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Um et al.

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(54) **ELECTRONIC SYSTEM WITH VERSION CONTROL MECHANISM AND METHOD OF OPERATION THEREOF**

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G06F 17/30	(2006.01)
G06F 12/06	(2006.01)
G06F 12/12	(2016.01)

(52) **U.S. Cl.**
CPC .. ***G06F 17/30309*** (2013.01); ***G06F 17/30008*** (2013.01); ***G06F 17/3023*** (2013.01); ***G06F 17/30548*** (2013.01); ***G06F 17/30551*** (2013.01); *G06F 12/0638* (2013.01); *G06F 12/12* (2013.01)

(58) **Field of Classification Search**
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USPC 711/104
See application file for complete search history.

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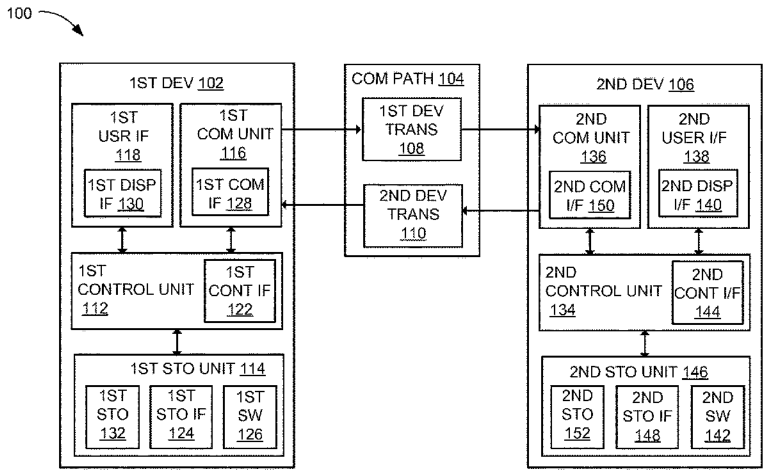
(57) **ABSTRACT**

An electronic system includes: a storage device configured to store a descriptor, including a key and a value, having multiple versions linked on the storage device; a storage interface, coupled to the storage device, configured to provide an entry having a location; and retrieve the descriptor, including the key and the value, based on the entry having the location for selecting one of the versions of the descriptor.

20 Claims, 12 Drawing Sheets



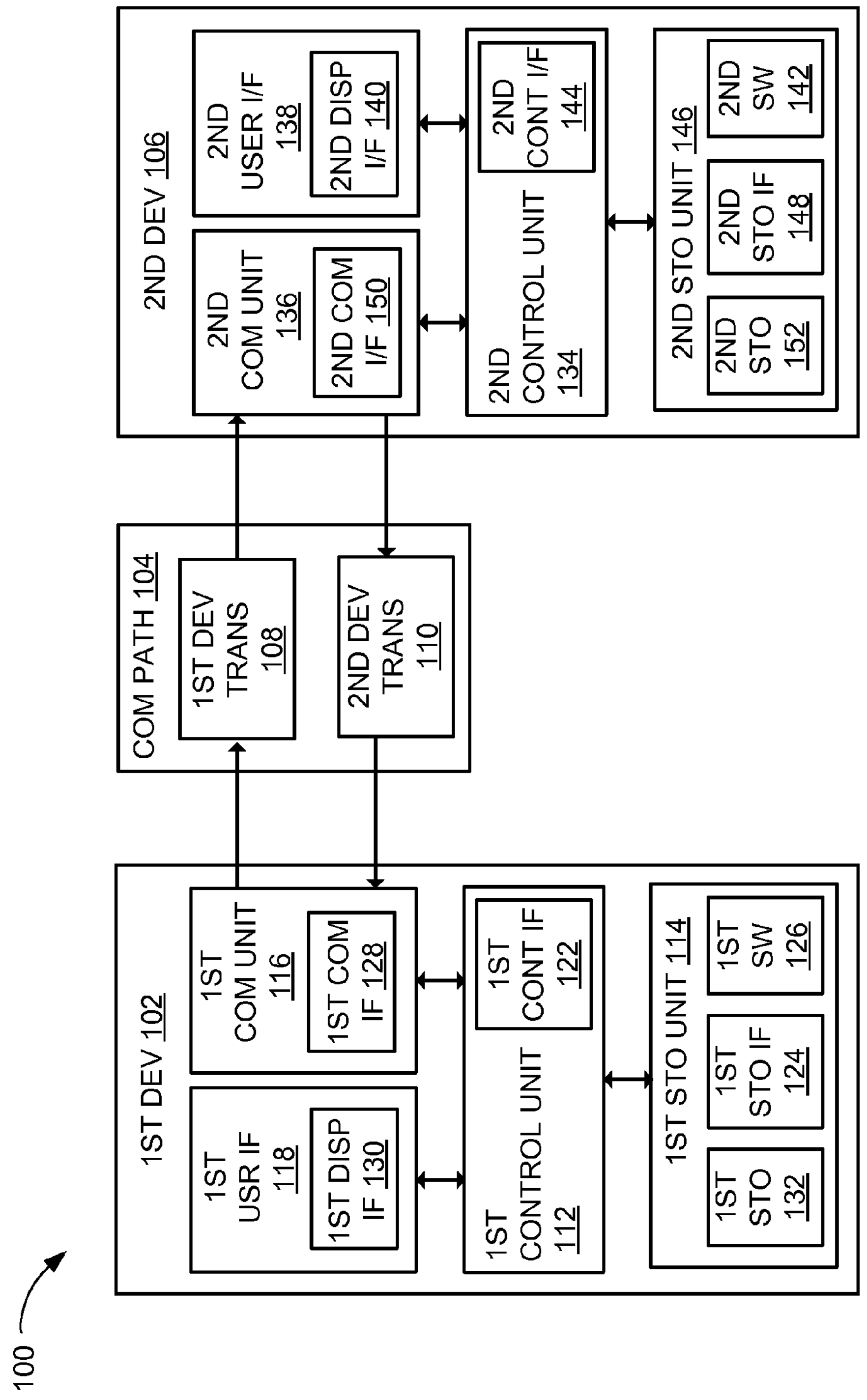

100
1ST DEV 102
1ST USR IF 118
1ST DISP IF 130
1ST COM UNIT 116
1ST COM IF 128
1ST CONTROL UNIT 112
1ST CONT IF 122
1ST STO UNIT 114
1ST STO 132
1ST STO IF 124
1ST SW 126
COM PATH 104
1ST DEV TRANS 108
2ND DEV TRANS 110
2ND DEV 106
2ND COM UNIT 136
2ND COM I/F 150
2ND USER I/F 138
2ND DISP I/F 140
2ND CONTROL UNIT 134
2ND CONT I/F 144
2ND STO UNIT 146
2ND STO 152
2ND STO IF 148
2ND SW 142

