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(54) **SYSTEM AND METHOD FOR ENHANCED SECURITY OF STORAGE DEVICES**

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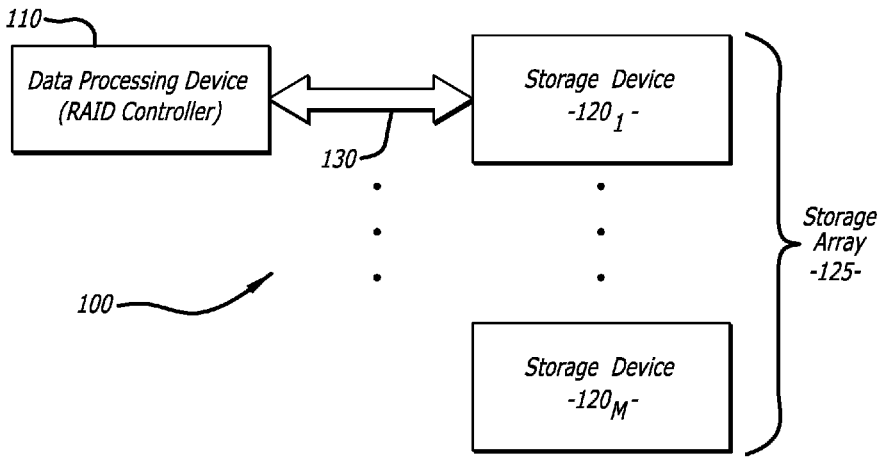
(57) **ABSTRACT**

A storage device features a processor and a random number generation which are communicatively coupled to a memory. The memory comprises an access control logic that is configured to (i) transmit a first message that comprises information associated with a random number generated by the random number generator and a first keying material, (ii) receive a second message in response to the first message, the second message comprises information generated using at least the random number, (iii) recover information from the second message, the recovered information comprises information generated using at least pre-stored keying material and a return value being based on the random number, (iv) compare the return value from the recovered information with the random number, and (v) alter an operating state of the storage device from a locked state to an unlocked state upon the return value matching the random number, the unlocked state allows one or more devices to control storage device including accessing stored content within the storage device.

19 Claims, 5 Drawing Sheets



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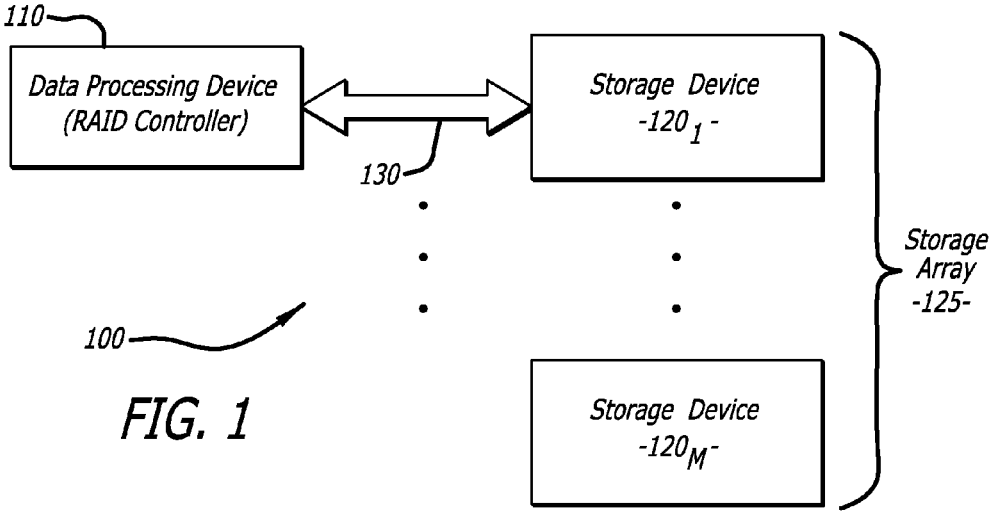
110
Data Processing Device
(RAID Controller)
130
Storage Device
-120 1 -
Storage Array
-125-
100
Storage Device
-120M-

