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### TAMPER-PROOF BATCH RECORDS

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#### Abstract

A system and method for creating and managing tamper-proof batch records are provided. An illustrative method initiating a batch transaction to be completed, where the batch transaction relates to a batch recipe of a batch production. The method further includes comparing the batch transaction against one or more rules defined in a batch endorsement policy, confirming, based on the comparison, that the batch transaction meets the endorsement policy. The method also includes transmitting a batch transaction validation request. The method further includes confirming that an entry has been added to an immutable distributed digital ledger in response to the batch transaction validation request and reporting that the immutable distributed digital ledger has been updated to include the entry.

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#### Background/Summary

## FIELD OF THE DISCLOSURE

[0001] The invention relates generally to batch processing and, in particular, toward securely documenting batch processing.

## BACKGROUND

[0002] Batch production is a manufacturing process in which a specific quantity of a product is produced at one time, known as a batch. In batch production, the production process is designed to create a predetermined quantity of a product, typically in a single production run. This process is often used in industries where the production of a specific quantity of a product is needed, such as food and beverage, pharmaceuticals, and cosmetics.

[0003] The batch production process involves several steps, including: raw material procurement; mixing and blending; processing; packaging; and quality control. In raw material procurement, the raw materials required for the production process are acquired and inspected to ensure they meet the necessary quality standards. In mixing and blending, the raw materials are mixed or blended together according to a specific formula or recipe. In processing, the blended materials are processed using specific techniques such as heating, cooling, and/or filtering. In packaging, a finished product is packaged in containers or packaging materials, labeled, and prepared for distribution. The quality control step may be performed throughout the batch production process. Quality control measures are taken to ensure that the product meets a required quality standards.

[0004] Batch transaction recording systems exist. However, existing batch transaction recording systems are not tamper-proof and/or lack transparency. In this way, existing batch transaction recording systems leave much to be desired.

## SUMMARY

[0005] These and other needs are addressed by the various embodiments and configurations of the present invention. The present disclosure can provide a number of advantages depending on the particular configuration. These and other advantages will be apparent from the disclosure of the invention(s) contained herein.

[0006] According to at least some aspects of the present disclosure, systems and methods are described which make use of digital ledger technology (e.g., blockchain, a digital distributed ledger, etc.). A distributed ledger according to the present disclosure may include a record of consensus with a cryptographic audit trail maintained and validated by nodes. The distributed ledger can be decentralized or centralized. Blockchain technologies provide one mechanism for implementing a distributed ledger, but not all distributed ledgers necessarily employ blockchains. In addition to leveraging distributed ledger technology, embodiment of the present disclosure may also utilize text mining techniques to automatically process the batch control system transaction to create a batch record and store it on to the digital ledger, which is immutable (e.g., tamper-proof).

[0007] According to at least some aspects, a batch operator may utilize one or more control systems, such as a human-machine interface (e.g., Human Interface Station (HIS) of Field Control Station (FCS)) to start production of a new batch. An operator may load a batch recipe into the HIS to start the batch process. Each and every action from an operator and intermediate steps between a start event and a completion event may be recorded on the distributed ledger and may further be reported to all HISs in a network. Current systems collect batch information and store the collected information in one or more databases to produce a batch report; however, these database are neither tamper-proof nor completely secure.

[0008] Detecting a transaction in a batch may require a lot of data processing, which can demand a lot of computing resources. Distributing transaction processing for real-time transaction tracking and recording as disclosed herein improves efficiency by usage of computing power on distributed nodes to detect a transaction in a batch.

[0009] According to at least some embodiments, a batch agent is contemplated to be deployed on multiple computing nodes in a batch chain network (e.g., a distributed computing network). A

batch agent, in some embodiments, may reside in some or all HIS nodes of a batch chain network. The batch agent may be configured to perform batch transaction detection and reporting to a batch chains ordering service.

[0010] The batch chain ordering service may be configured to receive some or all information describing transactions from various nodes in the network. The batch chain ordering service may be further configured to order the information describing the transactions in a sequential manner and broadcast the ordered information describing the transactions to each node in the batch chain network. The batch chain ordering service may further receive votes from the nodes in the batch chain network to confirm a batch transaction.

[0011] In accordance with at least some embodiments, a batch chain may be created for each discrete batch process. Once the batch end transaction is reported by one or more nodes in the batch chain network and the batch end transaction is confirmed by the ordering service, a batch record may be created and stored to a distributed ledger. Recording of the batch record on the distributed ledger may then be replicated to additional or all nodes in the batch chain network such that each node's version of the distributed ledger accurately reflects a current state of the batch process.