FIG. 1

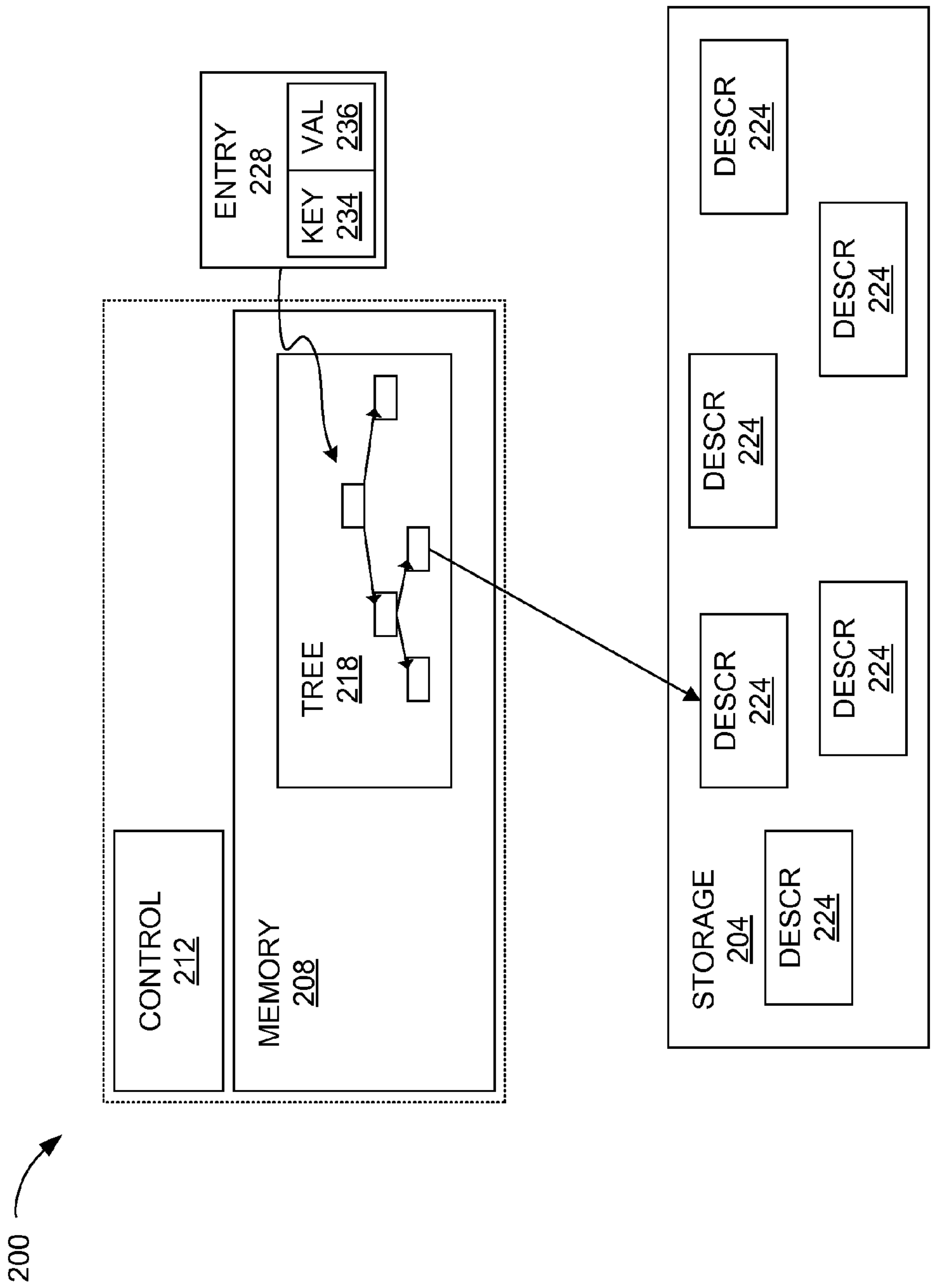

ENTRY 228
KEY 234
VAL 236
CONTROL 212
MEMORY 208
TREE 218
STORAGE 204
DESCR 224
200

FIG. 2

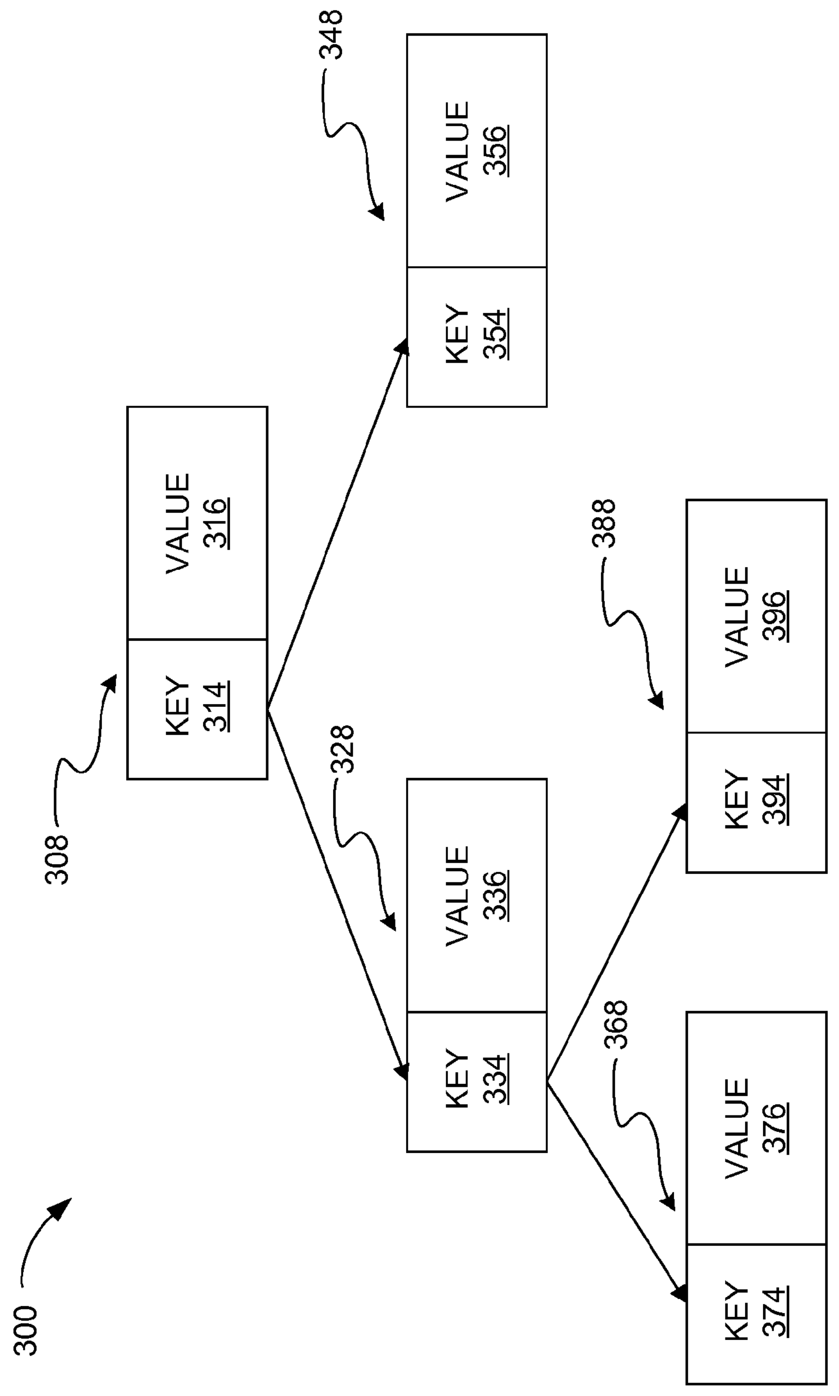

300
308
KEY 314
VALUE 316
328
KEY 334
VALUE 336
348
KEY 354
VALUE 356
368
KEY 374
VALUE 376
388
KEY 394
VALUE 396

FIG. 3

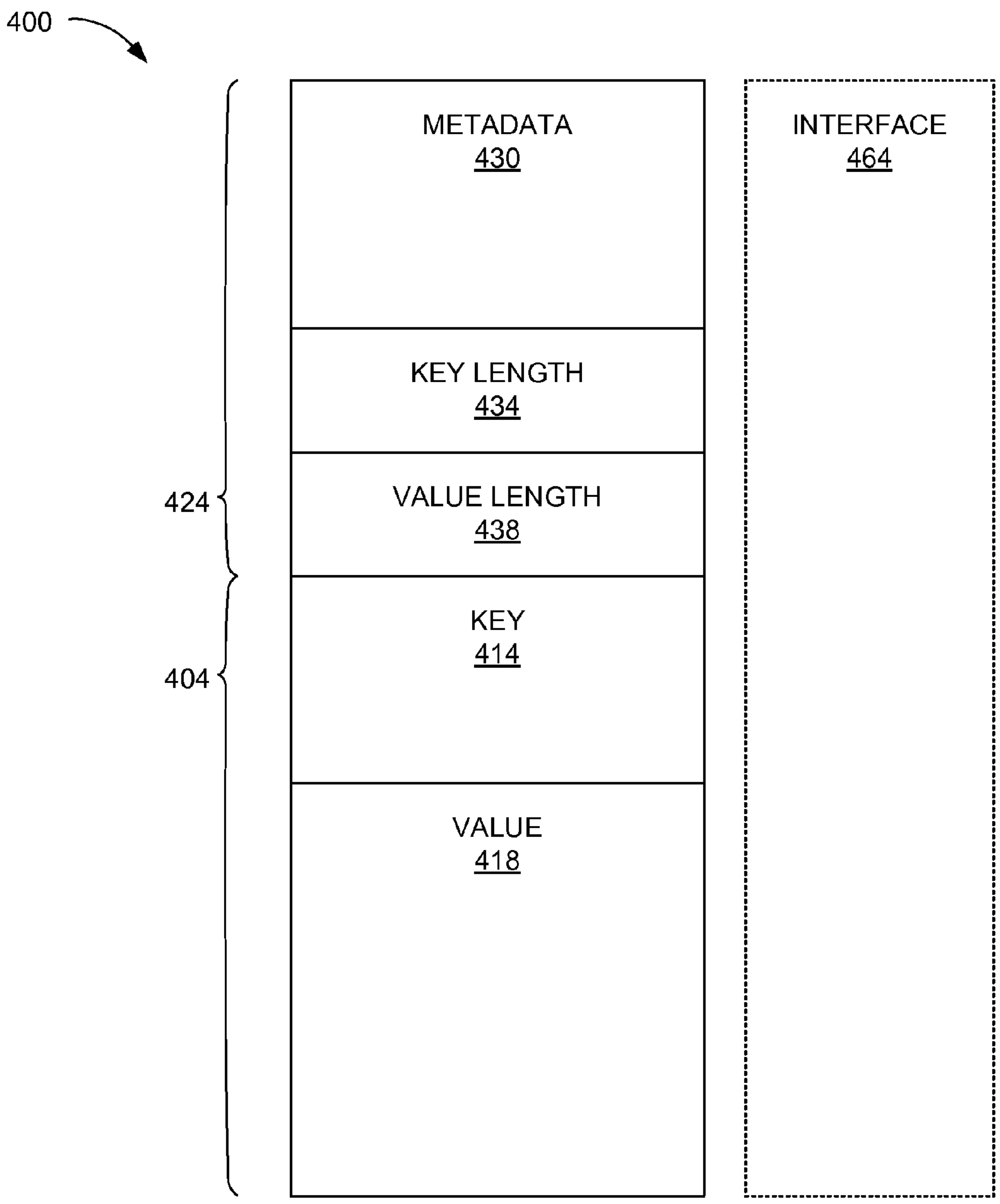

400
METADATA 430
KEY LENGTH 434
VALUE LENGTH 438
KEY 414
VALUE 418
INTERFACE 464
424
404

FIG. 4

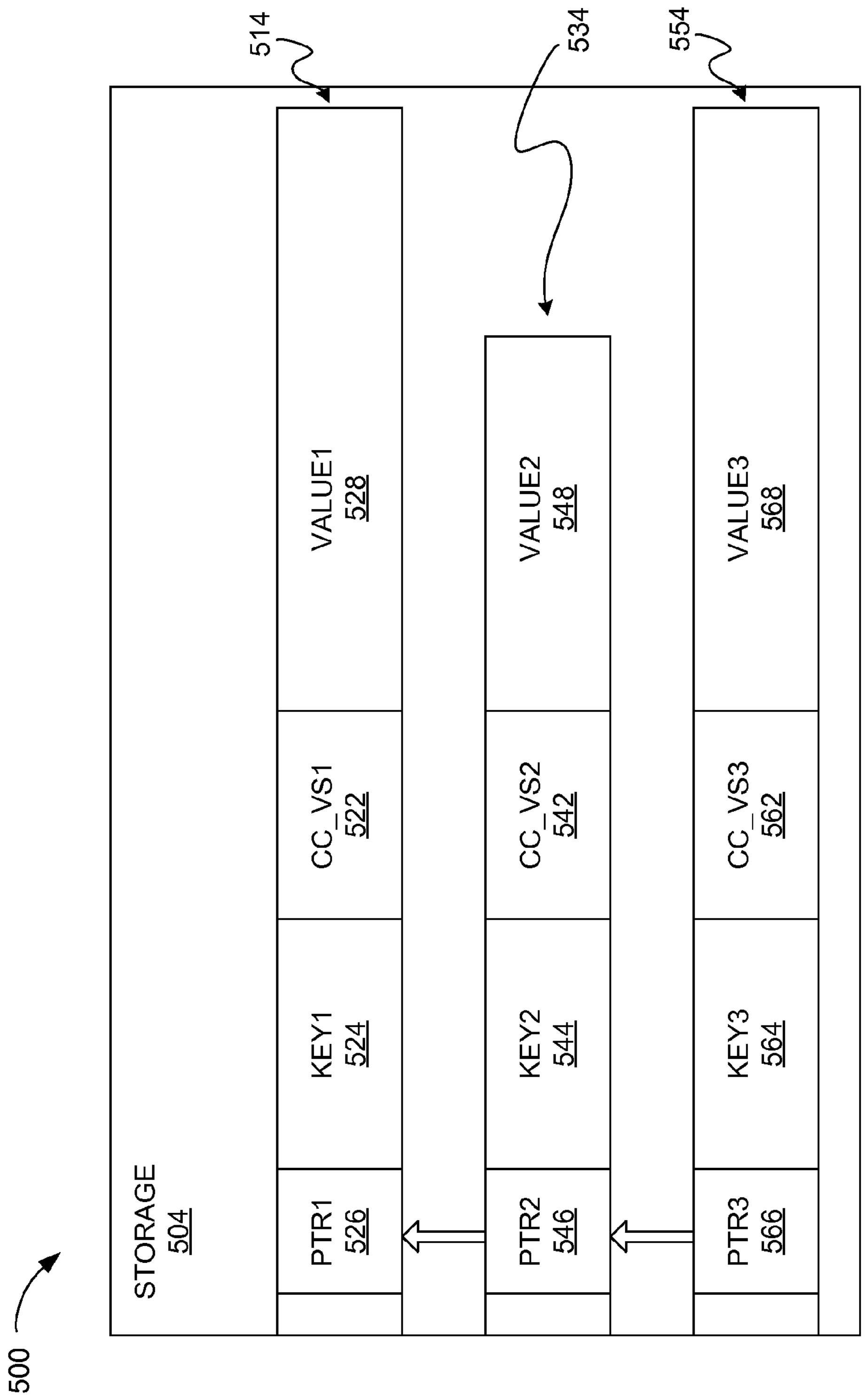

500
STORAGE 504
514
534
554
VALUE1 528
CC_VS1 522
KEY1 524
PTR1 526
VALUE2 548
CC_VS2 542
KEY2 544
PTR2 546
VALUE3 568
CC_VS3 562
KEY3 564
PTR3 566

FIG. 5

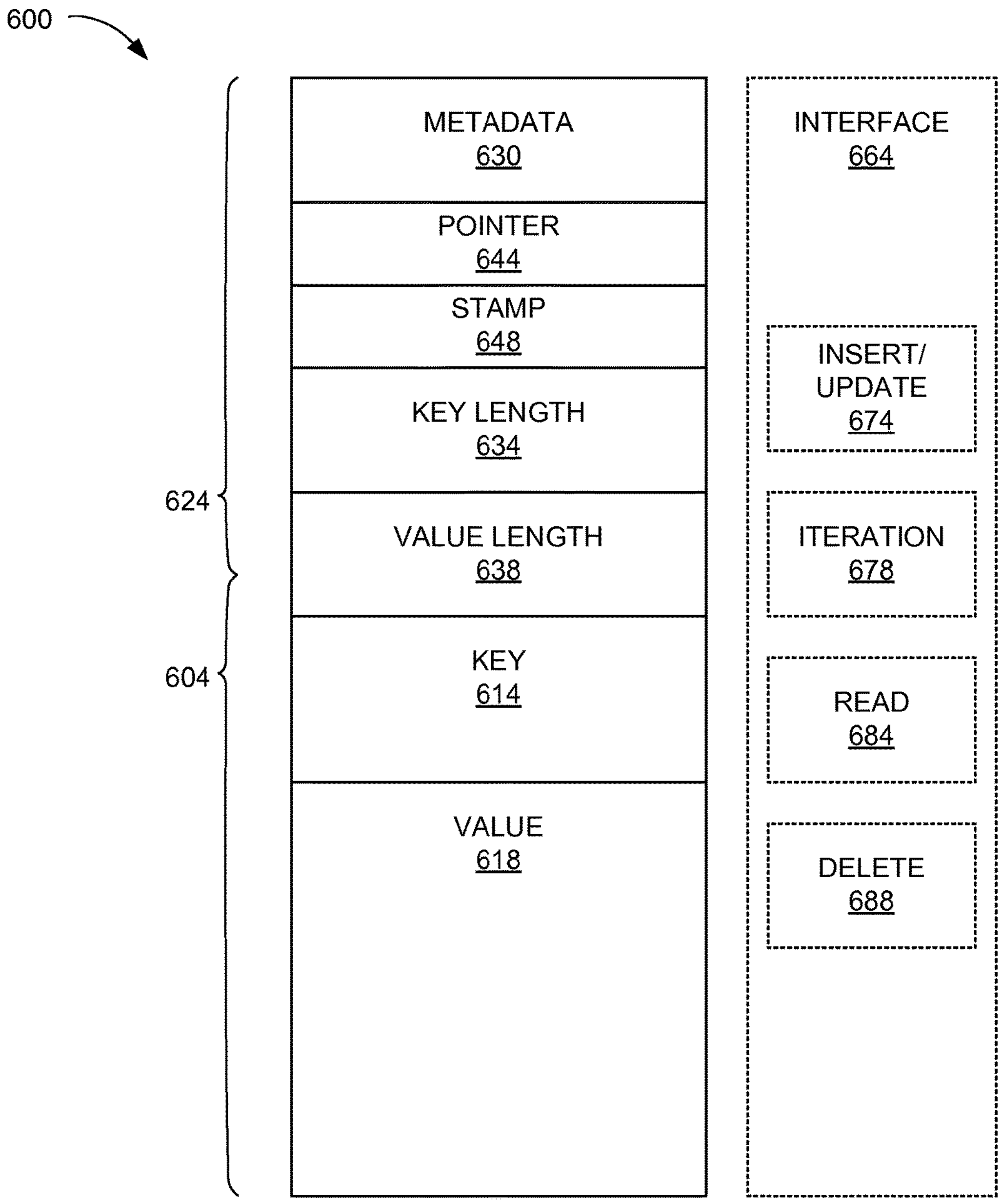

600
624
604
METADATA 630
POINTER 644
STAMP 648
KEY LENGTH 634
VALUE LENGTH 638
KEY 614
VALUE 618
INTERFACE 664
INSERT/ UPDATE 674
ITERATION 678
READ 684
DELETE 688

