400**. However, any changes to the data used to compute the short hash will cause a mismatch between the short hash and the authorized hash stored in the fork block **400**, breaking the link between the fork block **400** and the root block **401**.

[0054] According to an embodiment of the present invention, additional rules are imposed to prevent unauthorized forks from being recognized. For example, somebody might try to make an exact copy of the root block in order to fake an authorized fork. However, the system is configured to ignore exact copies of blocks and treat them as the same block. Exact copies can be detected by comparing the block hash or the short hash between two blocks that both reference the same previous block. The block hash is based at least on the previous hash, nonce, payload hash, timestamp, proof standard, descriptor, fork flag, and optionally the authorized hash, when present. Any blocks that try to chain off the copy of the root block are simply treated as chaining off the original root block, creating a fork that is indistinguishable from an unauthorized fork. In dealing with unauthorized forks, the longest chain is considered valid.

[0055] According to an embodiment of the present invention, the root block may also be a fork block. This is called a root fork. If the fork flag **411** in the root block **401** is set, then an authorized hash is stored identifying a second root block that begins a valid fork. When a root block is a fork block, the second root block must be created first. The short hash of the second root block is stored as the authorized hash **412** in the root fork block. The root fork short hash can then be computed and stored as the authorized hash **409** of the fork block **400**. Once the fork block is created, the block hashes for the fork block, the root fork block, and the second root block can then be computed in the required order, as described above.

[0056] According to an embodiment of the present invention shown in FIG. **5**, a fork block **500** may store more than one authorized hash to create multiple authorized forks from a single fork block **500**. The authorized hashes **502** are stored in a flexible structure that allows storage of one or more short hashes corresponding to one or more root blocks. The protocol rules for each valid fork may be stored in the fork block payload **504**, or in the root blocks **501** and **502** for each authorized fork chain respectively.

[0057] When a slidechain forks, the authorized root block referenced in the fork block represents one side of the fork. The other side of the fork is determined by the standard rule for a blockchain, where the longest blockchain is considered the valid chain and all other forks are abandoned. For example there may be three blocks that all reference a fork block as their previous hashes. The root block which has a short hash that matches the authorized hash in the fork block is automatically recognized as valid regardless of how long the chain from that root block is. Between the remaining two chains, the longest chain is considered the second valid chain and the shorter chain is abandoned by the distributed network.

[0058] According to an embodiment of the present invention, FIG. **6** shows a flowchart for the process of creating a valid slidechain fork. At step **601**, the system computes the payload hash for the root block. The payload hash is a mathematical summary of the payload data and does not have to meet any proof standard. At step **602** the system gets a timestamp for the root block. The distributed network follows rules for accepting new blocks that require the timestamp to be within a certain range. A timestamp that appears to be spoofed or faked will result in rejection of the root block by the distributed network.

[0059] At step **603**, the short hash is computed. The short hash uses at least the payload hash and timestamp as inputs, and may include other parts of the block as well. Including more parts of the block in the short hash improves the reliability and security of the slidechain by making it more difficult to spoof an apparently authorized chain fork. At step **604**, the fork block is created with the short hash from the root block stored as the authorized hash in the fork block. At step **605**, the block hash for the fork block is computed. The block hash must meet the proof standard stored in the fork block. This is accomplished by repeatedly adjusting the nonce until a hash is found that meets the proof standard.

[0060] At step **606**, the block hash from the fork block is stored as the previous hash in the root block. This completes the two-way reference between the fork block and the root

block, ensuring that the root block represents an authorized and valid fork from the fork block. At step **607**, the root block is validated or finalized by finding a block hash that meets the proof standard stored in the root block. This concludes the explanation of the slidechain. Following is a description of voting system and method implementations which use a standard blockchain technology or slidechain technology.

[0061] According to an embodiment of the voting system described herein, each voter is assigned a cryptographic key pair comprising a private key and a public key generated through asymmetric cryptography. The system may use any algorithm or standard for generating a key pair including ECDSA (Elliptic Curve Digital Signature Algorithm), RSA (Rivest Shamir Adleman) algorithm, or any other current or future key generation algorithm. The particular method for generating a key pair is not critical to the present invention. One or ordinary skill in the art would recognize that any method of generating a cryptographic key pair could be used without departing from the present invention. The voter is given either a physical representation of the keys printed as a barcode which may be the ballot itself, or an electronic storage device holding the key pair. The public key is used to uniquely identify the votes cast by the voter, and the private key is used to apply a digital signature to the votes. Each key pair is granted a single vote in each race that the voter is authorized to vote in. When a ballot or key pair is used to cast a vote, the ballot or key pair expires and can no longer be used to cast additional votes.