[0012] Many advantages can be realized by implementing a batch chain network as depicted and described herein. For instance, the proposed systems and methods provide increased transparency. Specifically, and without limitation, a batch chain can provide a secure, tamper-proof ledger of all transactions related to a batch, including the production process, materials used, and quality control measures. This increased transparency can help manufacturers and supply chain partners to quickly identify any issues or defects in the batch, and to trace the batch back to its origin.

[0013] Another advantage offered by implementing a batch chain network as depicted and described herein is improved traceability. With the batch chain technology disclosed herein, every step of the production process can be recorded and tracked, making it easier to trace a batch back to its source. This can be particularly useful in industries such as food and beverage, where traceability is critical for ensuring food safety and compliance with regulations.

[0014] A batch chain network may also provide improved quality control measures. For instance, a batch chain network can enable manufacturers to track every aspect of a batch, from the raw materials used to the production process and quality control measures. This can help to identify any issues or defects in the batch, allowing manufacturers to take corrective action quickly and prevent further issues.

[0015] The aforementioned advantages help improve trust and security in the batch process. As mentioned above, batch chain technology as described herein can help provide a secure, tamper-proof ledger to increase trust and security throughout the supply chain. By providing an auditable record of every transaction related to a batch, the batch chain network can help to prevent fraud, counterfeiting, and other forms of supply chain risk.

[0016] Moreover, because a batch chain network may be distributed by its nature, the distributed processing of each transaction and verification of such transaction across the nodes can be performed in near-real-time. Improving the speed of batch reporting helps to remove delays in the ultimate creation of a batch record.

[0017] According to at least some embodiments, the time of event reporting from two or more nodes in the batch chain network may not differ by more than  $N$  mil seconds.  $N$  may correspond to any numerical value (integer or decimal) that is configured through a user interface for a batch recipe or learned from the historical events. An event may be reported from some or all members of a batch chain network.

[0018] Additionally, event may belong to tags in the batch recipe. Corelated tags can be mined from a control engineering database or can be configured through an engineering user interface. In some embodiments, events may follow in an expected sequence for the batch recipe. According to some aspects, the sequence of events pattern can be learned from the engineering data or learned from the historical events or configured through a user interface.

[0019] In one embodiment, a method is disclosed, including: initiating, at a batch agent of a computing node in batch chain network, a batch transaction to be completed, where the batch transaction relates to a batch recipe of a batch production; comparing the batch transaction against one or more rules defined in a batch endorsement policy; confirming, based on the comparison, that the batch transaction meets the endorsement policy; in response to confirming the batch transaction meets the endorsement policy, transmitting a batch transaction validation request to one or more additional computing nodes in the batch chain network, where the batch transaction validation request comprises information describing the batch transaction along with a request for the one or more additional computing nodes to validate and add the information describing the batch transaction to an immutable distributed digital ledger; confirming that an entry has been added to the immutable distributed digital ledger in response to the batch transaction validation request; and reporting, to the batch chain network, that the immutable distributed digital ledger has been updated (e.g., modified with an add or append operation) to include the entry.

[0020] In one embodiment, a system is disclosed, including: a processor; and a memory capable of storing data thereon that, when processed by the processor, cause the processor to: initiate a batch transaction, where the batch transaction relates to a batch recipe of a batch production; request endorsement of the batch transaction against a batch endorsement policy; confirm, based on a response to the requested endorsement, that the batch transaction meets the endorsement policy; in response to confirming the batch transaction meets the endorsement policy, transmit a batch transaction validation request to one or more computing nodes in a batch chain network, where the batch transaction validation request comprises information describing the batch transaction along with a request for the one or more computing nodes to validate and add the information describing the batch transaction to an immutable distributed digital ledger; confirm that an entry has been added to the immutable distributed digital ledger in response to the batch transaction validation request; and report that the immutable distributed digital ledger has been updated to include the entry.

[0021] In one embodiment, a node of a batch chain network is disclosed, the node including: at least a portion of a distributed digital ledger including one or more entries for a block chain having entries related to a batch production; and a batch agent that is configured to: initiate a batch transaction, where the batch transaction relates to a batch recipe of a batch production; request endorsement of the batch transaction against a batch endorsement policy; confirm, based on a response to the requested endorsement, that the batch transaction meets the endorsement policy; in response to confirming the batch transaction meets the endorsement policy, transmit a batch transaction validation request to one or more computing nodes in the batch chain network, where the batch transaction validation request comprises information describing the batch transaction along with a request for the one or more computing nodes to validate and add the information describing the batch transaction to the distributed digital ledger; confirm that an entry has been added to the distributed digital ledger in response to the batch transaction validation request; and report that the distributed digital ledger has been updated to include the entry.