FIG. 6

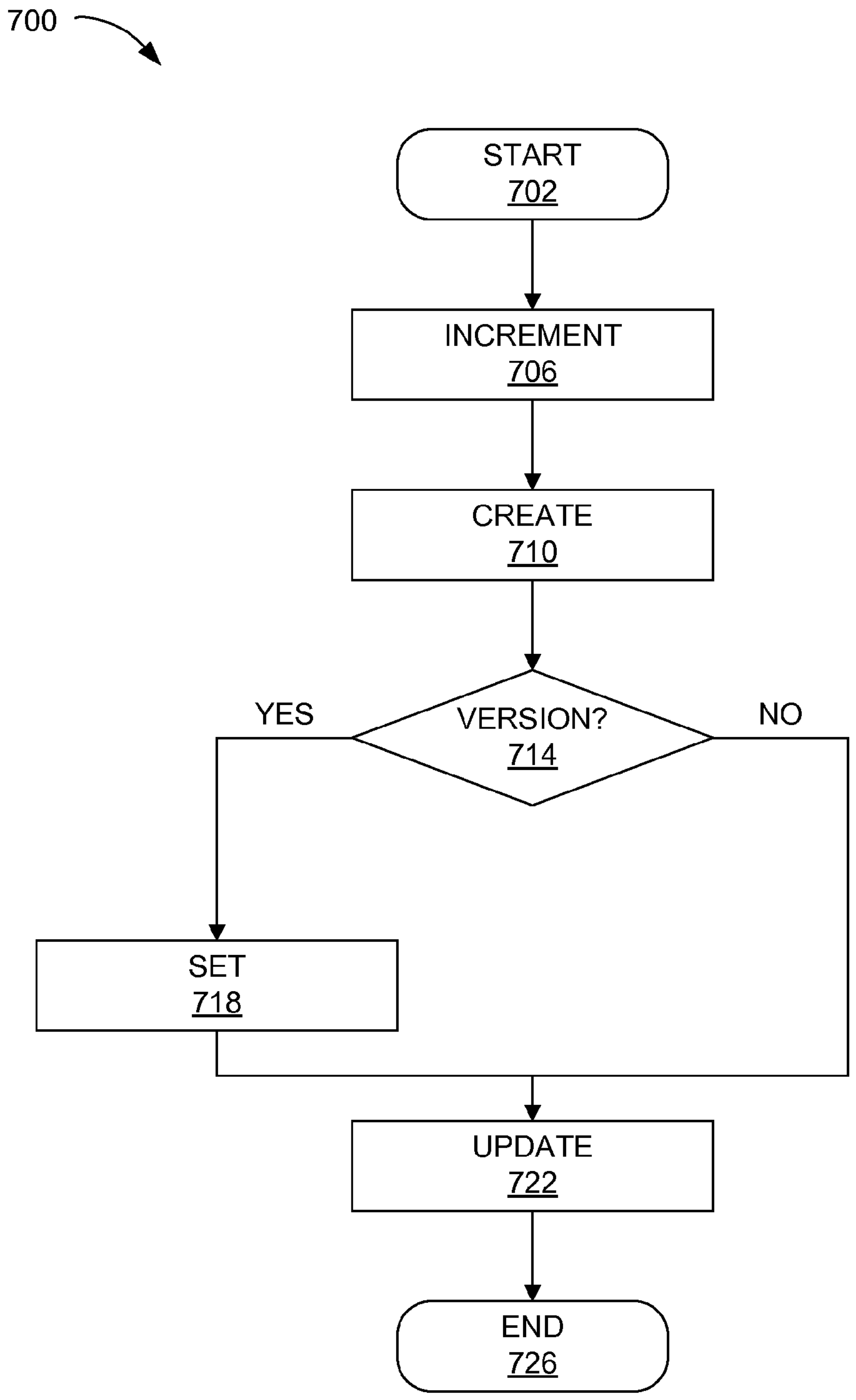

700
START
702
INCREMENT
706
CREATE
710
VERSION?
714
YES
NO
SET
718
UPDATE
722
END
726

FIG. 7

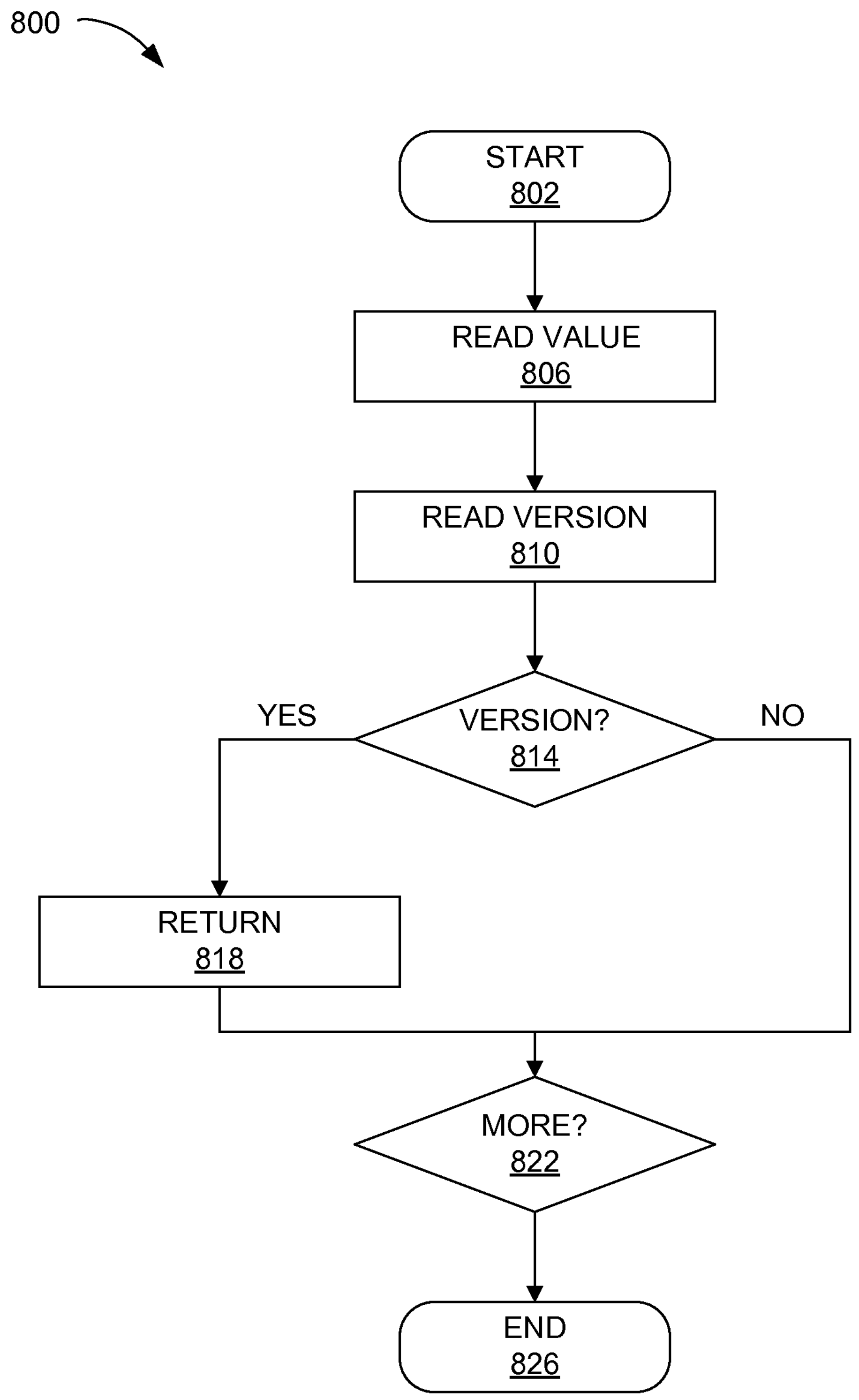

800
START
802
READ VALUE
806
READ VERSION
810
VERSION?
814
YES
NO
RETURN
818
MORE?
822
END
826

FIG. 8

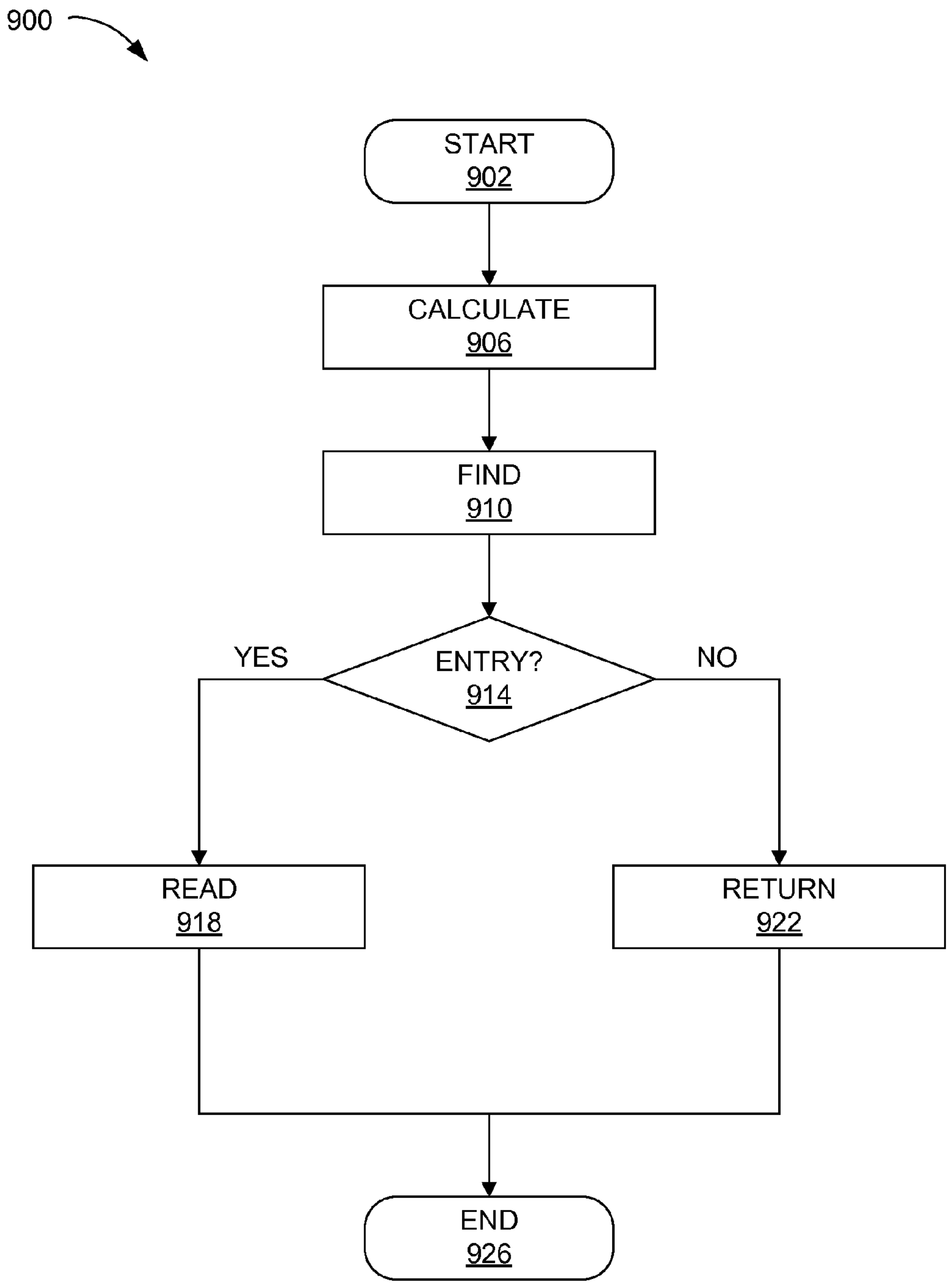

900
START
902
CALCULATE
906
FIND
910
ENTRY?
914
YES
NO
READ
918
RETURN
922
END
926

FIG. 9

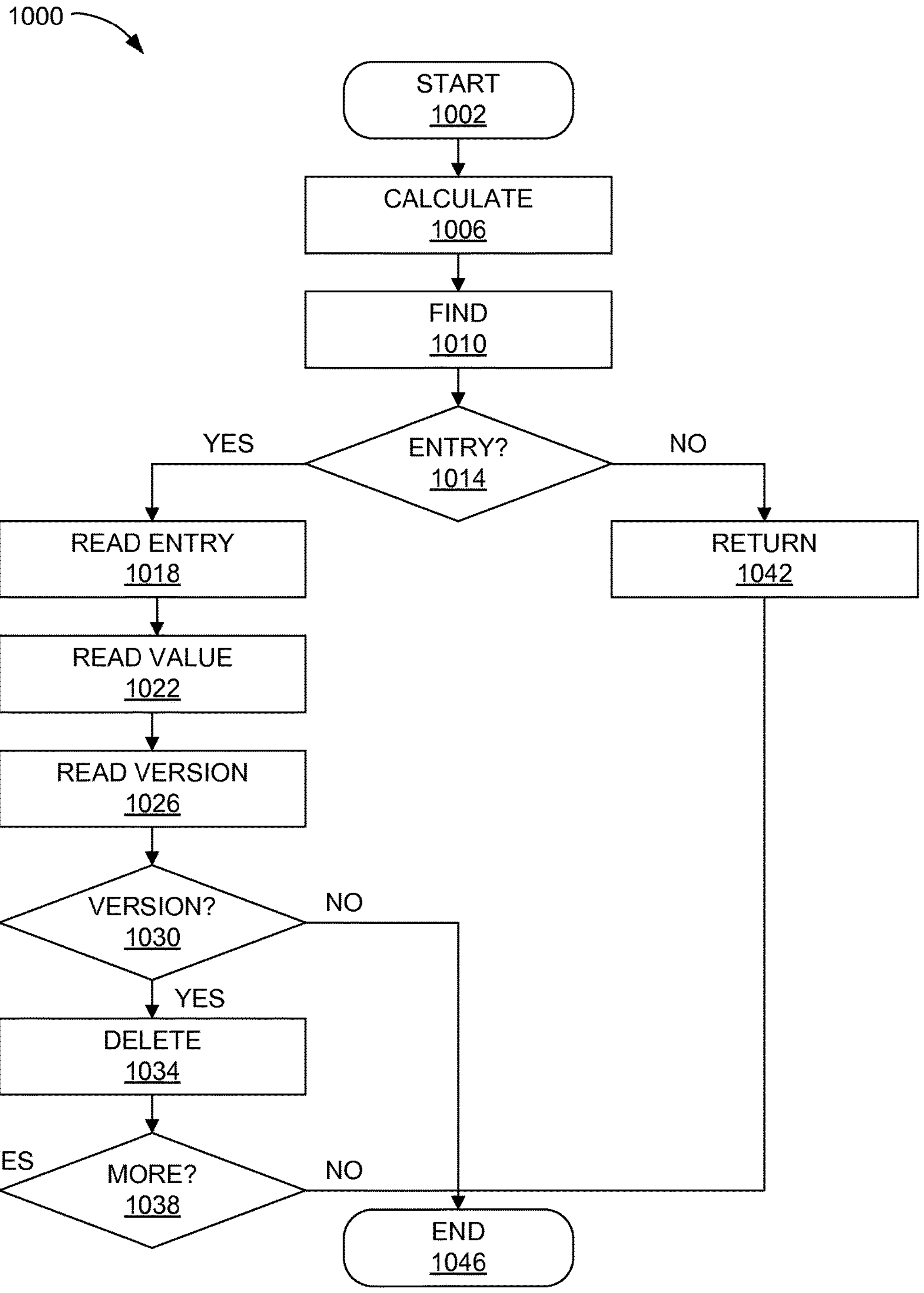

1000
START 1002
CALCULATE 1006
FIND 1010
ENTRY? 1014
YES
NO
READ ENTRY 1018
RETURN 1042
READ VALUE 1022
READ VERSION 1026
VERSION? 1030
NO
YES
DELETE 1034
YES
MORE? 1038
NO
END 1046