[0062] The private key is used to produce a digital signature of the voting data submitted by the voter. The digital signature can be verified using the public key without accessing the private key. A voter cannot digitally sign the voting data that corresponds to another voter's public key. This prevents a malicious actor from being able to change the voting data for other voters. The most a voter could do, without obtaining private keys would be to change the voting data corresponding to his own private key, which is hardly likely to influence the outcome of an election, and would, in the end, simply represent his own vote in the election.

[0063] FIG. **7** shows a block diagram of a proprietary voting machine **701** used in the present voting system according to an embodiment of the present invention. The voting machine **701** is a computerized system running software in conjunction with external hardware components, and includes a barcode scanner **702** for scanning data from a physical ballot. The voting machine includes a processor and computer readable memory loaded with voting software **703** and a proprietary blockchain client **704** software. The voting software receives the voting data from the voter by electronic input using a graphical interface, or through the scanner from the physical ballot, applies a digital signature to the voting data using the voter's private key. This signed voting data is passed to the blockchain client **704** which broadcasts the data to the distributed network through the network interface **705**.

[0064] The voting data is packaged in a blockchain block and the block is solved to be added to the blockchain by finding a valid hash for the block as described above and in the parent application. The voting data may be packaged in a blockchain block before being broadcast to the distributed network, or the signed voting data may be broadcast naked. When the voting data is broadcast naked, one or more of the voting machines on the network will package the data into a blockchain block and find a valid hash so it can be added to the blockchain. Alternatively, the blockchain client and voting software can be combined into a single software bundle, or the duties of applying a digital signature, packaging the vote data in a data block, and finding a valid hash can be shared or accomplished by one or the other software component. One of ordinary skill in the art would recognize that either the voting software **703** or the blockchain client **704**, or a third software component could assume any one or all of the steps described above.

[0065] FIG. **8**. Shows a network diagram of a distributed network of voting machines according to an embodiment of the present invention. Each voting machine is a node in the larger distributed network **803** connected through the internet and is capable of participating in accepting votes, and solving for new blocks on the blockchain. Alternatively voting machines may be added to the network with the sole purpose of solving for new blocks on the network. The voting data is broadcast to the whole network and all voting machines work simultaneously to solve the next block in the chain. According to one embodiment of the present invention, the voting machines are grouped into Zone **1 801** and Zone **2 802**. Zone **1 801** and Zone **2 802** may be located in separate municipalities with separate races where the voters in one municipality cannot vote in the election of the other municipality. Alternatively the zones may be assigned to separate districts with their own local elections and a larger regional election occurring simultaneously.

[0066] There are a variety of ways that the blockchain could be organized when voting machines are distributed among different elections that are either overlapping or completely independent of each other. According to one embodiment, a separate blockchain is created for each election district. According to another embodiment, a separate blockchain is used for each race. In this embodiment, the local races would have their own blockchain, but a larger overlapping regional election would share a blockchain across Zone **1 801** and Zone **2 802**. According to another embodiment, all voting data in all elections in all zones is stored on a single blockchain. Within Zone **1 801** and Zone **2 802**, a variety of different voting machine configurations can be used. These different voting machine configurations can be based on a desktop PC, laptop, dummy terminal, mobile computer, or PDA. The voting machines in each zone may be produced by different manufacturers or owned by different voting machine equipment providers. Each voting machine follows a common protocol in communicating with the distributed network **803** and solving for new blocks on the one or more blockchains stored in the network.

[0067] According to one embodiment of the present invention, voting machines are configured to accommodate voting in the zone where they reside. For example, the voting machines will allow only votes cast in elections that the voter is allowed to vote in. Each voting machine may be preconfigured with the fields for state, county, municipality, election district, the district for each office for which an election is held and in which the voter resides and which district boundaries are not contiguous with either the municipal, county or state boundaries. Alternatively, The keypairs can and will be customized to the individual voter on data fields including, without limitation, the fields for state, county, municipality, election district, the district for each office for which an election is held and in which the

voter resides and which district boundaries are not contiguous with either the municipal, county or state boundaries. These fields are stored in the blockchain as the voting data to designate which election each vote belongs to.

[0068] FIG. **9** is a diagram of a voting block **900** on the blockchain according to an embodiment of the present invention. As with a standard blockchain, the voting block includes a hash of the previous block stored in the previous hash **901** of the block **900**. In this embodiment, the voting data **903**, the digital signature **904** of the voting data, and the updated voting count **905** are all stored in the payload **902** of the block.