FIG. 1

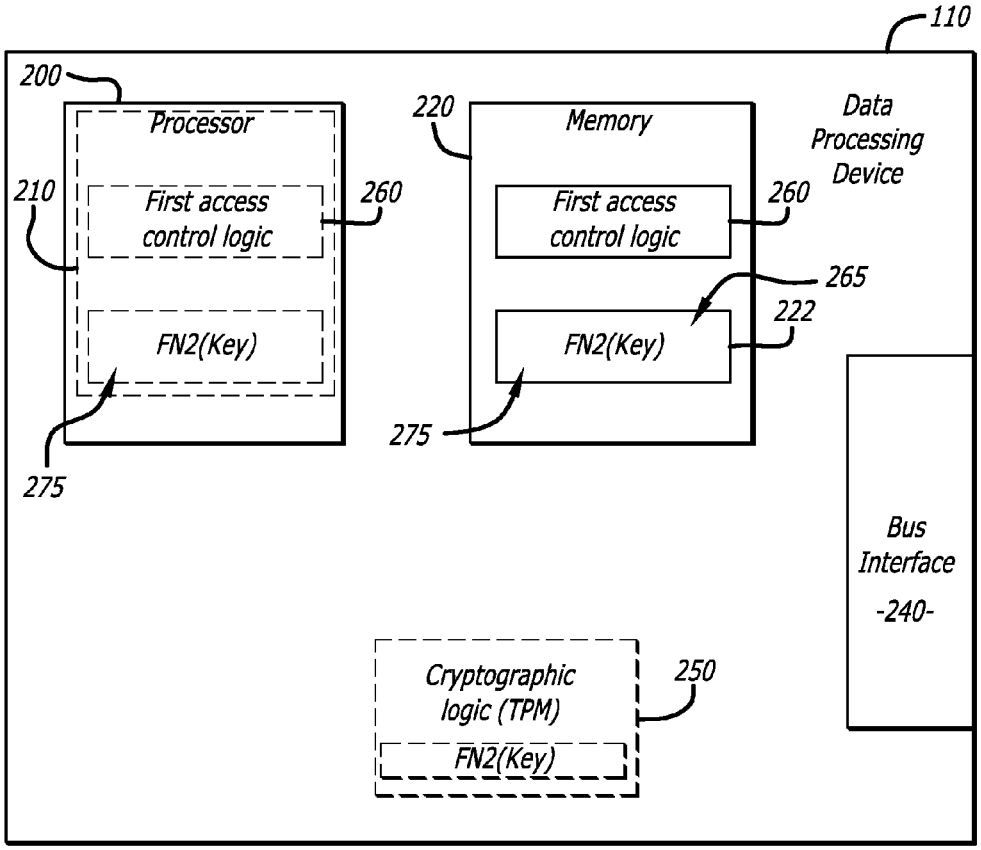
110
200
Processor
210
First access
control logic
260
FN2(Key)
275
220
Memory
First access
control logic
260
265
222
FN2(Key)
275
Data
Processing
Device
Bus
Interface
-240-
Cryptographic
logic (TPM)
250
FN2(Key)

FIG. 2

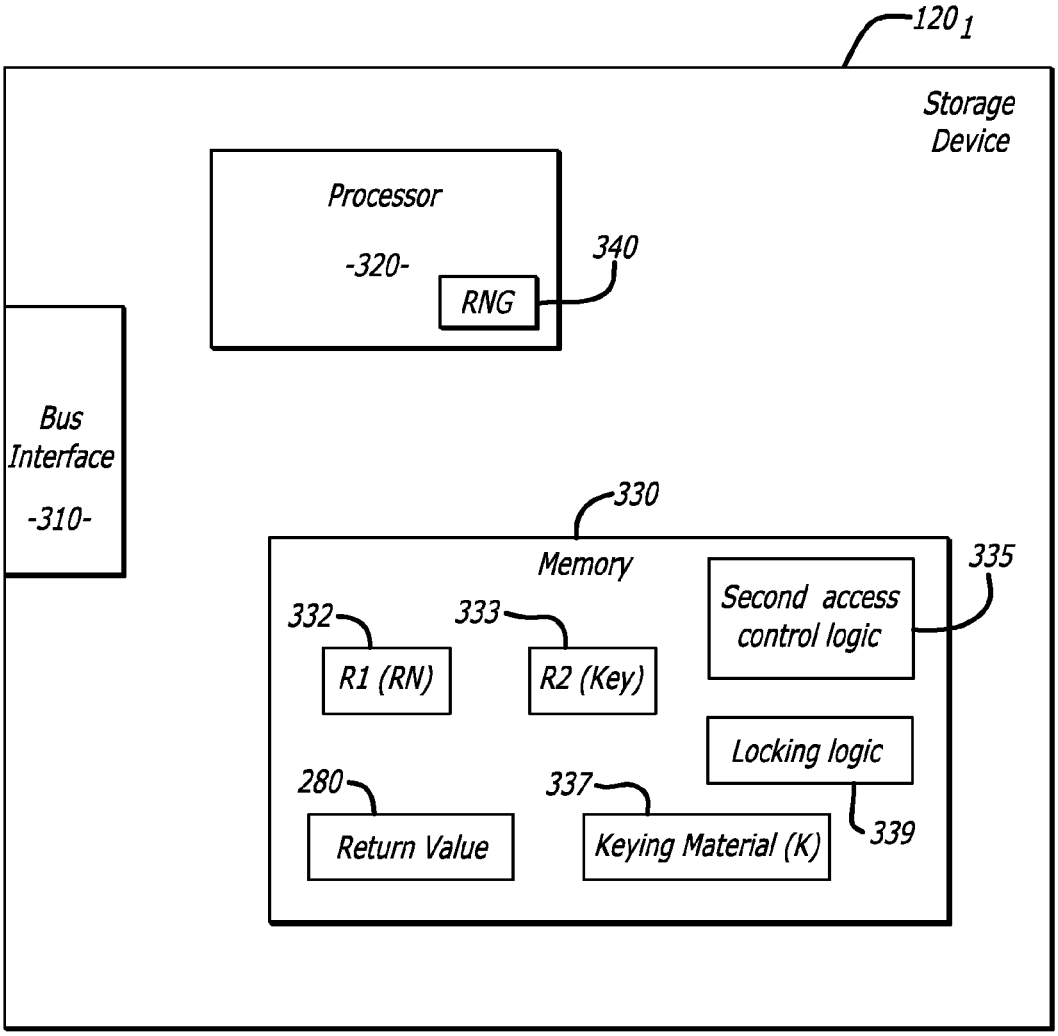
120 1
Storage Device
Processor
-320-
RNG
340
Bus Interface
-310-
330
Memory
335
Second access control logic
332
R1 (RN)
333
R2 (Key)
Locking logic
280
Return Value
337
Keying Material (K)
339