FIG. 10

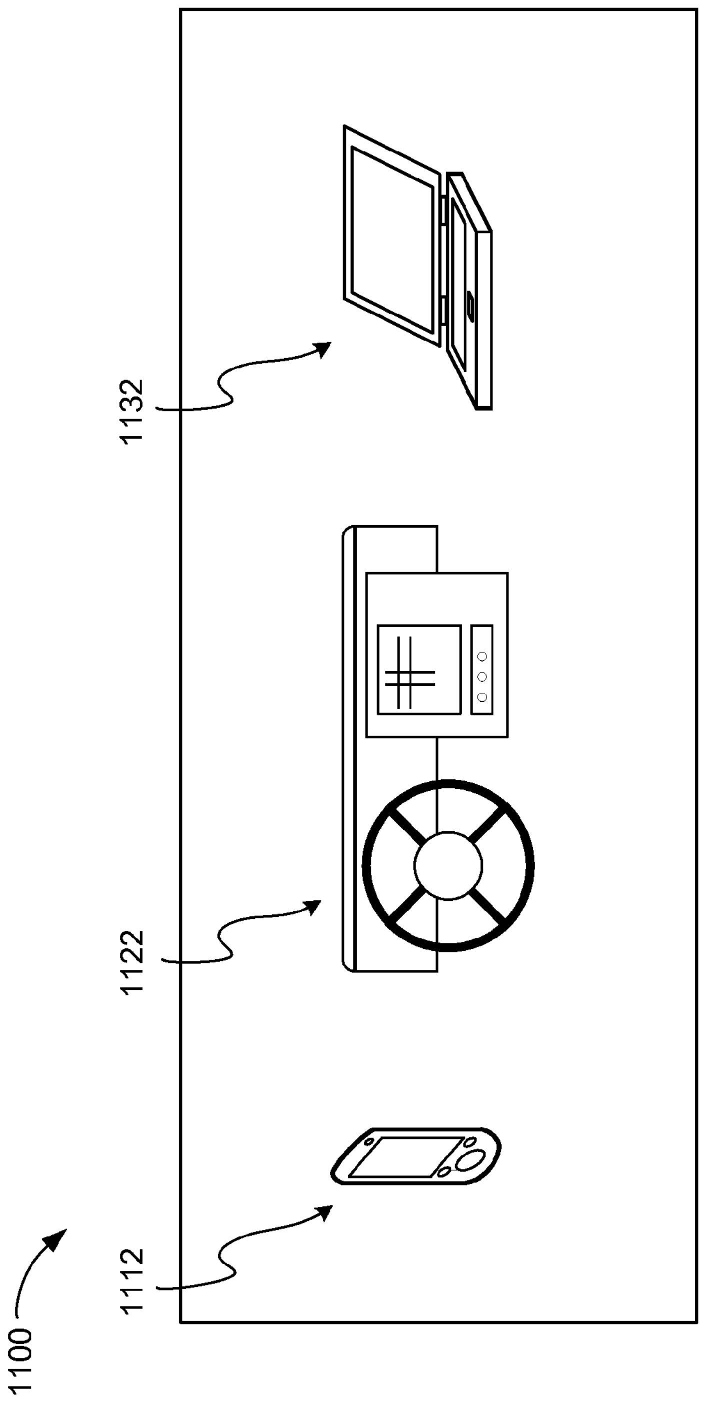


FIG. 11

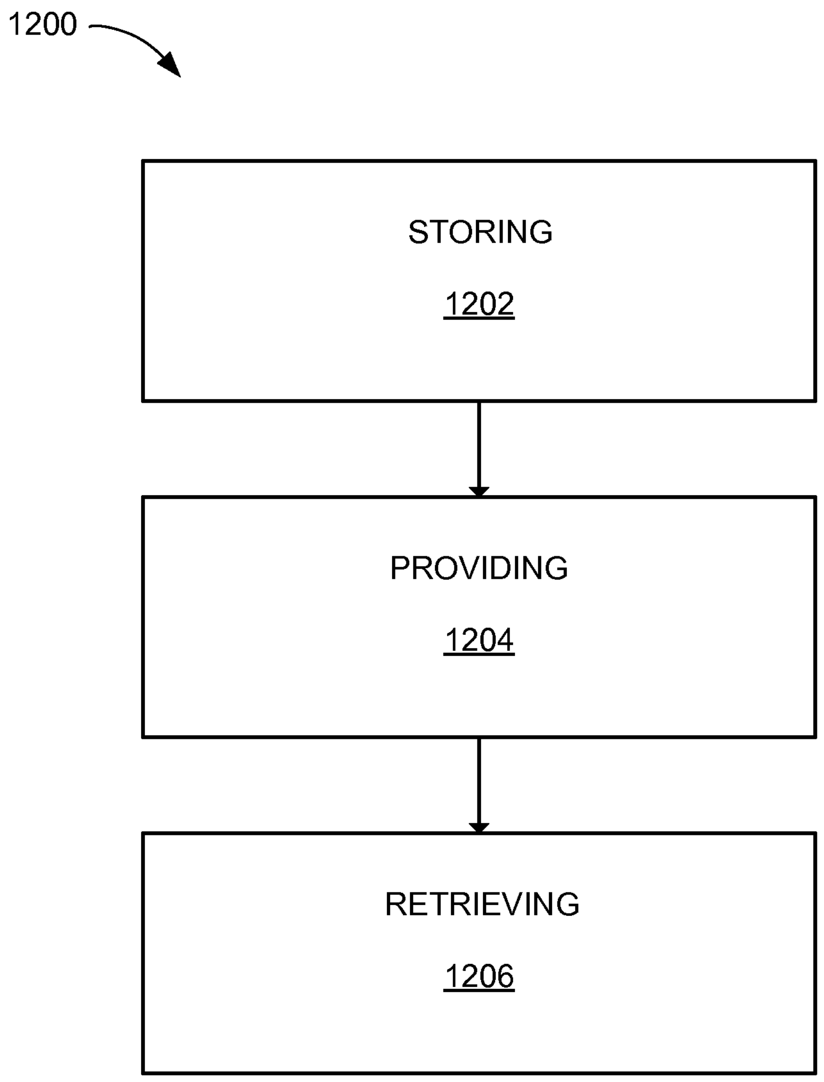


FIG. 12

ELECTRONIC SYSTEM WITH VERSION CONTROL MECHANISM AND METHOD OF OPERATION THEREOF

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims the benefit of U.S. Provisional Patent Application Ser. No. 62/043,105 filed Aug. 28, 2014, and the subject matter thereof is incorporated herein by reference thereto.

TECHNICAL FIELD

An embodiment of the present invention relates generally to an electronic system, and more particularly to a system for version control.

BACKGROUND

Electronic information storage and retrieval serves many consumer and industrial systems. Access to electronic information can be critical to many systems such as modern consumer and industrial electronics, including devices such as cellular phones, portable digital assistants, graphical display systems, televisions, projectors, and combination devices. The electronic information storage and retrieval provides increasing levels of functionality to support modern life. Research and development in the existing technologies can take a myriad of different directions.

Access to the electronic information for storage and retrieval can involve protecting portions of the electronic information when more than one systems attempts access. The protection of the portions of the electronic information prevents inconsistencies or errors with the electronic information storage and retrieval. The protection process can significantly impact performance of the access to the electronic information at least due to delays in waiting until a previous process or access is complete.

Thus, a need still remains for an electronic system with version control mechanism for access to electronic information. In view of the ever-increasing commercial competitive pressures, along with growing consumer expectations and the diminishing opportunities for meaningful product differentiation in the marketplace, it is increasingly critical that answers be found to these problems. Additionally, the need to reduce costs, improve efficiencies and performance, and meet competitive pressures adds an even greater urgency to the critical necessity for finding answers to these problems.

Solutions to these problems have been long sought but prior developments have not taught or suggested any solutions and, thus, solutions to these problems have long eluded those skilled in the art.

SUMMARY

An embodiment of the present invention provides an electronic system including: a storage device configured to store a descriptor, including a key and a value, having multiple versions linked on the storage device; a storage interface, coupled to the storage device, configured to provide an entry including a location; and retrieving the descriptor, including the key and the value, based on the entry including the location for concurrent accesses to the storage device.

An embodiment of the present invention provides a method of operation of an electronic system including: storing a descriptor on a storage device with the descriptor, including a key and a value, having multiple versions linked on the storage device; providing an entry, including a location, with a storage interface, coupled to the storage device; and retrieving the descriptor, including the key and the value, with the storage interface, coupled to the storage device, based on the entry including the location for selecting one of the versions of the descriptor.

An embodiment of the present invention provides a non-transitory computer readable medium including stored thereon instructions to be executed by a control unit including: storing a descriptor, including a key and a value, on a storage device with the descriptor having multiple versions linked on the storage device; providing an entry, including a location, on a memory device, coupled to the storage device; and retrieving the descriptor, including the key and the value, with the storage interface, coupled to the storage device, based on the entry including the location for selecting one of the versions of the descriptor.

Certain embodiments of the invention have other steps or elements in addition to or in place of those mentioned above. The steps or elements will become apparent to those skilled in the art from a reading of the following detailed description when taken with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an electronic system with a version control mechanism in an embodiment of the invention.

FIG. **2** is a block diagram of an electronic system with a version control in an embodiment of the invention.

FIG. **3** is a memory structure of the electronic system in an embodiment of the invention.

FIG. **4** is a storage structure of the electronic system in an embodiment of the invention.

FIG. **5** is a storage structure of the electronic system in an embodiment of the invention.

FIG. **6** is a storage structure of the electronic system in an embodiment of the invention.

FIG. **7** is an insert process flow of the electronic system in an embodiment of the invention.

FIG. **8** is an iterate process flow of the electronic system in an embodiment of the invention.

FIG. **9** is a read process flow of the electronic system in an embodiment of the invention.

FIG. **10** is delete process flow of the electronic system in an embodiment of the invention.

FIG. **11** is examples of embodiments of the electronic system.

FIG. **12** is a flow chart of a method of operation of an electronic system in an embodiment of the invention.

DETAILED DESCRIPTION

An embodiment of the present invention provides Multi-Version Concurrency Control (MVCC) processes for electronic systems such as database management systems. The MVCC process can provide concurrent access to the electronic system without locking electronic information, such as a database, preventing inconsistencies in datasets, avoiding increased latency, improving performance, or combination thereof. The MVCC process can avoid locking operations including a need for newer operations to wait until previous operations are complete. Such locking operations impact performance, increase latency, or combination thereof.

The following embodiments are described in sufficient detail to enable those skilled in the art to make and use the invention. It is to be understood that other embodiments would be evident based on the present disclosure, and that system, process, or mechanical changes may be made without departing from the scope of an embodiment of the present invention.

In the following description, numerous specific details are given to provide a thorough understanding of the invention. However, it will be apparent that the invention may be practiced without these specific details. In order to avoid obscuring an embodiment of the present invention, some well-known circuits, system configurations, and process steps are not disclosed in detail.

The drawings showing embodiments of the system are semi-diagrammatic, and not to scale and, particularly, some of the dimensions are for the clarity of presentation and are shown exaggerated in the drawing figures. Similarly, although the views in the drawings for ease of description generally show similar orientations, this depiction in the figures is arbitrary for the most part. Generally, the invention can be operated in any orientation. The embodiments have been numbered first embodiment, second embodiment, etc. as a matter of descriptive convenience and are not intended to have any other significance or provide limitations for an embodiment of the present invention.

The term "module" referred to herein can include software, hardware, or a combination thereof in an embodiment of the present invention in accordance with the context in which the term is used. For example, the software can be machine code, firmware, embedded code, application software, or a combination thereof. The software can also include a function, a call to a function, a code block, or a combination thereof.

Also for example, the hardware can be gates, circuitry, processor, computer, integrated circuit, integrated circuit cores, a pressure sensor, an inertial sensor, a microelectromechanical system (MEMS), passive devices, physical non-transitory memory medium having instructions for performing the software function, a portion therein, or a combination thereof. Further, if a module is written in the apparatus claims section below, the modules are deemed to include hardware circuitry for the purposes and the scope of apparatus claims.

Referring now to FIG. **1**, therein is shown an example of a block diagram of an electronic system **100** with a version control mechanism in an embodiment of the invention. The electronic system **100** can include a first device **102**, such as system including a client or a server, connected to a second device **106**, such as a system including a client or a server. The first device **102** can communicate with the second device **106** with a communication path **104**, such as a wireless network, a wired network, physical interfaces such as ATA, SATA, SAS, PCIe, any network, any physical interface, or combination thereof.

The first device **102** can include a first control unit **112**, a first storage unit **114**, a first communication unit **116**, and a first user interface **118**. The first control unit **112** can include a first control interface **122**. The first control unit **112** can execute a first software **126** of the electronic system **100**. The first storage unit **114** can be a volatile memory, a nonvolatile memory, an internal memory, an external memory, or a combination thereof. For example, the first storage unit **114** can be a nonvolatile storage such as non-volatile random access memory (NVRAM), solid-state storage device (SSD) including Flash memory, disk storage, or a volatile storage such as static random access memory (SRAM).

The second device **106** can be optimized for implementing an embodiment of the present invention in a multiple device embodiment with the first device **102**. The second device **106** can provide the additional or higher performance processing power compared to the first device **102**. The second device **106** can include a second control unit **134**, a second communication unit **136**, and a second user interface **138**. The second storage unit **146** can include a second storage interface **148**. The second storage interface **148** can be used for communication between other functional units in the second device **106**. The second storage interface **148** can also be used for communication that is external to the second device **106**.

The electronic system **100** can include the first device **102**, the communication path **104**, and the second device **106**. The first device **102** can send information in a first device transmission **108** over the communication path **104** to the second device **106**. The second device **106** can send information in a second device transmission **110** over the communication path **104** to the first device **102**.

The first control unit **112** can be implemented in a number of different manners. For example, the first control unit **112** can be a processor, an application specific integrated circuit (ASIC) an embedded processor, a microprocessor, a hardware control logic, a hardware finite state machine (FSM), a digital signal processor (DSP), or a combination thereof. The first control interface **122** can be used for communication between the first control unit **112** and other functional units in the first device **102**. The first control interface **122** can also be used for communication that is external to the first device **102**.

The first control interface **122** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the first device **102**. The first control interface **122** can be implemented in different ways and can include different implementations depending on which functional units or external units are being interfaced with the first control interface **122**.

The first storage unit **114**, the second storage unit **146**, or combination thereof, can include a memory component, a client memory, a server memory, flash memory, or combination thereof.

The first storage unit **114** can store the first software **126**. The first storage unit **114** can also store the relevant information, such as data representing images, sound files, text, data, or a combination thereof.

The first storage unit **114** can be a volatile memory, a nonvolatile memory, an internal memory, an external memory, or a combination thereof. For example, the first storage unit **114** can be a nonvolatile storage such as non-volatile random access memory (NVRAM), solid-state storage device (SSD) including Flash memory, disk storage, or a volatile storage such as static random access memory (SRAM).

The first storage unit **114** can include a first storage interface **124**. The first storage interface **124** can be used for communication between and other functional units in the first device **102**. The first storage interface **124** can also be used for communication that is external to the first device **102**.

The first storage interface **124** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the first device **102**.

The first storage interface **124** can include different implementations depending on which functional units or external units are being interfaced with the first storage unit **114**. The first storage interface **124** can be implemented with technologies and techniques similar to the implementation of the first control interface **122**.

The first communication unit **116** can enable external communication to and from the first device **102**. For example, the first communication unit **116** can permit the first device **102** to communicate with the second device **106**, an attachment, such as a peripheral device or a computer desktop, and the communication path **104**.

The first communication unit **116** can also function as a communication hub allowing the first device **102** to function as part of the communication path **104** and not limited to be an end point or terminal unit to the communication path **104**. The first communication unit **216** can include active and passive components, such as microelectronics or an antenna, for interaction with the communication path **104**.

The first communication unit **116** can include a first communication interface **128**. The first communication interface **128** can be used for communication between the first communication unit **116** and other functional units in the first device **102**. The first communication interface **128** can receive information from the other functional units or can transmit information to the other functional units.

The first communication interface **128** can include different implementations depending on which functional units are being interfaced with the first communication unit **116**. The first communication interface **128** can be implemented with technologies and techniques similar to the implementation of the first control interface **122**.

The first user interface **118** allows a user (not shown) to interface and interact with the first device **102**. The first user interface **118** can include an input device and an output device. Examples of the input device of the first user interface **118** can include a keypad, a mouse, a touchpad, soft-keys, a keyboard, a microphone, an infrared sensor for receiving remote signals, or any combination thereof to provide data and communication inputs.

The first user interface **118** can include a first display interface **130**. The first display interface **130** can include a display, a projector, a video screen, a speaker, or any combination thereof. The display, a projector, a video screen, a speaker, or any combination thereof, can display data stored on a first storage device **132**.

The first control unit **112** can operate the first user interface **118** to display information generated by the electronic system **100**. The first control unit **112** can also execute the first software **126** for the other functions of the electronic system **100**. The first control unit **112** can further execute the first software **126** for interaction with the communication path **104** via the first communication unit **116**.