[0069] FIG. **10** shows a blockchain for storing voting data according to an embodiment of the present invention. The genesis block **1001** marks the beginning of the blockchain and may or may not store any voting data. Each voting block **1002** includes the hash of the preceding block and the votes of a single voter. Alternatively, votes from multiple voters, with their corresponding digital signatures can all be stored in the same voting block **1002**.

[0070] In order to ensure that all the blocks can be solved within a reasonable amount of time after all votes have been cast, the difficulty of the proof standard can be adjusted and the maximum size of the blocks can be increased according to the number of voters voting in an election and the number of voting machines in use. For example, in a small municipal election, although only a handful of voting machines would be sufficient to receive every vote cast, additional voting machines can still be included in the distributed network from anywhere with an internet connection in order to help solve for blocks in the blockchain. As more voting machines participate in the distributed network, even if they are not directly used by voters, the difficulty of the proof standard can be increased without delaying the tallying or counting of votes. As the difficulty of the proof standard is increased, it becomes more difficult for a malicious actor to take control of the network and improperly influence the election outcome or change results after the election is over. Therefore it is advantageous to use as many voting machines as possible on the distributed network even for a small election.

[0071] FIG. **11** shows the connection between a voting block and a corresponding counting block when two blockchains are used to store voting data and counting data according to an alternate embodiment of the present invention. Each voting block **1100** stores a hash of the previous voting block in the voting blockchain in the voting previous hash **1101**; likewise, each counting block **1105** stores a hash of the previous counting block in the counting blockchain as the counting previous hash **1106**. Each counting block **1105** in the counting blockchain additionally stores a hash of the voting block whose votes it uses to update the voting count. The voting payload **1104** stores the voting data **1102** and the digital signature **1103** of the voter that submitted the voting data **1102**. The counting payload **1109** stores the updated voting count **1108** that results from the voting data stored in the voting block whose hash is stored in the voting hash **1107**.

[0072] FIG. **12** shows a voting blockchain **1201** and a counting blockchain **1203** which propagate in tandem. For each voting block **1202** added to the voting blockchain **1201**, a counting block **1204** is created with a reference to the hash of the voting block **1202**. The hash of each voting block **1202** is stored both in the next voting block and in a corresponding counting block **1204**. The counting block **1204** adds the votes in the referenced voting block **1202** to the count and stores it in the counting payload **1109**. This ties the counting block **1204** to a specific voting block **1202** and allows easy auditing of the votes stored in the voting blockchain **1201** and count stored in the counting blockchain **1203**.

[0073] According to an embodiment of the present invention, the counting blockchain **1203** grows at exactly the same rate as the voting blockchain **1201**. After each voting block **1100** is solved, the hash from that newly solved voting block **1100** is stored as the voting hash **1107** in the next counting block and the updated voting count is stored in the counting block payload **1109**. The voting count is updated simply by reading the voting count of the previous counting block and updating the voting count according to the votes cast in the last voting block. Because the counting block includes a hash of the voting block, the counting block corresponding to a particular voting block is always solved after the voting block. This improves security by adding an additional layer of verification and increasing the computation that must be done in order to change data stored in the blockchain. For example, if a malicious actor somehow changes a vote in the voting blockchain, the hash will change, and break the link to the corresponding counting block in the counting blockchain, forcing the malicious actor to re-compute not only the voting blockchain, but the counting blockchain as well. If the malicious actor tries to modify only the counting blockchain, it will be readily apparent that the count does not correspond to the votes in the voting blockchain.

[0074] According to another embodiment of the present invention, the counting blockchain need not have exactly the same number of blocks as the voting blockchain. Each counting block can simply reference the latest voting block and update the count based on every voting block created since the voting block referenced by the previous counting block. This will allow arbitrarily sized gaps between the voting blocks that are referenced by the counting blocks.

[0075] According to an embodiment of the present invention, the solving of counting blocks can be opened to the public, rather than relying solely on the computing power of the voting machines. A vote counting blockchain client may be provided which any user can install on their own computer and use to solve counting blocks. Since counting blocks only deal with information that has been securely stored in the voting blockchain, and do not need access to private keys, there is no security risk in allowing the public to participate in solving counting blocks. An incentive reward, such as digital coins, rewards points, or tax exemption points, may be provided to the user that solves each counting block. As the public distributed network solving for counting blocks grows larger, it becomes increasingly difficult for a malicious actor to tamper with voting data. Even if a malicious actor was able to spoof or otherwise obtain a large number of unused private keys and significantly alter the voting blockchain, managed by the voting machines, the size of the public distributed network solving the counting blockchain would make it prohibitively expensive to modify the counting blockchain to match the modified voting blockchain.