[0022] It is to be appreciated that any feature described herein can be claimed in combination with any other feature(s) as described herein, regardless of whether the features come from the same described embodiment.

[0023] The phrases “at least one,” “one or more,” “or,” and “and/or” are open-ended expressions that are both conjunctive and disjunctive in operation. For example, each of the expressions “at least one of A, B, and C,” “at least one of A, B, or C,” “one or more of A, B, and C,” “one or more of A, B, or C,” “A, B, and/or C,” and “A, B, or C” means A alone, B alone, C alone, A and B together, A and C together, B and C together, or A, B, and C together.

[0024] The term “a” or “an” entity refers to one or more of that entity. As such, the terms “a” (or “an”), “one or more,” and “at least one” can be used interchangeably herein. It is also to be noted that the terms “comprising,” “including,” and “having” can be used interchangeably.

[0025] The term “automatic” and variations thereof, as used herein, refers to any process or operation, which is typically continuous or semi-continuous, done without material human input when the process or operation is performed. However, a process or operation can be automatic, even though performance of the process or operation uses material or immaterial human input, if the input is received before performance of the process or operation. Human input is deemed to be material if such input influences how the process or operation will be performed. Human input that consents to the performance of the process or operation is not deemed to be “material.”

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The present disclosure is described in conjunction with the appended figures:

[0027] FIG. 1 depicts a batch chain network in accordance with embodiments of the present disclosure;

[0028] FIG. 2 depicts a batch chain transaction flow in accordance with embodiments of the present disclosure;

[0029] FIG. 3A depicts a first aspect of a data structure in accordance with embodiments of the present disclosure;

[0030] FIG. 3B depicts a second aspect of a data structure in accordance with embodiments of the present disclosure;

[0031] FIG. 3C depicts a third aspect of a data structure in accordance with embodiments of the present disclosure;

[0032] FIG. 3D depicts a fourth aspect of a data structure in accordance with embodiments of the present disclosure;

[0033] FIG. 4 is a flow chart depicting a first method in accordance with embodiments of the present disclosure;

[0034] FIG. 5 is a flow chart depicting a second method in accordance with embodiments of the present disclosure;

[0035] FIG. 6 is a flow chart depicting a third method in accordance with embodiments of the present disclosure; and

[0036] FIG. 7 is a flow chart depicting a fourth method in accordance with embodiments of the present disclosure.

### DETAILED DESCRIPTION

[0037] The ensuing description provides embodiments only and is not intended to limit the scope, applicability, or configuration of the claims. Rather, the ensuing description will provide those skilled in the art with an enabling description for implementing the embodiments. It will be understood that various changes may be made in the function and arrangement of elements without departing from the spirit and scope of the appended claims.

[0038] Any reference in the description comprising a numeric reference number, without an alphabetic sub-reference identifier when a sub-reference identifier exists in the figures, when used in the plural, is a reference to any two or more elements with the like reference number. When such a reference is made in the singular form, but without identification of the sub-reference identifier, it is a reference to one of the like numbered elements, but without limitation as to the particular one of the elements being referenced. Any explicit usage herein to the contrary or providing further qualification or identification shall take precedence.

[0039] The example systems and methods of this disclosure will also be described in relation to analysis software, modules, and associated analysis hardware. However, to avoid unnecessarily obscuring the present disclosure, the following description omits well-known structures, components, and devices, which may be omitted from or shown in a simplified form in the figures

or otherwise summarized.

[0040] For purposes of explanation, numerous details are set forth to provide a thorough understanding of the present disclosure. It should be appreciated, however, that the present disclosure may be practiced in a variety of ways beyond the specific details set forth herein.

[0041] FIG. 1 depicts a batch chain network **100** in accordance with embodiments of the present disclosure. The batch chain network **100** is illustrated to include a plurality of nodes **112**, **116a-N**, **120a-N** in communication with one another via a voting network **104** and/or a blockchain network **108**. The voting network **104** and/or blockchain network **108** may correspond to different logical paths established over a common communication network. Illustratively and without limitation, the networks **104**, **108** may be established over a wired or wireless communication network that utilizes one or more packet-based communication protocols to exchange information between member nodes **112**, **116a-N**, **120a-N** of the batch chain network **100**. The voting network **104** may correspond to a first communication pathway used by the nodes **112**, **116a-N**, **120a-N** to exchange votes for a proposed transaction. Thus, the voting network **104** may utilize a first type of communication protocol (e.g., a polling protocol) to facilitate the request for votes and to facilitate the collection of votes from the various nodes **112**, **116a-N**, **120a-N**.