FIG. 3

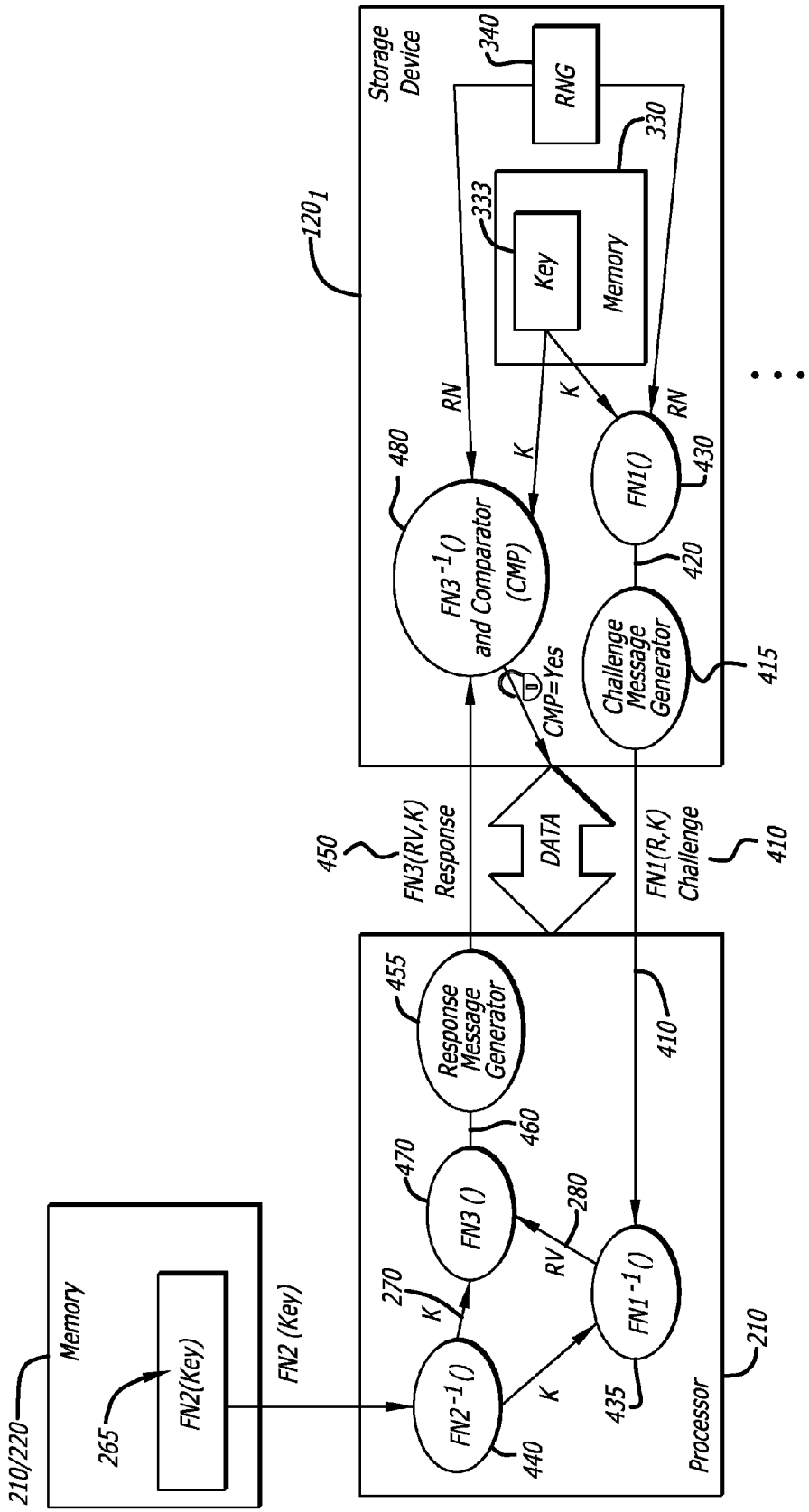
Storage Device
120_1
340
RNG
330
333
Key
Memory
RN
K
K
RN
480
FN3^{-1}() and Comparator (CMP)
FN1()
430
420
Challenge Message Generator
415
CMP=Yes
DATA
450
FN3(RV,K) Response
FN1(R,K) Challenge
410
455
Response Message Generator
410
460
470
FN3 ()
280
RV
270
K
FN2^{-1}()
K
FN1^{-1}()
435
440
Processor
210
210/220
Memory
265
FN2(Key)
FN2 (Key)