[0076] FIG. **13** is a diagram showing the connection between a voter block **1301** and a voting block according to an embodiment of the present invention using slidechain technology. Each voter block **1301** creates a fork from the

root chain. The root chain is chain that extends from the genesis block without following a fork. The fork chains created with each voter block **1301** stores the voting data belonging to a voter identified in the voter block **1301** that created the fork chain. Therefore, each fork chain created by a voter block **1301** will only have a single block storing voting data.

[0077] The voter block **1301** stores the hash of the previous block as the voter previous hash **1302** and the hash of the valid fork as the voting hash **1303**. The voter payload **1306** contains voter data **1304** identifying the voter, which may comprise the voter's public key, an identifier for each election in which the voter is allowed to cast a vote, state, county, municipality, election district, the district for each office for which an election is held and in which the voter resides and which district boundaries are not contiguous with either the municipal, county or state boundaries. A voter digital signature **1305** may also be applied to prevent unauthorized changes to the data in the voter payload **1306**.

[0078] The voting block stores the voter block has as the voting previous hash **1308** and the voting payload **1312** is used, at least in part, to produce a short hash which is stored in the voter block as the voting hash **1303**. The voting payload **1312** stores the actual vote data **1309** of the voter, with a voting digital signature **1310**, and an end chain script **1311** which prevents further votes on the fork chain produced by the voter block **1301**. The end chain script enforces the one vote per voter rule and prevents further votes from being cast on the fork chain.

[0079] FIG. **14** shows a diagram of the slidechain used to store voter data and voting data according to an embodiment of the present invention. The slidechain implementation has only a single blockchain **1400**, but each voter block **1401** produces a fork in the chain where votes are stored for a particular voter. According to an embodiment of the present invention, the voter is identified in the voter block. Each fork contains only a single voting block **1402**, which stores the votes cast by the voter identified in the voter block **1401**.

[0080] FIG. **15** shows a diagram of the slidechain used to store voter data and voting data according to an alternate embodiment of the present invention. In order to create a valid fork chain, slidechain technology stores within the fork block a hash of at least part of the root block of a valid fork. The short hash is computed from the root block **1502**, excluding the root block's **1502** previous hash. This short hash is stored in the voter block **1501**, which acts as the fork block, completing the voter block **1501** and allowing the voter block **1501** hash to be computed. The voter block **1501** hash is then stored in the root block **1502**, completing the root block **1502** and allowing the root block **1502** to be solved by finding a valid hash. This means that, at least according to one embodiment of the slidechain, the data stored in a root block **1502** must be known before the voter block **1501** can be completed.

[0081] According to one embodiment of the present invention, if the voting data is stored in a voting block **1503** chained to the root block **1502** rather than the root block itself, the slidechain can be used as a voter registration database. Voter data can be stored in the voter block for every registered voter and the rules that apply to the fork chains in the election are stored in the root blocks **1502**. As long as the data for the election and the voter are known in advance, a voter block and root block can be computed or pre-mined in advance for every voter. When each voter casts a vote, the voting data will be stored on that voter's corresponding fork chain in a voting block **1503** that chains onto the root block **1502**. Any voter that does not vote will leave an empty fork chain as shown where no voting block is chained to the root block **1504**. Pre-mining blocks on the slidechain allows processing of the election to speed up because computing power can be concentrated on solving the voting blocks without having to solve the voter blocks and root blocks during the election.

[0082] According to an embodiment of the present invention, the voting count is updated using a counting chain **1505** which is a specific fork chain on the slidechain dedicated to updating the count in the election. Each time a voter casts a vote, a new counting **1506** block is added to the counting chain **1505** which adds the voter's votes to the voting count from the previous block in the counting chain **1505**, and stores the updated voting count in a new counting block **1506** on the counting chain **1505**.

[0083] FIG. **16** shows a flowchart of a process for voting according to an embodiment of the present invention. It is assumed that at the start of the process shown in FIG. **16**, the voter's identity has been verified and the voter is allowed to vote under whichever laws apply in the jurisdiction. At step **1601**, the voter is issued a private key. This private key may be issued as a barcode printed on a piece of paper or another physical medium, a private key printed as a barcode on a physical ballot, or on an electronic medium such as a USB storage device, RFID device, or other computer readable medium.