[0042] The blockchain network **108** may correspond to a second communication pathway used by the nodes **112**, **116a-N**, **120a-N** to exchange information for building and maintaining the distributed ledger **128**. Because the information exchanged as part of maintaining the distributed ledger **128** is different from the information exchanged as part of facilitating voting, the blockchain network **108** may utilize a second type of communication protocol (e.g., a data push protocol), which is different from the first type of communication protocol used by the voting network **104**. In some embodiments, while the same nodes **112**, **116a-N**, **120a-N** are connected to one another by both network **104**, **108**, it should be appreciated that different threads on each node may be responsible for supporting the different communication protocols of each network **104**, **108**.

[0043] The different nodes **112**, **116a-N**, **120a-N** may correspond to similar types of computing and/or communication devices. However, the roles of the nodes within the context of the network **100** may vary. Specifically, but without limitation, each node **112**, **116a-N**, **120a-N** may correspond to a Personal Computer (PC), laptop, tablet, kiosk, smartphone, portable computing device, or the like. Each device may include one or more processors and one or more memory devices. As an example, each node may include a processor such as a microprocessor, an Integrated Circuit (IC) chip, a Central Processing Unit (CPU), a Graphics Processing Unit (GPU), a Field Programmable Gate Array (FPGA), an Application Specific Integrated Circuit (ASIC), combinations thereof, or the like. Examples of general-purpose microprocessors may comprise, a CPU with data values encoded in an instruction register (or other circuitry maintaining instructions) or data values comprising memory locations, which in turn comprise values utilized as instructions. The memory locations may further comprise a memory location that is external to the CPU. Such CPU-external components may be embodied as one or more of an FPGA, read-only memory (ROM), programmable read-only memory (PROM), erasable programmable read-only memory (EPROM), random access memory (RAM), bus-accessible storage, network-accessible storage, etc.

[0044] The processor of each node may be coupled with one or more memory devices, which may include computer memory that stores data and/or instructions sets that are executable by the processor of the node. A non-limiting example of such instructions sets and/or data may include a batch agent **132** that is executable by a processor of the node and that enables the node to participate in a batch chain network as will be described herein. In addition to storing data and/or executable instructions, the memory device(s) may also be configured to store data that is part of a distributed ledger **128**. In some embodiments, the distributed ledger **128** may be stored in whole or in part on memory of the different nodes. As additional entries or blocks are written to the distributed ledger **128**, the data structure of the distributed ledger **128** may be updated to reflect the changes (e.g., modified with an add or append operation). As can be appreciated, the machine-

executable instructions or data may be stored on one or more machine-readable mediums, such as CD-ROMs or other type of optical disks, floppy diskettes, ROMs, RAMs, EPROMs, EEPROMs, magnetic or optical cards, flash memory, or other types of machine-readable mediums suitable for storing electronic instructions or data.

[0045] FIG. 1 illustrates a single HIS engineering node **112** and a plurality of HIS nodes **116a-N**. The number of HIS nodes may be any integer number that is greater than or equal to one. Similarly, FIG. 1 illustrates a plurality of FCS nodes **120a-N**. The number of FCS nodes may be any integer number that is greater than or equal to one. It should also be appreciated that while the number of HIS nodes **116a-N** is shown to be the same as the number of FCS nodes **120a-N**, such a configuration is not required. Indeed, the number of HIS nodes **116a-N** may be different from the number of FCS nodes **120a-N** in the batch chain network **100**. In other words, there may be a greater number of HIS nodes **116a-N** as compared to the number of FCS nodes **120a-N**, or vice versa.

[0046] Every HIS node **116a-N** and FCS node **120a-N** may be a member of the batch chain network **100**. In some embodiments, the HIS engineering node **112** may take the responsibility of ordering node, and one or more of the HIS nodes **116a-N** may take the responsibility of a committer node. One or more HIS nodes **116a-N** that do not participate as a committer node may participate as an endorser node, as will be described in further detail herein.

[0047] Referring now to FIG. 2, additional details of a batch chain transaction flow **200** will be described in accordance with at least some embodiments of the present disclosure. In accordance with at least some embodiments, a new batch transaction can be initiated from any of the HIS nodes in the network **100**.