The second device **106** can be optimized for implementing an embodiment of the present invention in a multiple device embodiment with the first device **102**. The second device **106** can provide the additional or higher performance processing power compared to the first device **102**. The second device **106** can include a second control unit **134**, a second communication unit **136**, and a second user interface **138**.

The second user interface **138** allows a user (not shown) to interface and interact with the second device **106**. The second user interface **138** can include an input device and an output device. Examples of the input device of the second user interface **138** can include a keypad, a touchpad, soft-keys, a keyboard, a mouse, a microphone, or any combination thereof to provide data and communication inputs. Examples of the output device of the second user interface **138** can include a second display interface **140**. The second display interface **140** can include a display, a projector, a video screen, a speaker, or any combination thereof.

The second control unit **134** can execute a second software **142** to provide the intelligence of the second device **106** of the electronic system **100**. The second software **142** can operate in conjunction with the first software **126**. The second control unit **134** can provide additional performance compared to the first control unit **112**.

The second control unit **134** can operate the second user interface **138** to display information. The second control unit **134** can also execute the second software **142** for the other functions of the electronic system **100**, including operating the second communication unit **136** to communicate with the first device **102** over the communication path **104**.

The second control unit **134** can be implemented in a number of different manners. For example, the second control unit **134** can be a processor, an embedded processor, a microprocessor, hardware control logic, a hardware finite state machine (FSM), a digital signal processor (DSP), or a combination thereof.

The second control unit **134** can include a second control interface **144**. The second control interface **144** can be used for communication between the second control unit **134** and other functional units in the second device **106**. The second control interface **144** can also be used for communication that is external to the second device **106**.

The second control interface **144** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the second device **106**. The second control interface **144** can be implemented in different ways and can include different implementations depending on which functional units or external units are being interfaced with the second control interface **144**.

A second storage unit **146** can store the second software **142**. The second storage unit **146** can also store the relevant information such as data representing incoming images, sound files, text, data, or a combination thereof. The second storage unit **146** can be sized to provide the additional storage capacity to supplement the first storage unit **114**.

For illustrative purposes, the second storage unit **146** is shown as a single element, although it is understood that the second storage unit **146** can be a set of storage elements such as a storage array. Also for illustrative purposes, the electronic system **100** is shown with the second storage unit **146** as a single hierarchy storage system, although it is understood that the electronic system **100** can have the second storage unit **146** in a different configuration.

For example, the second storage unit **146** can be formed with different storage technologies forming a memory hierarchal system including different levels of caching, main memory, rotating media, or off-line storage. The second storage unit **146** can be a volatile memory, a nonvolatile memory, an internal memory, an external memory, or a combination thereof. For example, the second storage unit **146** can be a nonvolatile storage such as non-volatile random access memory (NVRAM), solid-state storage device (SSD) including Flash memory, disk storage, or a volatile storage such as static random access memory (SRAM).

The second storage unit **146** can include a second storage interface **148**. The second storage interface **148** can be used for communication between other functional units in the second device **106**. The second storage interface **148** can also be used for communication that is external to the second device **106**.

The second storage interface **148** can receive information from the other functional units or from external sources, or can transmit information to the other functional units or to external destinations. The external sources and the external destinations refer to sources and destinations external to the second device **106**.

The second storage interface **148** can include different implementations depending on which functional units or external units are being interfaced with the second storage unit **146**. The second storage interface **148** can be implemented with technologies and techniques similar to the implementation of the second control interface **144**.

The second communication unit **136** can enable external communication to and from the second device **106**. For example, the second communication unit **136** can permit the second device **106** to communicate with the first device **102** over the communication path **104**.

The second communication unit **136** can also function as a communication hub allowing the second device **106** to function as part of the communication path **104** and not limited to be an end point or terminal unit to the communication path **104**. The second communication unit **136** can include active and passive components, such as microelectronics or an antenna, for interaction with the communication path **104**.

The second communication unit **136** can include a second communication interface **150**. The second communication interface **150** can be used for communication between the second communication unit **136** and other functional units in the second device **106**. The second communication interface **150** can receive information from the other functional units or can transmit information to the other functional units.

The second communication interface **150** can include different implementations depending on which functional units are being interfaced with the second communication unit **136**. The second communication interface **150** can be implemented with technologies and techniques similar to the implementation of the second control interface **144**.

The first communication unit **116** can couple with the communication path **104** to send information to the second device **106** in the first device transmission **108**. The second device **106** can receive information in the second communication unit **136** from the first device transmission **108** of the communication path **104**.

The second communication unit **136** can couple with the communication path **104** to send information to the first device **102** in the second device transmission **110**. The first device **102** can receive information in the first communication unit **116** from the second device transmission **110** of the communication path **104**. The electronic system **100** can be executed by the first control unit **112**, the second control unit **134**, or a combination thereof. For illustrative purposes, the second device **106** is shown with the partition having the second user interface **138**, the second storage unit **146**, the second control unit **134**, and the second communication unit **136**, although it is understood that the second device **106** can have a different partition. For example, the second software **142** can be partitioned differently such that some or all of its

function can be in the second control unit **134** and the second communication unit **136**. Also, the second device **106** can include other functional units not shown in FIG. **1** for clarity.

For illustrative purposes, the first storage unit **114**, the second storage unit **146**, or combination thereof, are shown with the first storage device **132** and the second storage device **152**, although it is understood that the first storage unit **114**, the second storage unit **146** or combination thereof, can include any number or type of memory or storage devices. The first storage device **132** and the second storage device **152** can include one or more of a drive, a solid state drive (SSD), a solid state device, a non-volatile storage device, any storage device, or combination thereof.

The functional units in the first device **102** can work individually and independently of the other functional units. The first device **102** can work individually and independently from the second device **106** and the communication path **104**.

The functional units in the second device **106** can work individually and independently of the other functional units. The second device **106** can work individually and independently from the first device **102** and the communication path **104**.

For illustrative purposes, the electronic system **100** is described by operation of the first device **102** and the second device **106**. It is understood that the first device **102** and the second device **106** can operate any of the modules and functions of the electronic system **100**.

The modules, processes, functions, applications, or combination thereof, described in this application can be implemented as instructions stored on a non-transitory computer readable medium to be executed by a first control unit **112**, the second control unit **134**, or a combination thereof. The non-transitory computer medium can include the first storage unit **114**, the second storage unit **146**, or a combination thereof. The non-transitory computer readable medium can include non-volatile memory, such as a hard disk drive (HDD), non-volatile random access memory (NVRAM), solid-state storage device (SSD), compact disk (CD), digital video disk (DVD), universal serial bus (USB) flash memory devices, Blu-ray Disc™, any other computer readable media, or combination thereof. The non-transitory computer readable medium can be integrated as a part of the electronic system **100** or installed as a removable portion of the electronic system **100**.

Modules, processes, functions, applications, or combination thereof, in this application can be hardware implementation, hardware circuitry, or hardware accelerators in the first control unit **112** or in the second control unit **134**. The modules can also be hardware implementation, hardware circuitry, or hardware accelerators within the first device **102** or within the second device **106** but outside of the first control unit **112** or the second control unit **134**, respectively.

Modules, processes, functions, applications, or combination thereof, in this application can be at least a part of the first software **126**, the second software **142**, or a combination thereof. These modules can also be stored in the first storage unit **114**, in the second storage unit **146**, or a combination thereof. The first control unit **112**, the second control unit **134**, or a combination thereof can execute these modules for operating the electronic system **100**.

Referring now to FIG. **2**, therein is shown a block diagram of an electronic system **200** with a version control in an embodiment of the invention. The electronic system **200**, in a manner similar to the electronic system **100**, can provide multi-version concurrency control (MVCC) and snapshot isolation (SI) with storage, such as a solid-state storage device (SSD) including flash storage, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, or combination thereof, and memory, such as system memory, the first storage unit **114**, the second storage unit **146**, or combination thereof. The storage can include device level key value store for storage such as solid state storage drives (SSD) including a Smart SSD. The device level key value store can include multi-version concurrency control and snapshot isolation support on storage, such as SSD.

In an embodiment, a key value store can provide Multi-Version Concurrency Control (MVCC) with snapshot isolation (SI), including chaining or linking versions of a key value pair on media. The electronic system **200** can provide device firmware support for the MVCC in the key value store, for example on solid-state storage devices (SSD) including flash memory. The electronic system **200** can include the MVCC support on the key value store with multiple versions of a same key having at least one latest version. Versions of the key can be chained together on media such that the versions can be stored under the same key space with physical space occupying versioning.

In an embodiment, a Multi-Version Concurrency Control (MVCC) can mark older data as obsolete and write newer data in a different location, thus avoiding overwriting of the older data. The MVCC can provide multiple versions of a same dataset, such as a key value pair in a key value store. The multiple versions of the same dataset can coexist in the electronic system **200**. The MVCC can further provide access to a snapshot of data at a start of an operation without modification or deletions by another operation.

In an embodiment, multiple readers can read a consistent value of a given key concurrently with a writer writing a new version of the key in a different location. One or more of the readers can operate concurrently with one of the writer for the given key. A Multi-Version Concurrency Control (MVCC) does not block an operation, though a write operation can fail if a writer writes with an obsolete transaction identification, since another of the write operation might have changed the given key. The MVCC provides significantly improved performance.

In an embodiment, a Multi-Version Concurrency Control (MVCC) can provide each operation visibility to a snapshot of a database at a predetermined time, such as a chosen time or an assigned time, thus avoiding locking operations. The MVCC can provide a point in time consistent view of the database or dataset, such as the snapshot. A read transaction or operation can include a timestamp or a transaction identification (ID) for determining a state of the database at a time of the read transaction. Changes to the database after the snapshot can be unavailable for viewing, particularly for changes that have not been fully committed. The changes, such as future writes, can include a later of the timestamp or a later of the transaction identification, unavailable for viewing.

In an embodiment snapshot isolation can provide all readers a snapshot of a dataset such as a consistent snapshot taken when a read starts. Updates to the dataset, subsequent to the snapshot of the dataset taken when a read starts, succeed based on avoiding conflicts with other updates including concurrent updates. The snapshot isolation can provide significantly improved performance with eliminating serial access and providing concurrency control. The snapshot isolation can preferably be implemented with Multi-Version Concurrency Control (MVCC).

In an embodiment, a device level key value store can include a flash optimized key value store. The device level key value store can complement databases such as next generation databases, non-relational databases, distributed databases, open-source databases, horizontally scalable databases, web-scale databases, NoSQL (sometimes referred to as “not only sql”) databases, or combination thereof, with device-level functionality. The device level key value store can provide support for MVCC with snapshot isolation including operations such as get/put/update/delete by a single input output (I/O) operation. The device level key value store can also support MVCC operations with snapshot isolation by a single I/O access.

In an embodiment, Multi-Version Concurrency Control (MVCC) and snapshot isolation (SI) support can be optimized on a flash memory based key value store. The MVCC and SI on the key value store can be implemented with functionality support on an application level, in firmware, flash based, or combination thereof. The functionality support can include implementation of transaction primitives in device associated software, hardware, or combination thereof, eliminating or reducing needs for metadata at an application level, thus saving or minimizing use of system memory such as system DRAM.

In an embodiment, this functionality support can provide reduced input and output processes (IOs) with underlying storage device by linking all versions of a key value pair when writing a new version of the key value pair, reducing metadata stored on memory, for example random access memory (RAM), tracking all versions of a key value pair, or combination thereof. This support can further include implementing special functionalities with flash device firmware, linking all versions of key value pairs on a flash device thus providing one input and output process (IO) for one or more key value operation.

In an embodiment, the electronic system **200** including device level key value store, Multi-Version Concurrency Control (MVCC), snapshot isolation (SI), or combination thereof, can optimize MVCC features, SI features, or combination thereof. In particular, the electronic system **200** can provide optimization of MVCC features, SI features, or combination thereof, for databases such as next generation databases, non-relational databases, distributed databases, open-source databases, horizontally scalable databases, web-scale databases, NoSQL databases, or combination thereof.

In an embodiment, this optimization can include changing functionality of an underlying storage system including chaining versions of the key value pair on an actual storage device. The MVCC features, SI features, or combination thereof, can be optimized for databases designed for flash storage devices, and can include a linked list, firmware interface changes, or combination thereof. The linked list can include some or all versions of a key value pair maintained on flash storage. The firmware interface changes can include writing a new version of a key value pair on flash storage such that a linked list is formed, including as an example a latest version at a head or beginning of the linked list and an oldest version at a tail or end of a list. Further, only one input and output (IO) operation can be required for writing a new version on or in a storage medium, such as a flash memory.

In an embodiment, the electronic system **200** can include storage devices, such as a storage device **204**, a memory device **208**, the first storage unit **114**, the second storage unit **146**, or combination thereof. For example, the storage device **204**, the memory device **208**, or combination thereof, can be implemented in first storage device **132**, the second storage device **152**, the first storage unit **114**, the second storage unit **146**, or combination thereof.

In an embodiment, a control device **212**, such as the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, or combination thereof, can be coupled to the memory device **208**, the storage device **204**, other disclosed devices, any device, or combination thereof. For example, the control device **212** and the memory **208** can be included in the first device **102** of FIG. **1** depicted by the block having a dotted line.

In an embodiment, the memory device **208**, such as system memory, random access memory (RAM), a volatile memory device, any memory device, or combination thereof, can include a tree **218**. The storage device **204**, such as a drive, a solid state drive (SSD), a solid state device, a non-volatile storage device, any storage device, or combination thereof, can include a descriptor **224** such as key value index node (KVInode) data. For illustrative purposes, six (6) of the descriptors **224** are shown, although it is understood that any number of the descriptors **224** may be included and that the values or content of each of the descriptors **224** may be different.

In an embodiment, the tree **218**, such as a binary tree, hash tree, similar data structure, or combination thereof, can be implemented in the memory device **208**. The tree **218** can index mapping information and entries **228** of the tree **218** with keys **234**, value **236** such as KVInode Numbers, hash values, or combination thereof. A key **234** of an entry **228** can be included or inserted in the tree **218** and remain in the tree **218** until an application removes or deletes the key **234**. The tree **218** can include or consist of binary tree keys associated or pointing to locations of associated values.

For example, the tree **218** can include an entry **228**, for example a sixty-four bit (64-bit) hash, for each key **234**. The entry **228** including the value **236** can include a location of the descriptor **224**, such as the KVInode location. The location can be represented by a 64-bit address with logical block addressing (LBA) for a descriptor **224**, such as a KVInode, in the storage device **204**. For a given key **228**, an associated and unique descriptor **224**, such as a unique KVInode, can be found or associated with the address in the storage device **204**. For illustrative purposes, five (5) of the entries **228** are shown, although it is understood that any number of the entries **228** may be included and that the values or content of each of the entries **228** may be different.