[0084] At step **1602**, the private key is received at the voting machine. If the private key is a barcode it is received through a scanner on the voting machine. If the private key is on an electronic storage medium, it is received through whatever means is appropriate for the electronic storage medium.

[0085] At step **1603**, the validity of the private key is verified. Not just any private key can be used to vote. Otherwise, anyone could spoof votes simply by generating key pairs and using them to send votes to the distributed network. The voting machine checks to make sure the private key was issued through the proper authority, and has not yet been used.

[0086] At step **1604**, the voting machine receives votes from the voter, this is done electronically through a graphical interface of the voting machine, or by scanning a physical ballot through the voting machine's scanner.

[0087] At step **1605**, the votes are converted to a transaction format that is valid for storage on the blockchain. According to one embodiment, this involves storing the public key to uniquely identify the voter and the electronic identifiers of the candidates that the voter voted for. Typically the electronic identifiers of the candidates will also be public keys, but any identifier could be used to uniquely identify which candidates the voter voted for.

[0088] At step **1606**, the voting data is digitally signed using the voter's private key. This signature is verifiable mathematically using the voting data and the voter's public key stored with the voting data. The digital signature prevents others from modifying the voting data and proves that the voting data was produced by the voter that holds the private key corresponding to the public key stored with the voting data.

[0089] At step **1607**, the voting data is broadcast to the distributed network. Once the voting data is available to the

distributed network, one or more of the voting machines that act as nodes on the distributed network can try to solve for the next block with the voting data included in the payload of the voting block.

[0090] According to an embodiment of the present invention, the voting system combines three different security systems, of which none can be compromised or disabled in the same way. The three systems are (a) a physical record through paper or other hard copy version of a voting ballot, (b) a cloud based protection which would use a computer interface and the internet to transfer results taken after the scanning of special, one-use-only ballots and offload them onto a cloud storage, and (c) storage on a customized blockchain or blockchain type apparatus. Results would be stored in each of these three media. However, vote counting should be done using the two computer media for the sake of timeliness. The paper record preservation can assist in auditing the vote and other records.

[0091] According to an embodiment of the present invention, a system may be comprised of an optical scanner apparatus connected via a network or cable to a computer server. In this embodiment, the server may also connected to: a computer-readable storage medium that retains instructions and data, including a "write once" storage device (such as a Digital Versatile Disc, or "DVD", recording device); a network hardware interface whose operation can be disabled manually and visually confirmed to be operable or inoperable (such as by a network cable connection; or by using a previously attested dedicated network connection hardware indicator and physical switch that does not involve the direct use of software instructions that can be altered); and a computer printer. The primary purpose of such an embodiment is to scan election ballots marked by hand with checkmarks or crossmarks; record them onto the storage media of the "write once" device; on an elective basis print a summary of choices cast by ballot; and securely update a publicly viewable hash-based proof-of-work chain of transaction blocks (or "block chain") with ballot choices; thus providing a reliable audit trail of election voting.

[0092] According to an embodiment of the present invention, for the purposes of an in-use specimen, the system may date interacted with a hash-based proof-of-work chain of transaction blocks (or "block chain") having specific access permissions preventing modification by the public and using an application programming interface (API), where voting transactions were substituted for transactions of "bitcoin" currency generation and transfer; and comments of voting choices were also applied to the voting transactions of this hash-based proof-of-work chain of transaction blocks (or "block chain").

[0093] According to an embodiment of the present invention, an ability to interact with hash-based proof-of-work chains of transaction blocks (or "block chains") may also been integrated into a production specimen, along with an application to a separate hash-based proof-of-work chain of transaction blocks (e.g., "Florincoin"), thus further demonstrating the versatility of embodiments of this system to interact with various hash-based proof-of-work chains of transaction blocks (or "block chains") not just limited to those modeled on standards established by the "Bitcoin Core" software.

[0094] According to an embodiment of the present invention, for the purposes of improved security and to thwart compromise of such a system via network access, the system's interaction with a hash-based proof-of-work chain of voting transactions via its network hardware interface can be deferred until completion of all ballot scanning has been performed and transferred to the system's "write once" media. During the ballot scanning process, the network connection can remain disconnected. Consistency between the data stored on this media and a hash-based proof-of-work chain of voting transactions serves as an additional measure to prevent tampering with an election's results.