[0048] When a transaction is initiated, the initiating HIS node **204** (e.g., ordering node **204**) may propose a new batch transaction **208** to the ordered node **116a**. In some embodiments, the ordering node **204** may request endorsement **220** from the endorser nodes **112**, **116a-N** as per the transaction response **216**. If the endorsement policy is met for the transaction, then the orderer node **112** may create a new block **212** in the world state. Until the end batch transaction is reported by any of the participating nodes and endorsed by the network **100**, the orderer node **112** adds up all transactions **224** to this batch record/block **212**. Once the orderer node **112** detects the batch closure, the block in the world state will be transferred to the committer node **116a** to commit to the distributed ledger **128**. Once the block **212** is added to the distributed ledger **128**, the block **212** becomes immutable and it becomes impossible to alter the record in the distributed ledger **128**. The immutability of the record may be achieved cryptographically and/or by the distribution of the entry(ies) across a plurality of nodes in the network **100**.

[0049] Referring now to FIGS. 3A-D, additional details of the data structure(s) **300** that may be used to construct the digital ledger **128** will be described in accordance with at least some embodiments of the present disclosure. As mentioned herein, the digital ledger **128** may be used to store an immutable record of a product's batch production. In this sense, the digital ledger **128** may be referred to as a batch chain record on which one or more batch transactions are recorded. The batch chain may be constructed of a plurality of data structures **300**. In some embodiments, a batch chain can represent the history of a product's batch production. The batch production method for a particular grade of product may be tagged to a recipe. A recipe may correspond to a set of steps to be performed to make a product.

[0050] A batch record may contain all transactions (e.g., operator actions, alarms, operator window history, etc.) in a sequential manner they occurred during the batch process. Once the batch is completed, this record can be added to the digital ledger **128** and there will be one chain per recipe of a product, even though a product may have multiple recipes.

[0051] FIG. 3A illustrates that the data structure of the distributed ledger **128** may include an overall ledger **304** comprises a blockchain **312** and world state **308**. In some embodiments, the blockchain **312** may be used to determine the world state **308**.

[0052] As shown in FIG. 3B, the blockchain **312** may include a plurality of blocks **316** that are linked together by a pointer or link **316**. A first block **316** in the blockchain **312** may correspond to a genesis or first block (e.g., block B0) whereas other blocks **316** pointing to the genesis or first block may be referred to as linked blocks **316** (e.g., blocks B1, B2, B3). Each block **316** may include a header **324**, block data **328**, and block metadata **332**. The block data **328** may be used to store transaction data **336**, which may also be referred to as an entry **336**. Each entry **336** may correspond to a different step or transaction performed during a batch process. The collection of entries **336** in the blockchain **312** may describe the entire process and, in some embodiments, may correspond to a description of a recipe used to produce a product. The entries **336** in the blockchain **312** may also include a description of quality assurance checks, materials used, processing steps followed, packaging steps performed, and other transactions that were included in a batch process.

[0053] As shown in FIG. 3C the header **324** of each block **316** may store information that supports the creation of the links **316**. Specifically, but without limitation, the header **324** may include a block identifier **340** for the block **324** in which the header **324** is provided. The header **324** may also include a current block hash **344** as well as a previous block hash **348**. The current block hash **344** may correspond to a hash or plurality of hash values calculated based on the current transactions **336** stored in the block data **328** of the block **316**. The previous block hash **348** may correspond to a hash value that is a copy of a hash value computed for a previous block **316**. The previous block hash **348** may help create the link between a block and a previous block in the blockchain **312**.

[0054] As shown in FIG. 3D, the entry **336** may correspond to an entry for one or multiple transactions performed during a batch process. The entry **336** may include a header **352**, a signature **356**, a proposal field **360**, a response field **364**, and one or more endorsement fields **368**. The header **352** may include a description of the entry **336** (e.g., with an identification number, a memory location, an order during a sequence of entries, or the like). The signature **356** may include a cryptographic signature for the particular entry **336**. The proposal field **360** may store information describing the transaction proposal **208**. The response field **364** may store information describing the transaction response **216**. The endorsements field(s) **368** may store information describing the endorsed responses **220**.

[0055] Referring now to FIGS. 4-7, various methods will be described in accordance with at least some embodiments of the present disclosure. While certain steps of certain method will be described as being performed in a particular order, it should be appreciated that embodiments of the present disclosure are not so limited. Indeed, the various steps of one or more methods may be performed in different orders than those illustrated. Similarly, one or more steps from one method may be performed in another method without departing from the scope of the present disclosure.

[0056] Referring initially to FIG. 4, a first method **400** will be described in accordance with at least some embodiments of the present disclosure. The method **400** begins when a new batch transaction proposal **208** is generated for a batch production (step **404**). The method **400** continues by communicating the new batch transaction(s) from one node in the network **100** to another node in the network **100** (step **408**). As a non-limiting example, an ordering node **204** may communicate a new batch transaction (e.g., a description of a batch transaction or an identification of a batch recipe) to another node in the network **100**, such as the HIS engineering node **112** or another HIS node **116a-N**.