It has been discovered that the electronic system **200** including the storage **204** with the descriptor **224** and the memory **208** with the tree **218** can require only one input and output (IO) operation for writing a new version of the descriptor **224** on or in a storage medium. The descriptor **224** can include a linked list accessed with the tree **218** for operations by a single input and output (I/O) access.

Referring now to FIG. **3**, therein is shown a memory structure **300** of the electronic system **100** in an embodiment of the invention. The memory structure **300** such as an index, a binary tree, mapping information, a hash tree, or combination thereof, can be implemented in a storage system such as the electronic system **200** of FIG. **2** in a manner similar to the tree **218** of FIG. **2**. The storage system can include a memory device such as the memory device **208** of FIG. **2**, the storage unit **114** of FIG. **1**, the storage unit **146** of FIG. **1**, a volatile memory device, a non-volatile memory device, or combination thereof.

In an embodiment, the memory structure **300** can include locations for saved descriptors, such as key value index node (KVInode) data, in a non-volatile memory device. The memory structure **300** can include a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

In an embodiment, the memory structure **300** can include a first entry **308**. The first entry **308**, such as mapping information, can include a first key **314**, a first value **316**, or combination thereof. The first value **316** can include a key value index node (KVInode) number, an address, a location, or combination thereof, for a first descriptor such as key value index node (KVInode) data, the descriptor **224** of FIG. **2**, or combination thereof. The first key **314** can include a reference, a key, version of a key, or combination thereof, of the first descriptor such as the descriptor **224**.

For example, the first value **316** can include a location for the first descriptor, such as the descriptor **224**, with a simple number representing a start block address of logical block addressing (LBA) for a storage device such as the storage device **204** of FIG. **2**, the storage unit **114**, the storage unit **146**, any storage device, a non-volatile storage device, or combination thereof. The first value **316** can be used for locating the first descriptor for each key value pair, including a KVInode, the descriptor **224**, or combination thereof, which was stored in the non-volatile memory device. For example, the first value **316** can represent a start block address for a saved KVInode descriptor in the non-volatile memory device.

In an embodiment, the memory structure **300** can include a second entry **328** with a second key **334**, a second value **336**, or combination thereof. The second value **336** can include a key value index node (KVInode) number, an address, a location, or combination thereof, for a second descriptor such as key value index node (KVInode) data, the descriptor **224**, or combination thereof. The second key **334** can include a reference, a key, version of a key, or combination thereof, of the second descriptor such as the descriptor **224**. For example, in a manner similar to the first entry **308**, the second value **336** can include a location for the second descriptor with at least a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

In an embodiment, the memory structure **300** can include a third entry **348** with a third key **354**, a third value **356**, or combination thereof. The third value **356** can include a key value index node (KVInode) Number, an address, a location, or combination thereof, for a third descriptor such as key value index node (KVInode) data, the descriptor **224**, or combination thereof. The third key **354** can include a reference, a key, version of a key, or combination thereof, of the third descriptor such as the descriptor **224**. For example, in a manner similar to the first entry **308**, the third value **356** can include a location for the third descriptor with at least a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

In an embodiment, the memory structure **300** can include a fourth entry **368** with a fourth key **374**, a fourth value **376**, or combination thereof. The fourth value **376** can include a key value index node (KVInode) Number, an address, a location, or combination thereof, for a fourth descriptor such as key value index node (KVInode) data, the descriptor **224**, or combination thereof. The fourth key **374** can include a reference, a key, version of a key, or combination thereof, of the fourth descriptor such as the descriptor **224**. For example, in a manner similar to the first entry **308**, the fourth value **376** can include a location for the fourth descriptor with at least a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

In an embodiment, the memory structure **300** can include a fifth entry **388** with a fifth key **394**, a fifth value **396**, or combination thereof. The fifth value **396** can include a key value index node (KVInode) Number, an address, a location, or combination thereof, for a fifth descriptor such as key value index node (KVInode) data, the descriptor **224**, or combination thereof. The fifth key **394** can include a reference, a key, version of a key, or combination thereof, of the fifth descriptor such as the descriptor **224**. For example, in a manner similar to the first entry **308**, the fifth value **396** can include a location for the fifth descriptor with at least a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

For illustrative purposes, the memory structure **300** is shown with five entries, such as the first entry **308**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, or combination thereof, although it is understood that any number of entries may be included. Further, it is understood that the entries of the memory structure **300** can include any value, content, information, format, or combination thereof.

It has been discovered that the first entry **308**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof, can at least provide a location for saved descriptors in a non-volatile memory device. The first entry **308**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof, can at least include a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

Referring now to FIG. **4**, therein is shown a storage structure **400** of the electronic system **100** in an embodiment of the invention. The memory structure **400**, such as a key value index node (KVInode), the descriptor **224** of FIG. **2**, or combination thereof, can be implemented in a storage system such as the electronic system **200** of FIG. **2** including the descriptor **224**. The storage system can include a storage device such as the storage device **204** of FIG. **2**, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, any storage device, a non-volatile storage device, or combination thereof.

In an embodiment, the memory structure **400** can include information about key value pairs. An entry such as the entry **228** of FIG. **2**, the first entry **308** of FIG. **3**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof, can be associated with a unique memory structure **400** in the storage device. The entry can include a key, such as the key **234**, the first key **314**, the second key **334**, the third key **354**, the fourth key **374**, the fifth key **394**, similar additional keys, any keys, or combination thereof, associated with each key value pair and any associated information.

In an embodiment, the memory structure **400** can include information for a key value pair **404** including a key **414** and a value **418**. A header **424**, such as a KVInode header, can include metadata **430**, key length **434**, value length **438**, or combination thereof. The key **414** can be provided to a tree such as a binary or a hash tree, the memory structure **300** of FIG. **3**, the tree **218** of FIG. **2**, or combination thereof. The key **414** can be retrieved from the tree **218** to provide a location of the associated memory structure **400**. For illustrative purposes, the storage structure **400** is shown with the key value pair **404**, the key **414**, the value **418**, the header **424**, the metadata **430**, the key length **434**, and the value length **438**, although it is understood that the storage structure **400** can include any number or any type of component.

In an embodiment, the key value pair **404** can be stored in the storage, such as a non-volatile storage, in a new block of a new logical block addressing (LBA), bytes offset within a partially used logical block addressing (LBA), or combination thereof. The memory structure **400** can be written to the new block of the new logical block addressing (LBA), the bytes offset within the partially used logical block addressing (LBA), or combination thereof. An entry such as a tree node, a binary tree node, the entry **228** of FIG. **2**, the first entry **308** of FIG. **3**, or combination thereof, can include the key **414** and the value **418** including a start address. The entry or tree node can be included in a tree such as a binary tree, a hash tree, an index, mapping information, the tree **218** of FIG. **2**, the memory structure **300** of FIG. **3**, or combination thereof.

In an embodiment, an operation, such as a basic key value operation, can include an interface **464**, such as a firmware interface, that can provide writing, updating, inserting, iterating, deleting, or combination thereof, of the storage structure **400**. The storage structure can optionally include the interface **464** depicted by the block having a dotted line. The interface **464** can be implemented in hardware with the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, the control device **212** of FIG. **2**, the first storage unit **114**, the second storage unit **146**, the storage device **204**, or combination thereof.

It has been discovered that the storage structure **400** can provide information about key value pairs including a location of the associated memory structure **400**. The storage structure **400** can include the key **414**, the value **418**, the metadata **430**, the key length **434**, the value length **438**, or combination thereof.

It has been discovered that the interface **464**, such as a firmware interface, that can provide writing, updating, inserting, iterating, deleting, or combination thereof, of the storage structure **400**. The interface **464** can provide writing, updating, inserting, iterating, deleting, or combination thereof, based on pattern matching of the storage structure **400**.

Referring now to FIG. **5**, therein is shown a storage structure **500** of the electronic system **100** in an embodiment of the invention. The memory structure **500**, such as a linked list, can provide key storage for including multiple versions of a key or a descriptor such as the descriptor **224** of FIG. **2**, the storage structure **400** of FIG. **4**, or combination thereof. For illustrative purposes, the memory structure **500** is shown with three versions of the key although it is understood that any number of versions may be included in the memory structure **500**.

In an embodiment, all versions of a key value (KV) pair can be chained on a memory device or storage device such as a non-volatile memory, in a manner similar to the memory structure **300** of FIG. **3**, the tree **218** of the electronic system **200**, or combination thereof. An actual KVInode of the new version on a memory, such as a non-volatile memory, can hold the KVInode number or LBA locations of previous versions forming a reverse chain of all versions of a KV pair on the memory.

In an embodiment, an update operation for a particular key can create a new version of a key-value pair. The new version can be inserted at a logical block addressing (LBA) location, such as a new LBA location, thus maintaining older versions at other LBA locations, such as older LBA locations. A hash tree node associated with the key can be updated to hold a key value index node (KVInode) number of a new version. For example, the KVInode of the new version on a memory, such as a non-volatile memory, can hold the KVInode number or LBA location of a previous version. One or more of the previous versions can provide a linked list of versions in the memory.

In an embodiment, the memory structure **500** can provide tracking of all operations or accesses, for example insert, update, iterate, read, delete, state change, other storage operations, or combination thereof. The electronic system **100** can provide a unique identification (ID) for each operation such as a concurrency control version stamp (cc_vs).

For example, a read operation, an iterate operation, or combination thereof, can include an input, such as a concurrency control version stamp (cc_vs), that can be an output of another operation such as an insert, an update, a delete, or combination thereof. The read operation can read a version of a key representing a snapshot of a store identified by the cc_vs, supporting Snapshot Isolation (SI).

In an embodiment, the memory structure **500** can include a storage device **504**, a first descriptor **514** having a first concurrency control version stamp **522**, a first key **524**, a first pointer **526**, a first value **528**, or combination thereof. A second descriptor **534** can include a second concurrency control version stamp **542**, a second key **544**, a second pointer **546**, a second value **548**, or combination thereof. A third descriptor **554** can include a third concurrency control version stamp **562**, a third key **564**, a third pointer **566**, a third value **568**, or combination thereof.

For example, the first descriptor **514**, the second descriptor **534**, the third descriptor **554**, similar additional descriptors, or combination thereof, can provide key value index node (KVInode) data in a manner similar to the descriptor **224**, the storage structure **400**, or combination thereof. The first descriptor **514** can represent a first version such as V**1**, the second descriptor **534** represents a second version such as V**1**', the third descriptor **554** represents a third version such as V**1**".

In an embodiment, the first key **524**, the second key **544**, and the third key **564**, can represent multiple versions of a key such as the key **234** of FIG. **2**, the key **314** of FIG. **3**, the key **334** of FIG. **3**, the key **354** of FIG. **3**, the key **374** of FIG. **3**, the key **394** of FIG. **3**, or the key **414** of FIG. **4**. For example, the first key **524** can represent the first key value **528** such as VALUE**1**, second key **544** can represent the second key value **548** such as VALUE**2**', and the third key **564** can represent the third key value **568** such as VALUE**3**". For illustrative purposes, three versions of the key are shown, the first key **524**, the second key **544**, and the third key **564**, although it is understood that any number of versions may be included.

In an embodiment, the first pointer **526**, the second pointer **546**, the third pointer **566**, similar additional pointers, or combination thereof can include a logical block addressing pointer (LBA_Ptr) for pointing, linking, or coupling, multiple versions of the descriptors. The first descriptor **514**, the second descriptor **534**, the third descriptor **554**, similar additional descriptors, or combination thereof, can be linked on the storage device **504**, such as the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, the storage device **204** of FIG. **2**, or combination thereof.

In an embodiment, the first concurrency control version stamp **522**, the second concurrency control version stamp **542**, the third concurrency control version stamp **562**, any version stamp, or combination thereof, can represent an output of an operation such as insert, update, iterate, read delete, or combination thereof. Outputs of insert operations, update operations, iterate operations, read operations, delete operations, or combination thereof, can provide inputs to the storage structure **500** of the electronic system **100**.

For example, the third descriptor **554** can include a newest version of the key value such as VALUE**3**", the second descriptor **534** can include an older version of the key value such as VALUE**2**', and the first descriptor **514** can include an oldest version of a key value such as VALUE**1**. The third pointer **566** associated with the newest version of the key can point to the second pointer **546** associated with the older version of the key. Similarly, the second pointer **546** associated with the older version of the key can point to the first pointer **526** associated with the oldest version of the key. The electronic system **100** with storage structure **500** can provide a descriptor such as the descriptor **224** with multiple versions linked on the storage device **504** such as the storage device **204**.

It has been discovered that the storage system **500** provides a linked list with all versions of a key value (KV) pair chained on the storage device **504**. The first pointer **526**, the second pointer **546**, the third pointer **566**, or combination thereof, can point, link, or couple, multiple versions of the descriptors such as the first descriptor **514**, the second descriptor **534**, the third descriptor **554**, or combination thereof.

It has been discovered that the electronic system **200** including the storage **204** with the descriptor **224** and the memory **208** with the tree **218** can require only one input and output (IO) operation for writing a new version on or in a storage medium. The descriptor **224** can include the storage structure **500** having a linked list accessed with the tree **218** for operations by a single input and output (I/O) access.

Referring now to FIG. **6**, therein is shown a storage structure **600** of the electronic system **100** in an embodiment of the invention. The memory structure **600**, such as a key value index node (KVInode), the descriptor **224** of FIG. **2**, or combination thereof, can include a location such as key value index node (KVInode), a logical block addressing (LBA) location, or combination thereof, with fields for supporting access such as multi-version concurrency control (MVCC), snapshot isolation (SI), or combination thereof.

In an embodiment, the memory structure **600** can provide tracking of all operations, for example insert, update, iterate, read, delete, state change, other storage operations, or combination thereof. The electronic system **100** can provide a unique identification (ID) for each operation such as a concurrency control version stamp (cc_vs)

For example, a read operation, an iterate operation, or combination thereof, can include an input, such as a concurrency control version stamp (cc_vs), that can be an output of an operation such as an insert, an update, a delete, or combination thereof, such as provided by the interface **464** of FIG. **4**. The read operation can read a version of a key representing a snapshot of a store identified by the cc_vs supporting Snapshot Isolation (SI).

In an embodiment, the Snapshot Isolation (SI) can be supported by tracking each operation, such as insert, update, iterate, read, delete, or combination thereof, which changes a state of a database. Each operation that changes the state of the database can result in an increasing value for a transaction identification (ID) number such as a concurrency control version stamp (cc_vs). A read operation, an iterate operation, or combination thereof, can include the transaction ID number as an input for reading a version of a key that represents a snapshot created when the operation with the input transaction ID was implemented or executed.

In an embodiment, the memory structure **600** can include information about key value pairs. An entry such as the entry **228** of FIG. **2**, the first entry **308** of FIG. **3**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof, can be associated with a unique memory structure **600** in the storage device. The entry can include a key, such as the key **234**, the first key **314**, the second key **334**, the third key **354**, the fourth key **374**, the fifth key **394**, similar additional keys, any keys, or combination thereof, associated with each key value pair and any associated information.