FIG. 4

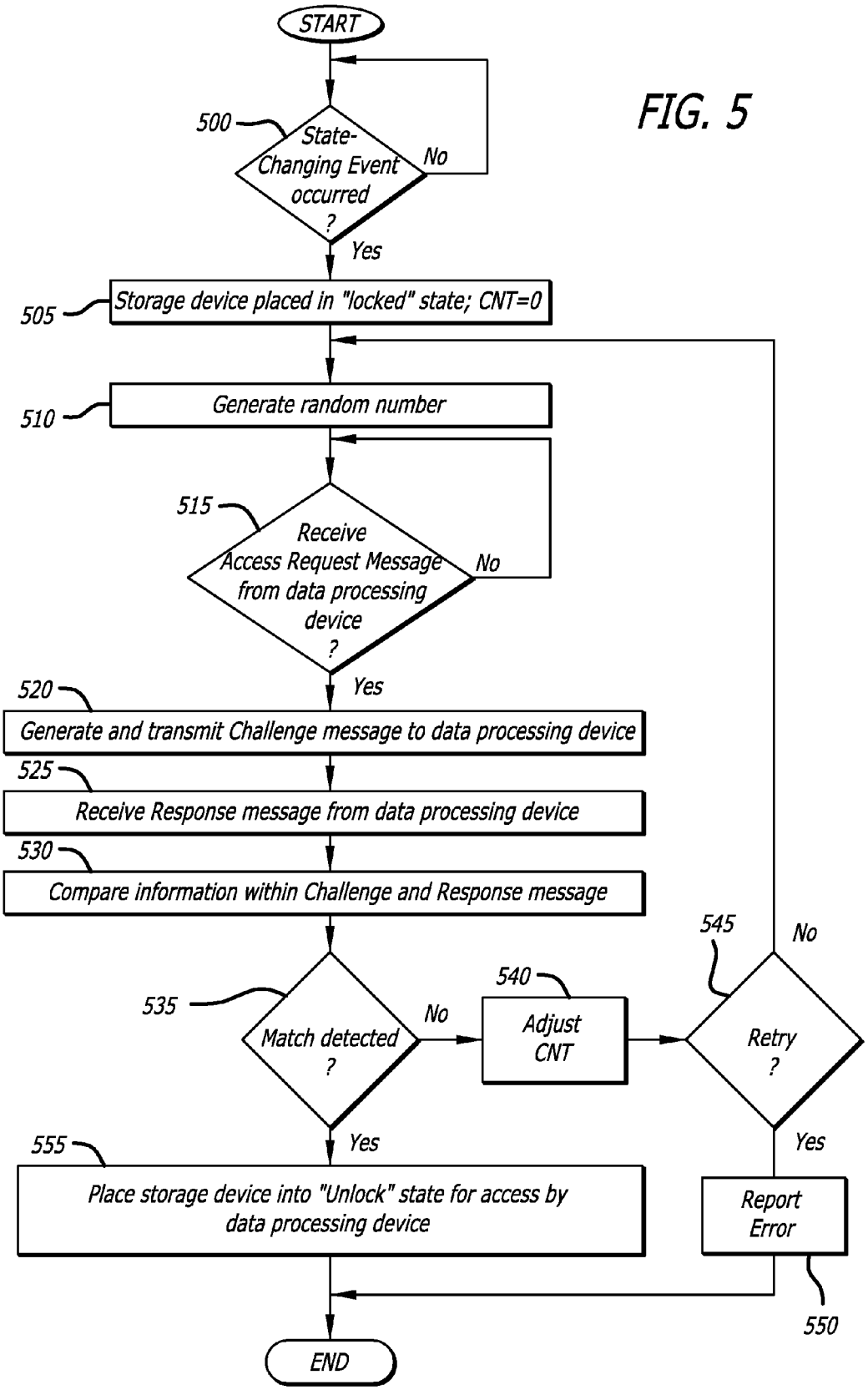
START
500
State-Changing Event occurred ?
No
Yes
505
Storage device placed in "locked" state; CNT=0
510
Generate random number
515
Receive Access Request Message from data processing device ?
No
Yes
520
Generate and transmit Challenge message to data processing device
525
Receive Response message from data processing device
530
Compare information within Challenge and Response message
535
Match detected ?
No
540
Adjust CNT
545
Retry ?
No
Yes
555
Place storage device into "Unlock" state for access by data processing device
Report Error
550
END