[0057] The HIS engineering node **112** or other HIS node **116a-N** that received the information for the new batch transaction may then request one or more endorsements for the batch transaction (step **412**). The method **400** then proceeds by ensuring that the batch transaction(s) meet an endorsement policy **416** (step **420**). In some embodiments, this particular step may include comparing information from the batch transaction to the endorsement policy **416**.

[0058] If the batch transaction meets the endorsement policy **416**, then the method **400** may continue by determining whether a world state has been opened for the batch (step **424**). If no



world state has yet been opened for the batch, then the method **400** continues by creating a new block **212** in the world state for the transaction (step **432**). After the new block in the world state has been created, then an entry describing the transaction may be added to the newly-created block (step **436**).

[0059] Referring back to step **424**, if the query is answered positively, then the transaction may be appended to a block in the existing world state (step **428**). Following step **428** or **432**, the method **400** continues by determining if any additional transactions are included in the batch process (step **440**). This particular step may include determining if an end state has been entered for the batch process.

[0060] If any additional transactions remain for the batch process, then the method **400** returns to step **404**. However, if no additional transactions remain for the batch process, then the method **400** proceeds by finalizing the blockchain (e.g., completing entries for the digital ledger **128**). More specifically, the method **400** includes completing the addition of all transactions to the block (step **444**). Thereafter, the block and its corresponding entries are added to the blockchain **312** (step **448**). As noted above, the completed blockchain may also be referred to as a batch chain. To protect data at rest (e.g., on disk), it may be desirable to add encryption using the private key of the committer node. To decrypt the records, the nodes in the network shall make use of public key issued while joining the network.

[0061] Referring now to FIG. 5, another method **500** will be described in accordance with at least some embodiments of the present disclosure. The method **500** may be performed as part of method **400** or any other method described herein without departing from the scope of the present disclosure.

[0062] The method **500** begins by initiating a batch transaction (step **504**). The batch transaction may be initiated in response to receiving a user input at an HIS node and/or FCS node. The user may select the batch transaction from a library of existing batch transactions (e.g., select a recipe for the batch process). Alternatively, for a new batch transaction, the user may indicate that a new recipe will be followed for the new batch transaction.

[0063] The method **500** continues by comparing the batch transaction against one or more rules defined in a batch endorsement policy (step **508**). In some embodiments, every computing node (e.g., HIS, FCS, etc.) may have many batch transactions happening/happened, but only a subset of those transactions belongs to the batch recipe concerned. For this reason, verification/validation is useful, specifically, that subset is verified/validated based on endorsement policy. In some embodiments, the validation may be based on one or more of: 1 (“timing”), 2 (“correlations”), 3 (“sequence”) and 4 (“from designated nodes”).

[0064] The method **500** continues by confirming, based on the comparison, that the batch transaction meets the endorsement policy (step **512**). After confirmation has been completed, the method **500** may continue by transmitting a batch transaction validation request (step **516**). In some embodiments, a batch transaction validation request may be transmitted only in response to confirming that the batch transaction meets the endorsement policy. Additionally, the batch transaction validation request may be transmitted to one or more additional computing nodes in the batch chain network **100**, where the batch transaction validation request includes information describing the batch transaction (e.g., a transaction ID, a recipe ID, etc.) along with a request for the one or more additional computing nodes to validate and add the information describing the batch transaction to an immutable distributed digital ledger **128**.

[0065] The method **500** may further include confirming that an entry **336** has been added to the digital ledger **128** (step **520**). More specifically, the method **500** may include confirming that the entry **336** has been added to a block **316** in the blockchain **312** and that the entry has been added in response to the batch transaction validation request.

[0066] The method **500** then continues by reporting that the digital ledger **128** has been updated to include the entry **336** (step **524**). In some embodiments, reporting may occur when each entry **336**

is added to the digital ledger **128**. In some embodiments, reporting may wait until such time as the batch process is complete and all entries for the batch process have been written to the digital ledger **128**.

[0067] Referring now to FIG. **6**, additional details of another method **600** will be described in accordance with at least some embodiments of the present disclosure. The method **600** may be performed as part of method **400** and/or method **500** and/or any other method described herein without departing from the scope of the present disclosure.

[0068] The method **600** begins with the initiation of an endorsement process (step **604**). The endorsement process may include sending one or more endorsement requests to an endorser node (step **608**). In some embodiments, endorsement requests may be transmitted to one, some, or all nodes in the network **100**. In some embodiments, the endorsement requests may be transmitted solely to nodes functioning as an endorser node for the batch transaction.