In an embodiment, the memory structure **600** can include information for a key value pair **604** including a key **614** and a value **618**. A header **624**, such as a KVInode header, can include metadata **630**, key length **634**, value length **638**, a pointer **644**, a stamp **648**, or combination thereof. These fields can be included in the memory structure **600** for multi-version concurrency control (MVCC) support, snapshot isolation (SI) support, or combination thereof.

In an embodiment, the pointer **644** can include a logical block addressing pointer (LBA_Ptr) for pointing to another location. The stamp **648** can include a concurrency control version stamp (cc_vs) that can be incremented based on operations. The key **614** can be provided to a tree such as a hash tree, a binary tree, the memory structure **300** of FIG. **3**, the tree **218** of FIG. **2**, or combination thereof. The key **614** can be retrieved from the tree **218** to provide a location of the associated memory structure **400**. For illustrative purposes, the storage structure **600** is shown with the key value pair **604**, the key **614**, the value **618**, the header **624**, the metadata **630**, the key length **634**, the value length **638**, the pointer **644**, and the stamp **648**, although it is understood that the storage structure **600** can include any number or any type of component.

In an embodiment, an insert block **674** can provide an insert operation, an update operation, or combination thereof, including incrementing a stamp **648**, such as a concurrency control version stamp (cc_vs), a global concurrency control version stamp, or combination thereof. The stamp **648** can provide a unique identifier such as a unique stamp **648** for an operation. For example, an application can store more than one older revision of a key for SI by storing a new revision of the key at a different LBA location and having a hash tree updated with the new or different LBA location. The insert block **674** can provide metadata for the new LBA location, which can also include an LBA location of an older revision in a key header for forming a reverse chain from the new version to the older or oldest version.

In an embodiment, an iteration block **678** can provide an iteration operation, including an input, such as the stamp **648**. The iteration block **678** can fetch a key value pair that exists based on predetermined criteria. For example, the iteration block **678** can fetch the key value pair that has a stamp **648** with a value that is less than or equal to the value of the input stamp **648**.

In an embodiment, a read block **684** providing a read operation, can provide reading of a latest consistent revision of a key value pair. For example, an older revision, with a stamp **648** having a value that is less than or equal to the input stamp **648**, can be read based on concurrent writing of a latest revision of a key value pair.

In an embodiment, a delete block **688** providing a delete operation, can provide invalidation of a key value pair. The delete block **688** can invalidate the key value pair record of a hash tree, increment the value of the stamp **648**, store the value of the stamp **648** for the invalidated key value pair in the hash tree, or combination thereof. For example, an actual trim or delete operation can be implemented asynchronously with the delete operation such as implemented at a different or later time.

In an embodiment, operations can be performed by hardware devices or implemented in hardware. The insert block **674**, the iteration block **678**, the read block **684**, the delete block **688**, can be implemented in hardware with the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, the control device **212** of FIG. **2**, the first storage unit **114**, the second storage unit **146**, the storage device **204**, or combination thereof.

In an embodiment, an operation, such as a basic key value operation, can include an interface **664**, such as a firmware interface, in a manner similar to the operation including the interface **464** of FIG. **4**. The interface **664** can support multi-version concurrency control (MVCC) and snapshot isolation (SI).

It has been discovered that the storage structure **600** can provide information about key value pairs including a location of the associated memory structure **600**. The storage structure **600** can include the key **614**, the value **618**, the metadata **630**, the key length **634**, the value length **638**, the pointer **644**, the stamp **648**, or combination thereof.

It has been discovered that the interface **664**, such as a firmware interface, that can provide writing, updating, inserting, iterating, deleting, or combination thereof, of the storage structure **600**. The interface **664** can provide writing, updating, inserting, iterating, deleting, or combination thereof, based on pattern matching of the storage structure **600**.

Referring now to FIG. **7**, therein is shown an insert process flow **700** of the electronic system **100** in an embodiment of the invention. The insert process flow **700** can also provide an update process such as an update process flow for inserting or updating a number such as the value **236** of FIG. **2**, the first value **316** of FIG. **3**, the second value **336** of FIG. **3**, the third value **356** of FIG. **3**, the fourth value **376** of FIG. **3**, the fifth value **396** of FIG. **3**, key value index nodes, or combination thereof, in a tree such as the tree **218** of FIG. **2**, the memory structure **300** of FIG. **3**, or combination thereof.

In an embodiment, the insert process flow **700** can be implemented with hardware including the storage device **204** of FIG. **2**, the memory device **208** of FIG. **2**, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, or combination thereof. For example, the storage device **204**, the memory device **208**, or combination thereof, can be implemented in the first storage unit **114**, the second storage unit **146**, or combination thereof.

In an embodiment, the insert process flow **700** can be implemented with hardware including the control device **212** of FIG. **2**, such as the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, or combination thereof, and can be coupled to the memory device **208**, the storage device **204**, other disclosed devices, any device, or combination thereof. For example, the control device **212** and the memory **208** can be included in the first device **102** of FIG. **1**.

For example, in a manner similar to the insert block **674** of FIG. **6**, each insert or update operation can include incrementing a global concurrency control version stamp and the insert or update operation can be given a unique identification such as a concurrency control version stamp. More than one older revision of a key for snapshot isolation can be stored, with a new revision stored at a different logical block addressing (LBA) location.

In an embodiment, the insert process flow **700** or update process flow can include a start operation **702**, an increment operation **706**, a create operation **710**, a version operation **714**, a set operation **718**, an update operation **722**, an end operation **726**, or combination thereof. Each of the start operation **702**, the increment operation **706**, the create operation **710**, the version operation **714**, the set operation **718**, the update operation **722**, the end operation **726**, or combination thereof, can be implemented with hardware in a manner similar to the insert process flow **700**.

In an embodiment, the increment operation **706** can increment a stamp for an input key, version of a key, or combination thereof. The stamp can include a concurrency control version stamp or a timestamp, such as the first concurrency control version stamp **522** of FIG. **5**, the second concurrency control version stamp **542** of FIG. **5**, third concurrency control version stamp **562** of FIG. **5**, any version stamp, any timestamp, or combination thereof.

In an embodiment, the create operation **710** can create a key value index node, key value, metadata, a concurrency control version stamp, a timestamp, or combination thereof. For example, create operation **710** can create or fill entries such as the entry **228** of FIG. **2**, the first entry **308** of FIG. **3**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof.

In an embodiment, the version operation **714** can determine a previous version of key value for the key. Based on whether a previous version exists, the version operation **714** can determine a next process or operation of the insert process flow **700**.

In an embodiment, the set operation **718** can be invoked by the version operation **714** based on an existing previous version of the key value. The set operation **718** can set a pointer to a previous version of the key value. The pointer can include the first pointer **526** of FIG. **5**, the second pointer **546** of FIG. **5**, the third pointer **566** of FIG. **5**, the pointer **644** of FIG. **6**, any pointer, or combination thereof.

In an embodiment, the update operation **722** can update a tree, such as a hash tree, binary tree, index, data structure, mapping information, or combination thereof. The update to the tree can include updating an entry with a new key value index node number. The update operation **722** can be based on the set operation **718**, the version operation **714**, or combination thereof. For example, version operation **714** can determine that "yes" a previous version of a key value exists and the set operation **718** can provide a pointer to the previous version for the update operation **722**. Alternatively for example, the version operation **714** can determine that "no" a previous version of a key value does not exist and the update operation **722** is invoked.

Referring now to FIG. **8**, therein is shown an iteration process flow **800** of the electronic system **100** in an embodiment of the invention. The iteration process flow **800** can receive a version stamp, such as a concurrency control version stamp (cc_vs). The iteration process can retrieve a key value pair that includes a version less than or equal to the current cc_vs in a manner similar to the iteration block **678** of FIG. **6**.

In an embodiment, the iteration process flow **800** can be implemented with hardware including the storage device **204** of FIG. **2**, the memory device **208** of FIG. **2**, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, or combination thereof. For example, the storage device **204**, the memory device **208**, or combination thereof, can be implemented in the first storage unit **114**, the second storage unit **146**, or combination thereof.

In an embodiment, the iteration process flow **800** can be implemented with hardware including the control device **212** of FIG. **2**, such as the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, or combination thereof, can be coupled to the memory device **208**, the storage device **204**, other disclosed devices, any device, or combination thereof. For example, the control device **212** and the memory **208** can be included in the first device **102** of FIG. **1**.

In an embodiment, the iteration process flow **800**, can include a start operation **802**, a read value operation **806**, a read version **810** operation, a version operation **814**, a return operation **818**, a more operation **822**, an end operation **826**, or combination thereof. Each of the start operation **802**, the read value operation **806**, the read version **810** operation, the version operation **814**, the return operation **818**, the more operation **822**, the end operation **826**, or combination thereof, can be implemented with hardware in a manner similar to the iteration process flow **800**.

In an embodiment, the read value operation **806** can read a key value pair from a key value store device. The key value pair such as the key value pair **404** of FIG. **4**, the key value pair **604** of FIG. **6**, any key value pair, or combination thereof, can be read from a key value store such as the storage structure **400** of FIG. **4**, the storage structure **600** of FIG. **6**, any storage, or combination thereof.

In an embodiment, the read version **810** operation can read a concurrency control version stamp (cc_vs) value of the key value pair. The concurrency control version stamp (cc_vs) can include values of the first concurrency control version stamp **522** of FIG. **5**, the second concurrency control version stamp **542** of FIG. **5**, the third concurrency control version stamp **562** of FIG. **5**, any version stamp, or combination thereof.

In an embodiment, the version operation **814** can compare a received concurrency control version stamp (cc_vs) with a current cc_vs and determine if the received version is less than or equal to current version. The version operation **814** can determine a positive outcome ("yes") or a negative outcome ("no") to determine a next process or operation of the iteration process flow **800**.

In an embodiment, the return operation **818** can be invoked by the version operation **814** based on the comparison of the received cc_vs with a current cc_vs. The return operation **818** can provide or return a key value index node such as the value **236** of FIG. **2**, the first value **316** of FIG. **3**, the second value **336** of FIG. **3**, the third value **356** of FIG. **3**, the fourth value **376** of FIG. **3**, the fifth value **396** of FIG. **3**, key value index nodes, or combination thereof.

In an embodiment, the more operation **822** can determine if more key value pairs are in the key value store to determine a next process or operation of the iteration process flow **800**. For example, the more operation **822** can determine that "yes" there are more key value pairs and invoke the read value operation **806**. Alternatively for example, the more operation **822** can determine that "no" there are no more key value pairs and invoke the end operation **826**.

Referring now to FIG. **9**, therein is shown a read process flow **900** of the electronic system in an embodiment of the invention. The read process flow **900** can read a latest consistent revision or version of a key value pair. The read process flow **900** can determine the latest consistent revision based on concurrent writing of a key value pair and determining an input version stamp in a manner similar to the read block **684** of FIG. **6**.

In an embodiment, the read process flow **900** can be implemented with hardware including the storage device **204** of FIG. **2**, the memory device **208** of FIG. **2**, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, or combination thereof. For example, the storage device **204**, the memory device **208**, or combination thereof, can be implemented in the first storage unit **114**, the second storage unit **146**, or combination thereof.

In an embodiment, the read process flow **900** can be implemented with hardware including the control device **212** of FIG. **2**, such as the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, or combination thereof, can be coupled to the memory device **208**, the storage device **204**, other disclosed devices, any device, or combination thereof. For example, the control device **212** and the memory **208** can be included in the first device **102** of FIG. **1**.

In an embodiment, the read process flow **900** can include a start operation **902**, a calculate operation **906**, a find operation **910**, an entry operation **914**, a read operation **918**, a return operation **922**, an end operation **926**, or combination thereof. Each of the start operation **902**, the calculate operation **906**, the find operation **910**, the entry operation **914**, the read operation **918**, the return operation **922**, the end operation **926**, or combination thereof, can be implemented with hardware in a manner similar to the read process flow **900**.

In an embodiment, the calculate operation **906** can calculate a value such as a hash value, a binary value, an index value, a mapping value, a tree value, or combination thereof. The value can be calculated based on a key such as the key value pair **404** of FIG. **4**, the key value pair **604** of FIG. **6**, any key value pair, or combination thereof.

In an embodiment, the find operation **910** can find a key with the calculated value in a tree. The calculated value can include a hash value, a binary value, an index value, a mapping value, or combination thereof. The tree can include the tree **218** of FIG. **2**, the memory structure **300** of FIG. **3**, or combination thereof.

In an embodiment, the entry operation **914** can determine if a key entry is in the tree. The key entry can include the entry **228** of FIG. **2**, the first entry **308** of FIG. **3**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof.

In an embodiment, the read operation **918** can be invoked based on a "yes" that the key entry is in the tree by the entry operation **914**. Based on the "yes" the key entry is in the tree, the read operation **918** can read a value of the key from a key value index node location in the tree. The value of the key or key value can include the value **418** of FIG. **4**, the first key value **528** of FIG. **5**, the second key value **548** of FIG. **5**, and the third key value **568** of FIG. **5**, the value **618** of FIG. **6**, or combination thereof.

In an embodiment, the return operation **922** can be invoked based on a "no" that the key entry is not in the tree by the entry operation **914**. Based on the "no" the key entry is not in the tree, the return operation **922** can provide or return a "no key error" based on the key not found in entry operation **914**.

Referring now to FIG. **10**, therein is shown a delete process flow **1000** of the electronic system in an embodiment of the invention. The delete process flow **1000** can delete values based on a concurrency control version stamp (cc_vs) value less than or equal to an input cc_vs value from a key value store device. If all versions of a key value pair are intended for deletion, the key value pair record in the hash tree can be deleted. The delete process flow **1000** can

provide functions in addition to, or in place of the functions of the delete block **688** of FIG. **8**. For example in a manner similar to the delete block **688**, the delete process flow **1000** can optionally invalidate a key value pair record of a hash tree, and implement a trim or delete of the key value pairs asynchronously at a different or later time.

In an embodiment, the delete process flow **1000** can be implemented with hardware including the storage device **204** of FIG. **2**, the memory device **208** of FIG. **2**, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, or combination thereof. For example, the storage device **204**, the memory device **208**, or combination thereof, can be implemented in the first storage unit **114**, the second storage unit **146**, or combination thereof.

In an embodiment, the delete process flow **1000** can be implemented with hardware including the control device **212** of FIG. **2**, such as the first control unit **112** of FIG. **1**, the second control unit **134** of FIG. **1**, or combination thereof, can be coupled to the memory device **208**, the storage device **204**, other disclosed devices, any device, or combination thereof. For example, the control device **212** and the memory **208** can be included in the first device **102** of FIG. **1**.

In an embodiment, the delete process flow **100** can include a start operation **1002**, a calculate operation **1006**, a find operation **1010**, an entry process **1014**, a read entry operation **1018**, a read value operation **1022**, a read version operation **1026**, a version operation **1030**, a delete operation **1034**, a more operation **1038**, a return operation **1042**, an end operation **1046**, or combination thereof. Each of the start operation **1002**, the calculate operation **1006**, the find operation **1010**, the entry process **1014**, the read entry operation **1018**, the read value operation **1022**, the read version operation **1026**, the version operation **1030**, the delete operation **1034**, the more operation **1038**, the return operation **1042**, the end operation **1046**, or combination thereof, can be implemented with hardware in a manner similar to the delete process flow **1000**.