FIG. 5

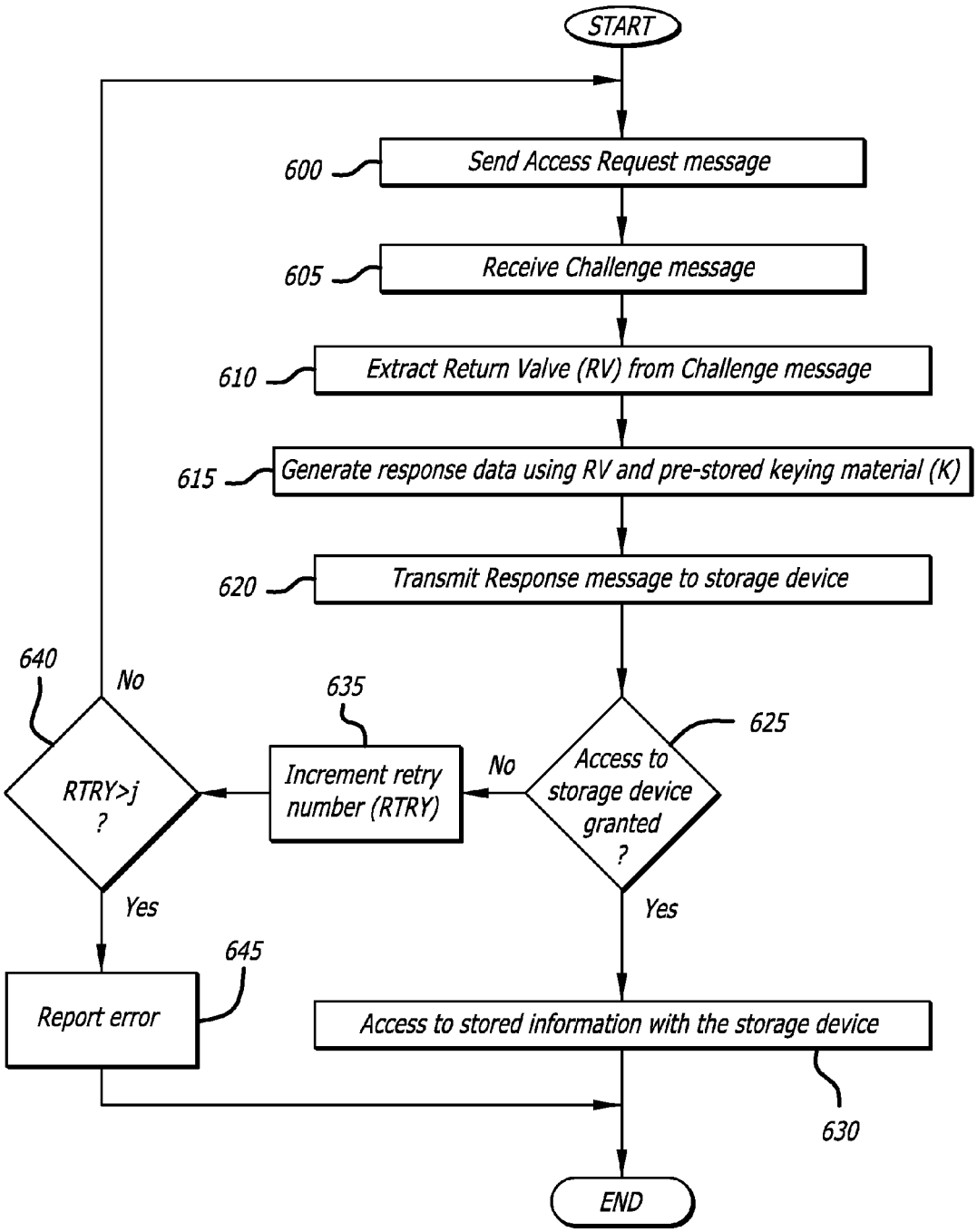
START
600
Send Access Request message
605
Receive Challenge message
610
Extract Return Valve (RV) from Challenge message
615
Generate response data using RV and pre-stored keying material (K)
620
Transmit Response message to storage device
640
No
635
625
RTRY>j ?
Increment retry number (RTRY)
No
Access to storage device granted ?
Yes
Yes
645
Report error
Access to stored information with the storage device
630
END

FIG. 6

SYSTEM AND METHOD FOR ENHANCED SECURITY OF STORAGE DEVICES

This Application claims the benefit of priority on U.S. Provisional Application No. 61/902,102 filed Nov. 8, 2013, the entire contents of which are incorporated by reference herein.

FIELD

Embodiments of the disclosure relate to the field of data security, and in particular, to a system and method directed to enhancing security of one or more storage devices such as hard disk drives.

GENERAL BACKGROUND

Over the past few years, many companies have recognized that hard disk drives and other types of data storage devices are highly susceptible to attack. Currently, some types of electronic devices, such as laptop computers for example, rely on password-entry security processes to control access to its hard disk drive. However, other types of electronic devices are unable to effectively utilize password-entry security processes.

For instance, generally speaking, web servers are in constant operation (24×7). However, on occasion, a particular server undergoes a reboot operation (e.g. power-down immediately followed by a power-on operation), which are normally conducted in the early morning hours to avoid disruption in the services offered by the server. During the reboot operation, in accordance with the ATA/ATAPI Command Set-2 specification (2009), a security unlock command is sent to the drive(s) on the server, where the security unlock command includes the password in plain text to unlock the drive. Given that this password is susceptible to an interloper who may try to monitor communications with the server (referred to as "tapping"), administrative level oversight is needed. This administrative oversight is costly and highly inconvenient as this typically requires information technology (IT) personnel to participate in a password-entry security process every time the server is forced to reboot.

Furthermore, due to remoteness of many servers, password-entry security processes are susceptible to the interloper who may intercept password information provided from the server after reboot and, with knowledge of the password, bypass all the security features of these drives in order to recover proprietary software code and other stored content within a hard drive of the server.