[0095] According to an embodiment of the present invention, software instructions on the server can be used to facilitate the generation of election ballots prior to an election using a specification based on the popular software industry standard of Extensible Markup Language (or "XML"). Any errors or contradictions made in the specification of voting choices are informatively reported to the operator upon submission to the server.

[0096] According to an embodiment of the present invention, once ballots are designed using a server's XML specification facility, they can be printed along with the simultaneous generation of voting transaction blocks on the hash-based proof-of-work chain of transaction blocks. Ideally, this initial ballot and voting transaction block preparation should be done by parties who are not directly performing the later distribution, optical scanning, and retrieval of these ballots; such a "separation of concerns" encourages checks and balances of the voting process, with each group of parties scrutinizing the integrity of the others actions.

[0097] According to an embodiment of the present invention, server instructions impart unique "QR codes" (per the public specification of the International Standards Organization: ISO/IEC 18004) to each ballot that are based on unique account addresses used by a hash-based proof-of-work chain of transaction blocks (or "block chain").

[0098] According to an embodiment of the present invention, since voting transactions are effectively used as records of account, with each ballot being given an allocation and having an address, an elective option is supported for allocation of voting transactions to an intermediary voter's address, as opposed to a final address, to enable support for voting by proxy. "Proxy voting" can be accommodated so long as: 1) the address of any proxy voter has been listed on the ballot through use of the aforementioned XML specification; and 2) the scanning of ballots of proxy voters on behalf of other voters are only scanned upon completion of scanning of all non-proxy voters.

[0099] According to an embodiment of the present invention, printed paper ballots accommodate a standard checkbox next to each voting choice which, per instructions printed on the ballot and specifications in the original XML layout, can be used to indicate either a single choice or multiple choices for any given propositions being voted on. Informative validation of the ballot is performed either at the time each ballot is scanned, or en-mass (or as a "batch", for the purposes of a later audit), per the specification of poll-workers, to prevent the entry of excess choices for any given ballot proposition; or to enforce any stipulated required choices that cannot be left blank.

[0100] According to an embodiment of the present invention, in addition to the server recording votes onto "write once" media to prevent later alteration of the voting record, the server can also impart a uniquely visible "QR code" label to that same media based on a cryptographic "checksum" of the voting transaction ids used in the hash-based proof-of-

work chain of transaction blocks. The checksum is a series of alphanumeric characters that are consistently reproduced when based on a larger set of voting transaction ids (an alteration of that set of voting transaction ids would result in a different checksum, thus identifying alteration of recorded ballot data). Checksums used to date have been generated according to the "AES" encryption standard; other popular and compact checksum encryption standards could also be readily supported. Checksums can be printed on an elective and periodic basis during ballot scanning, to be stored with those ballots in order to expedite audit and validation of them on a later date.

[0101] Traditionally, a computer program consists of a finite sequence of computational instructions or program instructions. It will be appreciated that a programmable apparatus (i.e., computing device) can receive such a computer program and, by processing the computational instructions thereof, produce a further technical effect.

[0102] A programmable apparatus includes one or more microprocessors, microcontrollers, embedded microcontrollers, programmable digital signal processors, programmable devices, programmable gate arrays, programmable array logic, memory devices, application specific integrated circuits, or the like, which can be suitably employed or configured to process computer program instructions, execute computer logic, store computer data, and so on. Throughout this disclosure and elsewhere a computer can include any and all suitable combinations of a special-purpose computer, programmable data processing apparatus, processor, processor architecture, and so on.

[0103] It will be understood that a computer can include a computer-readable storage medium and that this medium may be internal or external, removable and replaceable, or fixed. It will also be understood that a computer can include a Basic Input/Output System (BIOS), firmware, an operating system, a database, or the like that can include, interface with, or support the software and hardware described herein.

[0104] Embodiments of the system as described herein are not limited to applications involving conventional computer programs or programmable apparatuses that run them. It is contemplated, for example, that embodiments of the invention as claimed herein could include an optical computer, quantum computer, analog computer, or the like.

[0105] Regardless of the type of computer program or computer involved, a computer program can be loaded onto a computer to produce a particular machine that can perform any and all of the depicted functions. This particular machine provides a means for carrying out any and all of the depicted functions.