[0069] The method **600** continues when a response to the endorsement request is received from the endorser node (step **612**). In some embodiments, ordering node/engineering node (HIS) may automatically validate/verify transactions based on endorsement policies (taking endorsement votes from the participating nodes). As an example, the endorsement policies may include the criteria of endorsement, which is based on co-relationships among processing units of each batch, as well as configurations to detect which transaction is related to which batch. Ultimately, the goal is to receive one or more endorsement responses from one or more endorser nodes indicating that the endorsement policy is met. In some embodiments, a single endorsement response indicating that the endorsement policy is met may be sufficient to continue. In other embodiments, the method **600** may require that more than one (e.g., a predetermined number greater than one) endorsement responses are received indicating that the endorsement policy is met.

[0070] When the endorsement process is satisfied in step **612**, the method **600** continues by finalizing confirmation of the endorsement policy being met (step **616**). As can be appreciated, the method **600** may be performed as a number of steps within step **420** and/or step **512**.

[0071] Referring now to FIG. **7**, additional details of another method **700** will be described in accordance with at least some embodiments of the present disclosure. The method **700** may be performed as part of method **400** and/or method **500** and/or method **600** and/or any other method described herein without departing from the scope of the present disclosure.

[0072] The method **700** begins by aggregating a block entry **336** with at least one additional entry **336** describing a different batch transaction (step **704**). Specifically, but without limitation, entries from different batches may be aggregated together by tagging to help correlate different batches and/or different recipes. Aggregation of different batches by aggregation of block entries helps to more quickly detect events for one entry when an event is detected for another, related, entry.

[0073] In some embodiments, the method **700** continues by detecting a batch closure for a batch associated with the first entry (step **708**). When the first entry is associated with a second entry of another batch transaction, the method **700** may further include reporting the batch closure as well as an event for the other batch transaction with which the second entry is associated (step **712**). In some embodiments, the entry and the at least one additional entry are ordered in sequence according to time requested in the immutable distributed digital ledger.

[0074] In the foregoing description, for the purposes of illustration, methods were described in a particular order. It should be appreciated that in alternate embodiments, the methods may be performed in a different order than that described without departing from the scope of the embodiments. It should also be appreciated that the methods described above may be performed as algorithms executed by hardware components (e.g., circuitry) purpose-built to carry out one or more algorithms or portions thereof described herein. In another embodiment, the hardware component may comprise a general-purpose microprocessor (e.g., CPU, GPU) that is first converted to a special-purpose microprocessor. The special-purpose microprocessor then having had loaded therein encoded signals causing the, now special-purpose, microprocessor to maintain

machine-readable instructions to enable the microprocessor to read and execute the machine-readable set of instructions derived from the algorithms and/or other instructions described herein. The machine-readable instructions utilized to execute the algorithm(s), or portions thereof, are not unlimited but utilize a finite set of instructions known to the microprocessor. The machine-readable instructions may be encoded in the microprocessor as signals or values in signal-producing components by, in one or more embodiments, voltages in memory circuits, configuration of switching circuits, and/or by selective use of particular logic gate circuits. Additionally or alternatively, the machine-readable instructions may be accessible to the microprocessor and encoded in a media or device as magnetic fields, voltage values, charge values, reflective/non-reflective portions, and/or physical indicia.

[0075] In another embodiment, the microprocessor further comprises one or more of a single microprocessor, a multi-core processor, a plurality of microprocessors, a distributed processing system (e.g., array(s), blade(s), server farm(s), “cloud”, multi-purpose processor array(s), cluster(s), etc.) and/or may be co-located with a microprocessor performing other processing operations. Any one or more microprocessors may be integrated into a single processing appliance (e.g., computer, server, blade, etc.) or located entirely, or in part, in a discrete component and connected via a communications link (e.g., bus, network, backplane, etc. or a plurality thereof).