Hence, to provide better security, especially for servers and other remotely located storage devices, a security mechanism is needed with some capability to mitigate any attempts to "tap" and access exchanged communications in response to reboot or other state-changing events that may require authorization before granting access control.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may best be understood by referring to the following description and accompanying drawings that are used to illustrate embodiments of the disclosure.

FIG. **1** is an exemplary embodiment of a network that comprises a data processing device conducting secure pairing operations with one or more storage devices.

FIG. **2** is an exemplary embodiment of the data processing device implemented within the network of FIG. **1**.

FIG. **3** is an exemplary embodiment of one of the storage devices implemented within the network of FIG. **1**.

FIG. **4** is an exemplary embodiment of a message exchange for an authorization process between a data processing device and a storage device of FIG. **1** for hardened data store security.

FIG. **5** is a general flowchart illustrating operations conducted by a storage device during the authorization process prior to placement of the storage device into an unlocked state.

FIG. **6** is a general flowchart illustrating operations conducted by a data processing device during the authorization process prior to placement of the storage device into an unlocked state.

DETAILED DESCRIPTION

Embodiments of the disclosure are directed to a security mechanism that is adapted to automatically conduct an authorization process between one or more storage devices and a data processing device configured to collectively manage the storage device(s). This secure authorization process relies on the communicative devices having access to the same keying material, which may be used to obfuscate information within exchanged Challenge-Response messages and/or automatically recover particular information from these messages. The recovery of this particular information may be used to identify and authorize access by the requesting device to one or more storage devices, which occurs without user intervention and in a secure manner. Such access may involve administrative-level access to particular stored content within the storage device(s), control of storage space configurations associated with the storage device(s), or the like.

I. General Discussion

In general, according to one embodiment of the disclosure, in response to a "state-changing" event, namely an event that is designed to change an operating state of a storage device such as supplying or re-supplying a level of power to a storage device for placement into an active operating state for example (e.g. reboot, initial power up, wake-up from sleep mode, timer interrupt, etc.), logic within the storage device generates a random number that is stored within an internal data store. In response to a data processing device requesting access to the storage device, the random number is obfuscated prior to being transmitted as part of a Challenge message to the data processing device. The Challenge message is one of the transmissions conducted during this authorization process.

More specifically, at least the random number and keying material are obfuscated, where the resultant information (referred to herein as "challenge data") is provided as part of the Challenge message. At this time, the storage device is currently in its default (locked) state that precludes unauthorized devices, such as the data processing device for example, from having any control of the storage device including accessing stored content.

According to one embodiment of the disclosure, prior to transmission, the keying material and the random number are obfuscated in accordance with a first function (FN1( )). As an illustrative example, the first function (FN1( )) may represent an Exclusive OR (XOR) function in which the keying material, being a stored "secret" key or a derivation of the key such as a hash value of the key for example, and the random number undergo an XOR operation conducted in

a bitwise manner. For example, the keying material (K) may be XOR'ed with the random number (RN), namely K XOR RN, to produce the challenge data. In another example, the keying material and/or random number may undergo other forms of reversible arithmetic or logical functions (e.g. ADD, SUB, MODULO, SHIFT, MULT, etc.) or the combination of such in a more complex form (e.g. AES, Triple-DES, etc.).

Upon receipt of the Challenge message, according to one embodiment of the disclosure, the data processing device accesses and decrypts a key stored in encrypted form in accordance with a second function (FN2( )). The encrypted key corresponds to the "secret" key stored in the storage device, where the keying material used to obfuscate the return value is based on the decrypted key. For instance, similar to keying material utilized by the storage device, the keying material produced by the data processing device may be the decrypted key itself or may be a derivation of the decrypted key such as a fixed-length hash value produced from the decrypted key. Thereafter, the keying material also is provided in a Response message prior to transmission.

The Response message includes information based on both (i) the keying material based on the decrypted key and/or (ii) a return value. This information, sometimes referred to herein as "response data," may be the result of the keying material and the return value being obfuscated using a third function (FN3( )) prior to transmission. According to one embodiment, the third function (FN3( )) is different from the first function (FN1( )). For instance, the third function (FN3( )) may be an arithmetic or logical operation that is stateless (e.g., any arithmetic or logical function that is 1:1, 1:n or 1:n mapping), or stateful (e.g. time varying, or any function whose output depends on states based on previous history) or the like. Also, the logical operations conducted by FN3( ) to produce the response data may vary for different Response messages.

The "return value" is information produced by conducting an operation on the challenge data in accordance with an inverse FN1 ($FN1^{-1}$( )) function. For this illustrative example, the return value should be equivalent to the random number, which is recovered by conducting the same XOR operation as conducted within the storage device to produce the challenge data.

In the event of a successful authorization (e.g. comparison of the return value with the random number and/or keying materials), the data processing device is provided access control of the storage device(s), with access to stored content within the storage device(s). This may be accomplished by the storage device altering its operating state from a default "locked" state to an "unlocked" state. This "unlocked" state may remain for all communications with the data processing device until the next state-changing event occurs. Otherwise, in the event of an unsuccessful authorization, the data processing device is precluded from accessing stored content within the storage device as the storage device remains in a "locked" state.