In an embodiment, the calculate operation **1006** can calculate a value such as a hash value, a binary value, an index value, a mapping value, a tree value, or combination thereof. The value can be calculated based on a key such as the key value pair **404** of FIG. **4**, the key value pair **604** of FIG. **6**, any key value pair, or combination thereof.

In an embodiment, the find operation **1010** can find a key with the calculated value in a tree. The calculated value can include a hash value, a binary value, an index value, a mapping value, or combination thereof. The tree can include the tree **218** of FIG. **2**, the memory structure **300** of FIG. **3**, or combination thereof.

In an embodiment, the entry operation **1014** can determine if a key entry is in the tree. The key entry can include the entry **228** of FIG. **2**, the first entry **308** of FIG. **3**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof.

In an embodiment, the read entry operation **1018** can be invoked based on a "yes" that the key entry is in the tree by the entry operation **1014**. Based on the "yes" the key entry is in the tree, the read entry operation **1018** can read the entry **228** of FIG. **2** including a key value index number in the tree. The key value index can include the value **236** of FIG. **2**, the first value **316** of FIG. **3**, the second value **336** of FIG. **3**, the third value **356** of FIG. **3**, the fourth value **376** of FIG. **3**, the fifth value **396** of FIG. **3**, a key value index, or combination thereof.

In an embodiment, the read value operation **1022** can read key value pairs from a key value store based on the key value index number in a tree of the read entry operation **1018**. The key value pairs can include the value **418** of FIG. **4**, the first key value **528** of FIG. **5**, the second key value **548** of FIG. **5**, and the third key value **568** of FIG. **5**, the value **618** of FIG. **6**, or combination thereof. The key value store can include the storage structure **400** of FIG. **4**, the storage structure **600** of FIG. **6**, any storage, or combination thereof.

In an embodiment, the read version operation **1026** can read a concurrency control version stamp (cc_vs) value based on the key value pairs of the read value operation **1022**. The concurrency control version stamp (cc_vs) can include values of the first concurrency control version stamp **522** of FIG. **5**, the second concurrency control version stamp **542** of FIG. **5**, the third concurrency control version stamp **562** of FIG. **5**, any version stamp, or combination thereof.

In an embodiment, the version operation **1030** can compare a received concurrency control version stamp (cc_vs) with a current cc_vs and determine if the received version is less than or equal to current version. The version operation **1030** can determine a positive outcome ("yes") or a negative outcome ("no") to determine a next process or operation of the iteration process flow **1000**.

In an embodiment, the delete operation **1034** can delete values, a key value pair, key value pairs, key value pair record in a hash tree, or combination thereof, based on the positive outcome ("yes") of the version operation **1030**. Optionally, the actual trim or delete can be implemented asynchronously at a different time.

In an embodiment, the return operation **1042** can be invoked based on a "no" the key entry is not in the tree by the entry operation **1014**. The return operation **1042** can provide or return a "no key error" based on the key not found in entry operation **1014**.

In an embodiment, the more operation **1038** can determine if more key value pairs are in the key value store to determine a next process or operation of the iteration process flow **1000**. For example, the more operation **1038** can determine that "yes" there are more key value pairs and invoke the read value operation **1022**. Alternatively for example, the more operation **1038** can determine that "no" there are no more key value pairs and invoke the end operation **1046**.

Referring now to FIG. **11**, therein is shown examples of embodiments of the electronic system **100**. The embodiments can include application examples for the electronic system **100** such as a smart phone **1112**, a dash board of an automobile **1122**, a notebook computer **1132**, or combination thereof.

These application examples illustrate purposes or functions of various embodiments of the invention and importance of improvements in version control including improving system performance, reducing input and output operations, eliminating redundant input and output operations, reducing the need for metadata at the application level, reducing system memory, or combination thereof.

For example, the memory structure **600** of FIG. **6** can maximize system performance, minimize overhead of the memory transactions, minimize area of the memory modules, minimize cost, minimize memory bandwidth consumption, eliminate memory bandwidth consumption, minimize memory transaction conflicts, eliminate memory transaction conflicts, or combination thereof.

In an example where an embodiment of the invention is an integrated physical logic circuit and the memory structure **300** of FIG. **3**, the memory structure **500** of FIG. **5**, the memory structure **600**, or combination thereof, is integrated in the storage device **204**, the first storage unit **114** of FIG. **1**, the second storage unit **146** of FIG. **1**, or combination thereof, transactions can be significantly reduced, such as requiring only one input and output (I/O) based on devices without the memory structure **300**, the memory structure **500**, the memory structure **600**, or combination thereof.

Various embodiments of the invention provide optimizing operations, improving system performance, improving energy efficiency, enabling new memory technologies, enabling compatibility with current memory hierarchies, providing transparent implementation for user applications, or combination thereof.

The electronic system **100**, such as the smart phone **1112**, the dash board of the automobile **1122**, and the notebook computer **1132**, can include a one or more of a subsystem (not shown), such as a printed circuit board having various embodiments of the invention, or an electronic assembly (not shown) having various embodiments of the invention. The electronic system **100** can also be implemented as an adapter card in the smart phone **1112**, the dash board of the automobile **1122**, and the notebook computer **1132**.

Thus, the smart phone **1112**, the dash board of the automobile **1122**, the notebook computer **1132**, other electronic devices, or combination thereof, can provide significantly faster throughput with the electronic system **100** such as processing, output, transmission, storage, communication, display, other electronic functions, or combination thereof. For illustrative purposes, the smart phone **1112**, the dash board of the automobile **1122**, the notebook computer **1132**, other electronic devices, or combination thereof, is shown although it is understood that the electronic system **100** can be used in any electronic device.

Referring now to FIG. **12**, therein is shown a flow chart of a method **1200** of operation of an electronic system **100** in an embodiment of the present invention. The method **1200** includes: storing a descriptor, including a key and a value, on a storage device with the descriptor having multiple versions linked on the storage device in a block **1202**; providing an entry, including a location, with a storage interface, coupled to the storage device in a block **1204**; and retrieving the descriptor, including the key and the value, with the storage interface, coupled to the storage device, based on the entry including the location for selecting one of the versions of the descriptor in a block **1206**.

The method **1200** for block **1202** can include storing the descriptor on a solid state device, storing the entry on a volatile device, the storage device configured to receive the entry, or combination thereof. The method **1200** for block **1206** can include retrieving a version of the descriptor. The method **1200** can further include storing a stamp on the storage device, storing a pointer on the storage device, or combination thereof. The method **1200** can further include versions with entries. Tracking the entries enables selecting from the versions of entries.

In an embodiment, the electronic system **200** of FIG. **2** including the storage **204** of FIG. **2** with the descriptor **224** of FIG. **2** and the memory **208** of FIG. **2** with the tree **218** of FIG. **2** can require only one input and output (IO) operation for writing a new version on or in a storage medium. The descriptor **224** can include a linked list accessed with the tree **218** for operations by a single input and output (I/O) access.

In an embodiment, the first entry **308** of FIG. **3**, the second entry **328** of FIG. **3**, the third entry **348** of FIG. **3**, the fourth entry **368** of FIG. **3**, the fifth entry **388** of FIG. **3**, similar additional entries, any entries, or combination thereof, can at least provide a location for saved descriptors in a non-volatile memory device. The first entry **308**, the second entry **328**, the third entry **348**, the fourth entry **368**, the fifth entry **388**, similar additional entries, any entries, or combination thereof, can at least include a simple number representing a start block address for locating the saved descriptor for each key value pair that was stored in the non-volatile memory device.

In an embodiment, the storage structure **400** of FIG. **4** can provide information about key value pairs including a location of the associated memory structure **400**. The storage structure **400** can include the key **414** of FIG. **4**, the value **418** of FIG. **4**, the metadata **430** of FIG. **4**, the key length **434** of FIG. **4**, the value length **438** of FIG. **4**, or combination thereof.

In an embodiment, the interface **464** of FIG. **4**, such as a firmware interface, that can provide writing, updating, inserting, iterating, deleting, or combination thereof, of the storage structure **400**. The interface **464** can provide writing, updating, inserting, iterating, deleting, or combination thereof, based on pattern matching of the storage structure **400**.

In an embodiment, the storage system **500** of FIG. **5** provides a linked list with all versions of a key value (KV) pair chained on the storage device **504** of FIG. **5**. The first pointer **526** of FIG. **5**, the second pointer **546** of FIG. **5**, the third pointer **566** of FIG. **5**, or combination thereof, can point, link, or couple, multiple versions of the descriptors such as the first descriptor **514** of FIG. **5**, the second descriptor **534** of FIG. **5**, the third descriptor **554** of FIG. **5**, or combination thereof.

In an embodiment, the storage structure **600** of FIG. **6** can provide information about key value pairs including a location of the associated memory structure **600**. The storage structure **600** can include the key **614** of FIG. **6**, the value **618** of FIG. **6**, the metadata **630** of FIG. **6**, the key length **634** of FIG. **6**, the value length **638** of FIG. **6**, the pointer **644** of FIG. **6**, the stamp **648** of FIG. **6**, or combination thereof.

In an embodiment, the interface **664** of FIG. **6**, such as a firmware interface, that can provide writing, updating, inserting, iterating, deleting, or combination thereof, of the storage structure **600**. The interface **664** can provide writing, updating, inserting, iterating, deleting, or combination thereof, based on pattern matching of the storage structure **600**.

All of the modules, processes, functions, applications, or combination thereof, herein can be implemented as hardware, hardware circuitry, or hardware accelerators with the first control unit **112** of FIG. **1** or with the second control unit **134** of FIG. **1**. The modules can also be implemented as hardware, hardware circuitry, or hardware accelerators with the first device **102** of FIG. **1** or with the second device **106**, and outside of the first control unit **112** or the second control unit **134**, respectively.

All or at least a portion of the modules, processes, functions, applications, or combination thereof, herein can be included in the first software **126** of FIG. **1**, the second software **142** of FIG. **1**, or a combination thereof. All or at least a portion of the modules herein can also be included in the first storage unit **114** of FIG. **1**, the second storage unit **246** of FIG. **2**, or a combination thereof. The first control unit **112**, the second control unit **134**, or a combination thereof can execute all of the modules for operating the electronic system **100** of FIG. **1**.

The resulting method, process, apparatus, device, product, and/or system is straightforward, cost-effective, uncomplicated, highly versatile, accurate, sensitive, and effective, and can be implemented by adapting known components for ready, efficient, and economical manufacturing, application, and utilization. Another important aspect of an embodiment of the present invention is that it valuably supports and services the historical trend of reducing costs, simplifying systems, and increasing performance. These and other valuable aspects of an embodiment of the present invention consequently further the state of the technology to at least the next level.

While the invention has been described in conjunction with a specific best mode, it is to be understood that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the aforegoing description. Accordingly, it is intended to embrace all such alternatives, modifications, and variations that fall within the scope of the included claims. All matters set forth herein or shown in the accompanying drawings are to be interpreted in an illustrative and non-limiting sense.

What is claimed is:

1. An electronic system comprising:

a storage device configured to:

store versions of a descriptor, including a pointer, a key, and a value, wherein the pointer includes a location of a preceding version of the descriptor on the storage device;

a memory device, coupled to the storage device configured to:

provide an entry corresponding to one of the versions of the descriptor, wherein the entry includes the location of the descriptor; and

a storage interface, coupled to the memory device, configured to:

retrieve the descriptor, including the key and the value, based on the entry including the location for selecting one of the versions of the descriptor.

2. The system as claimed in claim **1** wherein the storage interface is configured to retrieve a version of the descriptor.

3. The system as claimed in claim **1** wherein the storage device is configured to store a stamp for each of the versions of the descriptor, wherein the stamp uniquely identifies a specific instance of an operation performed on or access to the descriptor.

4. The system as claimed in claim **1** wherein the storage device is configured to store the pointer to form a link list for the versions of the descriptor.

5. The system as claimed in claim **1** wherein the storage device is a solid state device.

6. The system as claimed in claim **1** wherein the storage device is a volatile device.

7. The system as claimed in claim **1** wherein the storage device is configured to track the versions with a snapshot for the versions of the descriptor, wherein the snapshot is accessible for read access during a state change operation to the descriptor.

8. A method of operation of an electronic system comprising:

storing versions of a descriptor, including a pointer, a key, and a value, on a storage device with the descriptor, wherein the pointer includes a location of a preceding version of the descriptor on the storage device;

providing an entry corresponding to one of the versions of the descriptor, wherein the entry includes the location of the descriptor with a memory device, coupled to the storage device; and

retrieving the descriptor, including the key and the value, with the storage interface, coupled to the storage device, based on the entry including the location for selecting one of the versions of the descriptor.

9. The method as claimed in claim **8** wherein retrieving the descriptor includes retrieving a version of the descriptor.

10. The method as claimed in claim **8** further comprising storing a stamp for each of the versions of the descriptor on the storage device, wherein the stamp uniquely identifies a specific instance of an operation performed on or access to the descriptor.

11. The method as claimed in claim **8** further comprising storing, on the storage device, the pointer to form a link list for the versions of the descriptor.

12. The method as claimed in claim **8** wherein storing the descriptor on the storage device includes storing the descriptor on a solid state device.

13. The method as claimed in claim **8** wherein storing the entry includes storing the entry on a volatile device.

14. The method as claimed in claim **8** further comprising tracking the versions with a snapshot for the versions of the descriptor, wherein the snapshot is accessible for read access during a state change operation to the descriptor.

15. A non-transitory computer readable medium including stored thereon instructions to be executed by a control unit comprising:

storing versions of a descriptor, including a pointer, a key, and an value, on a storage device with the descriptor, wherein the pointer includes a location of a preceding version of the descriptor on the storage device;

providing an entry corresponding to one of the versions of the descriptor, wherein the entry includes the location of the descriptor with a memory device, coupled to the storage device; and

retrieving the descriptor, including the key and the value, with the storage interface, coupled to the storage device, based on the entry having the location for selecting one of the versions of the descriptor.

16. The medium as claimed in claim **15** wherein retrieving the descriptor includes retrieving a version of the descriptor.

17. The medium as claimed in claim **15** further comprising storing a stamp for each of the versions of the descriptor on the storage device, wherein the stamp uniquely identities a specific instance of an operation performed on or access to the descriptor.

18. The medium as claimed in claim **15** further comprising storing, on the storage device, the pointer to form a link list for the versions of the descriptor.

19. The medium as claimed in claim **15** wherein storing the descriptor on the storage device includes storing the descriptor on a solid state device.

20. The medium as claimed in claim **15** further comprising tracking the versions with a snapshot for the versions of the descriptor, wherein the snapshot is accessible for read access during a state change operation to the descriptor.

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