## Claims

1. A method, comprising: initiating, at a batch agent of a computing node in batch chain network, a batch transaction to be completed, wherein the batch transaction relates to a batch recipe of a batch production; comparing the batch transaction against one or more rules defined in a batch endorsement policy; confirming, based on the comparison, that the batch transaction meets the batch endorsement policy; in response to confirming the batch transaction meets the batch endorsement policy, transmitting a batch transaction validation request to one or more additional computing nodes in the batch chain network, wherein the batch transaction validation request comprises information describing the batch transaction along with a request for the one or more additional computing nodes to validate and add the information describing the batch transaction to an immutable distributed digital ledger; confirming that an entry has been added to the immutable distributed digital ledger in response to the batch transaction validation request; and reporting, to the batch chain network, that the immutable distributed digital ledger has been updated to include the entry.
2. The method of claim 1, wherein the immutable distributed digital ledger comprises a block chain and wherein the entry comprises a new block added to the block chain.
3. The method of claim 2, wherein the entry comprises a link to another block in the block chain and wherein the information describing the batch transaction comprises at least one of a block header, a block number, a hash value, and a description of a batch action, and wherein the description of the batch action comprises at least one of an operator alarm, an alarm, a window history, a product description, and a recipe.
4. The method of claim 1, wherein the computing node comprises an orderer node with a user interface and wherein the one or more additional computing nodes comprise at least one of an endorser node and a committer node.
5. The method of claim 1, wherein the batch chain network comprises a plurality of human interface stations and a plurality of field control stations connected via one or more communication networks.
6. The method of claim 1, further comprising: transmitting an endorsement request to an endorser node; and receiving an endorsement response from the endorser node indicating that the batch endorsement policy is met.
7. The method of claim 1, further comprising: aggregating the entry with at least one additional

entry describing a second batch transaction; detecting batch closure; and in response to detecting batch closure, reporting the at least one additional entry along with the entry.

**8.** The method of claim 7, wherein the entry and the at least one additional entry are ordered in sequence according to time requested in the immutable distributed digital ledger.

**9.** The method of claim 1, wherein the batch chain network comprises a distributed network of computing nodes.

**10.** A system, comprising: a processor; and a memory capable of storing data thereon that, when processed by the processor, cause the processor to: initiate a batch transaction, wherein the batch transaction relates to a batch recipe of a batch production; request endorsement of the batch transaction against a batch endorsement policy; confirm, based on a response to the requested endorsement, that the batch transaction meets the batch endorsement policy; in response to confirming the batch transaction meets the batch endorsement policy, transmit a batch transaction validation request to one or more computing nodes in a batch chain network, wherein the batch transaction validation request comprises information describing the batch transaction along with a request for the one or more computing nodes to validate and add the information describing the batch transaction to an immutable distributed digital ledger; confirm that an entry has been added to the immutable distributed digital ledger in response to the batch transaction validation request; and report that the immutable distributed digital ledger has been updated to include the entry.

**11.** The system of claim 10, wherein the immutable distributed digital ledger comprises a block chain and wherein the entry comprises a new block added to the block chain.

**12.** The system of claim 11, wherein the entry comprises a link to another block in the block chain and wherein the information describing the batch transaction comprises at least one of a block header, a block number, a hash value, and a description of a batch action, and wherein the description of the batch action comprises at least one of an operator alarm, an alarm, a window history, a product description, and a recipe.

**13.** The system of claim 10, wherein the one or more computing nodes comprise at least one of an endorser node and a committer node.

**14.** The system of claim 10, wherein the batch chain network comprises a plurality of human interface stations and a plurality of field control stations connected via one or more communication networks.

**15.** A node of a batch chain network, the node comprising: at least a portion of a distributed digital ledger comprising one or more entries for a block chain having entries related to a batch production; and a batch agent that is configured to: initiate a batch transaction, wherein the batch transaction relates to a batch recipe of a batch production; request endorsement of the batch transaction against a batch endorsement policy; confirm, based on a response to the requested endorsement, that the batch transaction meets the batch endorsement policy; in response to confirming the batch transaction meets the batch endorsement policy, transmit a batch transaction validation request to one or more computing nodes in the batch chain network, wherein the batch transaction validation request comprises information describing the batch transaction along with a request for the one or more computing nodes to validate and add the information describing the batch transaction to the distributed digital ledger; confirm that an entry has been added to the distributed digital ledger in response to the batch transaction validation request; and report that the distributed digital ledger has been updated to include the entry.

**16.** The node of claim 15, wherein the distributed digital ledger comprises a block chain and wherein the entry comprises a new block added to the block chain.

**17.** The node of claim 15, wherein the batch agent is further configured to validate batch transaction validation requests received from other nodes in the batch chain network.

**18.** The node of claim 15, further comprising a user interface to receive a request that initiates the batch transaction.

**19.** The node of claim 15, wherein the entry comprises a link to another block in the distributed

digital ledger and wherein the distributed digital ledger is immutable.

**20.** The node of claim 15, wherein a time associated with the batch transaction is reported from the node to at least one other computing node in the one or more computing nodes in the batch chain network, wherein the entry comprises a tag that is correlated with tags of other entries associated with a common batch recipe, and wherein the tags are configured to be mined, wherein the entry follows in an expected sequence for the common batch recipe.

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