II. General Terminology

In the following description, certain terminology is used to describe features of the disclosure. For example, the term "device" generally represents electronics that support the receipt and/or transmission of information over any type of interconnect. More specifically, the terms "storage device" and "data processing device" are used herein. A "storage device" may include any device with information storage capabilities such as one or more physical disk drives (e.g. magnetic disk drives, magneto-optical disk drives, optical disk drives, self encrypted drives, etc.) that may be remotely located from the data processing device, or an external data store (e.g. a flash drive, an external hard disk drive, etc.). A "data processing device" comprises logic that is adapted to manage one or more storage devices, where the logic may be in the form of a circuit board upon which components for data processing are mounted. The circuit board may constitute a motherboard of the electronic device or a RAID (Redundant Array of Independent Disks) controller. Examples of the data processing device may include a computer (e.g., laptop, tablet, desktop, etc.), another type of consumer electronics (e.g., television, a set-top box, a content streaming player such a Roku® player, etc.) or electronics configured to support communications with the storage device (e.g., router, brouter, bridge, controller, access point, base station, etc.).

Herein, the term "logic" is generally defined as hardware, software and/or firmware. For example, as hardware, logic may include processing circuitry (e.g., a microcontroller, any type of processor, a programmable gate array, an application specific integrated circuit, etc.), semiconductor memory, combinatorial logic, or the like. As software, logic may be one or more software modules, such as executable code in the form of an executable application, an application programming interface (API), a subroutine, a function, a procedure, an object method/implementation, an applet, a servlet, a routine, a source code, an object code, a shared library/dynamic load library, or one or more instructions. These software modules may be stored in any type of a suitable non-transitory storage medium (described above) or transitory computer-readable transmission media (e.g., electrical, optical, acoustical or other form of propagated signals such as carrier waves, infrared signals, digital signals).

"Firmware" denotes software that controls functionality of the device. Examples of firmware include software pertaining to an operating system or Basic Input Output System (BIOS).

The term "keying material" generally refers to information associated with protected data such as a cryptographic (secret) key or information derived from the key such as a hash value produced by the key undergoing a one-way cryptographic hash function (e.g. a MD-based function, SHA-based function, etc.). The term "content" generally refers to stored information that may be sent over a network as one or more messages, where each message may be in the form of a packet, a frame, an Asynchronous Transfer Mode "ATM" cell, or any other series of bits having a prescribed format.

An "interconnect" is generally defined as one or more communication pathways established over one or more types of medium. The medium may be a physical medium (e.g., electrical wire, optical fiber, cable, bus traces, etc.), a wireless medium (e.g., air in combination with wireless signaling technology), or a combination thereof. The data transferred over the interconnect may be in accordance with a variety of communication protocols including, but not limited or restricted to SATA, SAS, PCIe, Ethernet or other wired protocols, or wireless protocols such as any type of IEEE 802.11 standards (e.g., IEEE 802.11ac, 802.11n, etc.), IEEE 802.3 standard, or the like.

The term "computerized" generally represents any corresponding operations that are conducted by hardware in combination with software and/or firmware. Also, the term "compare" generally means determining whether digital

information associated with one item substantially corresponds or is identical to the digital information associated with another item.

Lastly, the terms "or" and "and/or" as used herein are to be interpreted as inclusive or meaning any one or any combination. Therefore, "A, B or C" or "A, B and/or C" mean "any of the following: A; B; C; A and B; A and C; B and C; A, B and C." An exception to this definition will occur only when a combination of elements, functions, steps or acts are in some way inherently mutually exclusive.

As this invention is susceptible to embodiments of many different forms, it is intended that the present disclosure is to be considered as an example of the principles of the invention and not intended to limit the invention to the specific embodiments shown and described.

III. General Architecture

Referring to FIG. **1**, an exemplary embodiment of a network **100** that comprises a data processing device **110** in communication with one or more storage devices $\mathbf{120}_1$-$\mathbf{120}_M$ (M≥1) is shown. As illustrated, data processing device **110** is communicatively coupled to storage devices $\mathbf{120}_1$-$\mathbf{120}_M$ via interconnect **130**. Hence, data processing device **110** may transmit messages over interconnect **130** to one or more storage devices $\mathbf{120}_1$-$\mathbf{120}_M$, and similarly, storage device(s) $\mathbf{120}_1$-$\mathbf{120}_M$ may transmit messages over interconnect **130** to data processing device **110**.

According to one embodiment of the disclosure, data processing device **110** may be configured as a RAID controller that is adapted to manage storage devices $\mathbf{120}_1$-$\mathbf{120}_M$, such as one or more physical disk drives operating as a storage array **125** for example. Furthermore, as a RAID controller, data processing device **110** may present these drives for display as logical units. Hence, upon successful authorization of a corresponding storage device (e.g., storage device $\mathbf{120}_i$, i≥1), the data processing device **110** is permitted access to that storage device $\mathbf{120}_i$. Of course, it is contemplated that, in lieu of the data processing device **110** operating as a RAID controller, it is contemplated that intermediary logic in communication with the data processing device **110** and the storage devices $\mathbf{120}_1$-$\mathbf{120}_M$ may operate as the RAID controller.