[0106] Any combination of one or more computer readable medium(s) may be utilized. The computer readable medium may be a computer readable signal medium or a computer readable storage medium. A computer readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer readable storage medium would include the following: an electrical connection having one or more wires, a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), an optical fiber, a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer readable storage medium may be any tangible medium that can contain, or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0107] According to an embodiment of the present invention, a data store may be comprised of one or more of a database, file storage system, relational data storage system or any other data system or structure configured to store data, preferably in a relational manner. In a preferred embodiment of the present invention, the data store may be a relational database, working in conjunction with a relational database management system (RDBMS) for receiving, processing and storing data. In the preferred embodiment, the data store may comprise one or more databases for storing information related to the processing of moving information and estimate information as well one or more databases configured for storage and retrieval of moving information and estimate information.

[0108] Computer program instructions can be stored in a computer-readable memory capable of directing a computer or other programmable data processing apparatus to function in a particular manner. The instructions stored in the computer-readable memory constitute an article of manufacture including computer-readable instructions for implementing any and all of the depicted functions.

[0109] A computer readable signal medium may include a propagated data signal with computer readable program code embodied therein, for example, in baseband or as part of a carrier wave. Such a propagated signal may take any of a variety of forms, including, but not limited to, electromagnetic, optical, or any suitable combination thereof. A computer readable signal medium may be any computer readable medium that is not a computer readable storage medium and that can communicate, propagate, or transport a program for use by or in connection with an instruction execution system, apparatus, or device.

[0110] Program code embodied on a computer readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber cable, RF, etc., or any suitable combination of the foregoing.

[0111] The elements depicted in flowchart illustrations and block diagrams throughout the figures imply logical boundaries between the elements. However, according to software or hardware engineering practices, the depicted elements and the functions thereof may be implemented as parts of a monolithic software structure, as standalone software modules, or as modules that employ external routines, code, services, and so forth, or any combination of these. All such implementations are within the scope of the present disclosure.

[0112] In view of the foregoing, it will now be appreciated that elements of the block diagrams and flowchart illustrations support combinations of means for performing the specified functions, combinations of steps for performing the specified functions, program instruction means for performing the specified functions, and so on.

[0113] It will be appreciated that computer program instructions may include computer executable code. A variety of languages for expressing computer program instructions are possible, including without limitation C, C++, Java, JavaScript, assembly language, Lisp, HTML, Perl, and so on. Such languages may include assembly languages, hard-

ware description languages, database programming languages, functional programming languages, imperative programming languages, and so on. In some embodiments, computer program instructions can be stored, compiled, or interpreted to run on a computer, a programmable data processing apparatus, a heterogeneous combination of processors or processor architectures, and so on. Without limitation, embodiments of the system as described herein can take the form of web-based computer software, which includes client/server software, software-as-a-service, peer-to-peer software, or the like.

[0114] In some embodiments, a computer enables execution of computer program instructions including multiple programs or threads. The multiple programs or threads may be processed more or less simultaneously to enhance utilization of the processor and to facilitate substantially simultaneous functions. By way of implementation, any and all methods, program codes, program instructions, and the like described herein may be implemented in one or more thread. The thread can spawn other threads, which can themselves have assigned priorities associated with them. In some embodiments, a computer can process these threads based on priority or any other order based on instructions provided in the program code.

[0115] Unless explicitly stated or otherwise clear from the context, the verbs "execute" and "process" are used interchangeably to indicate execute, process, interpret, compile, assemble, link, load, any and all combinations of the foregoing, or the like. Therefore, embodiments that execute or process computer program instructions, computer-executable code, or the like can suitably act upon the instructions or code in any and all of the ways just described.

[0116] The functions and operations presented herein are not inherently related to any particular computer or other apparatus. It is possible to modify or customize general-purpose systems to be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will be apparent to those of skill in the art, along with equivalent variations. In addition, embodiments of the invention are not described with reference to any particular programming language. It is appreciated that a variety of programming languages may be used to implement the present teachings as described herein, and any references to specific languages are provided for disclosure of enablement and best mode of embodiments of the invention. Embodiments of the invention are well suited to a wide variety of computer network systems over numerous topologies. Within this field, the configuration and management of large networks include storage devices and computers that are communicatively coupled to dissimilar computers and storage devices over a network, such as the Internet.

[0117] Throughout this disclosure and elsewhere, block diagrams and flowchart illustrations depict methods, apparatuses (i.e., systems), and computer program products. Each element of the block diagrams and flowchart illustrations, as well as each respective combination of elements in the block diagrams and flowchart illustrations, illustrates a function of the methods, apparatuses, and computer program products. Any and all such functions ("depicted functions") can be implemented by computer program instructions; by special-purpose, hardware-based computer systems; by combinations of special purpose hardware and computer instructions; by combinations of general purpose hardware specialized through computer instructions; and so on—any and all of which may be generally referred to herein as a "circuit," "module," or "system."

[0118] While the foregoing drawings and description set forth functional aspects of the disclosed systems, no particular arrangement of software for implementing these functional aspects should be inferred from these descriptions unless explicitly stated or otherwise clear from the context.

[0119] Each element in flowchart illustrations may depict a step, or group of steps, of a computer-implemented method. Further, each step may contain one or more sub-steps. For the purpose of illustration, these steps (as well as any and all other steps identified and described above) are presented in order. It will be understood that an embodiment can contain an alternate order of the steps adapted to a particular application of a technique disclosed herein. All such variations and modifications are intended to fall within the scope of this disclosure. The depiction and description of steps in any particular order is not intended to exclude embodiments having the steps in a different order, unless required by a particular application, explicitly stated, or otherwise clear from the context.

[0120] The functions, systems and methods herein described could be utilized and presented in a multitude of languages. Individual systems may be presented in one or more languages and the language may be changed with ease at any point in the process or methods described above. One of ordinary skill in the art would appreciate that there are numerous languages the system could be provided in, and embodiments of the present invention are contemplated for use with any language.

[0121] While multiple embodiments are disclosure, still other embodiments of the present invention will become apparent to those skilled in the art from this detailed description. The invention is capable of myriad modifications in various obvious aspects, all without departing from the spirit and scope of the present invention. Accordingly, the drawings and descriptions are to be regarded as illustrative in nature and not restrictive.

1. A voting system comprising:

one or more voting machines connected to each other by network connections to form a distributed network;

wherein each of said one or more voting machines comprises:

a computer processor;

a non-volatile computer-readable memory;

a scanner configured to read data from barcodes and/or voting ballots; and

a network interface;

wherein the non-volatile computer-readable memory is configured with computer instructions configured to:

receive a private key and public key pair from a voter,

receive voting data comprising one or more votes for one or more candidates in an election,

use said private key to digitally sign said voting data to produce signed voting data,

broadcast said signed voting data with said public key to a distributed network, and

store said signed voting data with said public key on a blockchain database managed by the one or more voting machines forming said distributed network.

2. The system of claim **1** wherein said computer instructions are further configured to:

store voting data with said public key in a voting block on a voting blockchain;

update a voting count according to said voting data; and

store said voting count in a counting block on a counting blockchain, wherein each counting block also stores a hash of the voting block storing the voting data which was used to update the voting count, the result of which is stored in the counting block.

3. The system of claim **1** wherein said computer instructions are further configured to:

store, in a voter block which is a fork block of a slidechain, voter data identifying the voter and elections in which said voter is allowed to cast votes,

store voting data from said voter in a voting block which is a slidechain root block storing a voter hash of said voter block,

wherein said voter block also stores a voting hash computed from data in said voting block, and

accept the longest chain on said slidechain as a valid chain and accept as valid a chain where any voter block stores a voting hash of a voting block which, in turn, stores a voter hash of said any voter block.

4. The system of claim **3** wherein said computer instructions are further configured to:

update a voting count according to said voting data;

store said voting count in a counting block on a counting chain which is a fork chain of said slidechain, and

wherein each counting block in said counting chain also stores a hash of an immediately preceding counting block.

5. The system of claim **1** wherein said computer instructions are further configured to:

store, in a voter block which is a fork block of a slidechain, voter data identifying the voter and elections in which said voter is allowed to cast votes,

create a slidechain root block storing a voter hash of said voter block,

store, in said voter block, a root hash computed from data in said root block,

store said voting data in a voting block

store said root hash in said voting block, and

accept the longest chain on said slidechain as a valid chain and accept, as valid, a chain where any voter block stores a root hash of a root block which, in turn, stores a voter hash of said any voter block.

6. The system of claim **6** wherein said computer instructions are further configured to:

update a voting count according to said voting data;

store said voting count in a counting block on a counting chain which is a fork chain of said slidechain, and

wherein each counting block in said counting chain also stores a hash of an immediately preceding counting block.

7. A method of securing voting data comprising the steps of:

receiving voting data produced by a voter;

receiving a private key and public key corresponding to said voter;

signing the voting data with said private key to produce signed voting data;

storing the signed voting data in a voting block on a voting blockchain;

updating a voting count based on said voting data; and

storing said voting count in counting block of a counting blockchain, wherein the counting block a has of an immediately preceding block in the counting blockchain and stores a voting hash of the voting block containing the voting data used to update the voting count stored in the counting block.

* * * * *