Referring to FIG. **2**, an exemplary embodiment of data processing device **110** implemented within the network of FIG. **1** is shown. Herein, data processing device **110** comprises one or more processors **200**, a non-volatile memory **220**, bus interface logic **240** and optional cryptographic logic **250**. According to one embodiment of the disclosure, some or all of these components **200**, **220**, **240** and/or **250** may be communicatively coupled together through one or more interconnects (not shown). Alternatively, according to another embodiment of the disclosure, these components may be integrated as part of a system-on-a-chip (SoC) implementation.

As shown in FIG. **2**, bus interface logic **240** enables data processing device **110** to establish external communications with storage devices $\mathbf{120}_1$-$\mathbf{120}_M$ through interconnect **130** (e.g. Advanced Technology Attachment "ATA" bus, Ethernet cable, etc.), as shown in FIG. **1**.

According to one embodiment of the disclosure, memory **220** includes a first access control logic **260** and at least one cryptographic key **265** encrypted in accordance with a second function (illustrated as "FN2(key) **275**"). FN2(key) **275** may be stored within a register **222** being part of memory **220**, where memory **220** may be located on a RAID controller card or a motherboard of data processing device **110**, perhaps on a separate circuit board than the processor(s) **200**. Produced from FN2(key) **275**, the keying material **270** may be the key **265** itself or a derivation of the key **265** such as a hash value produced from key **265**.

According to one embodiment of the disclosure, the first access control logic **260** is software that, when executed by one or more processor(s) **200**, generates and transmits (i) one or more Access Request messages to request access to storage device(s) $\mathbf{120}_1$-$\mathbf{120}_M$ and/or (ii) a Response message in response to a corresponding Challenge message being part of the authorization process. Furthermore or in the alternative, first access control logic **260** may handle the retrieval of the encrypted key (FN2(key) **275**) and/or extraction of information from an incoming Challenge message received via the bus interface **240** from a storage device responding to an Access Request message. Such extraction utilizes, at least in part, the keying material **270** based on the key **265** recovered from FN2(key) **275**.

As described below in greater detail, the Access Request message is a message to request access to a particular storage device (e.g. storage device $\mathbf{120}_1$), which commences the Challenge-Response authorization process described below. The Response message is a message that includes information for the storage device $\mathbf{120}_1$ of FIG. **1** to confirm that the data processing device **110** is authorized to manage as well as access stored content within the particular storage device $\mathbf{120}_1$.

As further shown in FIG. **2**, an optional cryptographic logic **250**, such as a Trusted Platform Module (TPM), may be implemented within the data processing device **110** to store the keying material **270** and assist in the cryptographic operations.

According to another embodiment of the disclosure, in lieu of storage within memory **220**, first access control logic **260** and/or FN2(key) **275** may be implemented as part of the processor(s) **200** or stored within non-volatile (NV) memory within the processor(s) **200**. For instance, first access control logic **260** may be implemented within on-chip local NV memory allocated to the Basic Input/Output Subsystem (BIOS). Additionally or in the alternative, FN2(key) **275** may be stored within local NV memory **210**.

Referring now to FIG. **3**, an exemplary embodiment of storage device $\mathbf{120}_1$ implemented within network **100** of FIG. **1** is shown. Herein, storage device $\mathbf{120}_1$ comprises bus interface logic **310**, one or more processors **320** and a memory **330**, and a random number generator (RNG) **340**. According to one embodiment of the disclosure, some or all of these components **310**, **220**, **330** and/or **340** may be communicatively coupled together through one or more interconnects (not shown). Alternatively, according to another embodiment of the disclosure, these components may be integrated as part of a SoC implementation.

According to one embodiment of the disclosure, the RNG **340** may be implemented as any of a variety of number generators (e.g. pseudo random number generator "RNG", Arithmetic Pseudo RNG, Quasi RNG, Physical RNG, etc.) deployed within processor(s) **320** that generates at least one pseudo-random number (RN) in response to storage device $\mathbf{120}_1$ undergoing a state-changing event. Alternatively, it is contemplated that the RNG **340** may generate at least one pseudo-random number (RN) upon receipt of an Access Request message by bus interface logic **310**. Bus interface logic **310** enables storage device $\mathbf{120}_1$ to establish external communications with the data processing device **110**.

According to one embodiment of the disclosure, memory **330** includes a first data store **332**, a second data store **333**, second access control logic **335**, keying material **337** and

locking logic **339**. Herein, first data store **332** may be implemented as a read-only register that stores the random number (RN) generated by the RNG **340**. The second data store **333** may be implemented as a register that stores a cryptographic key that is used to produce keying material (K) **337** (e.g. where "K" is a hash value produced from the stored key).

According to this embodiment, keying material **337** may include one or more keys (or information derived from the key) that are pre-loaded into memory **330**. The keying material **337** is used to obfuscate the random number (RN) generated by the random number generator **340** as well as recover and/or temporarily store a return value **280** associated with the response data included in a Response message sent from the data processing device **110** in response to the Challenge message, as described below.

The locking logic **339** is directed to control of an operating state of storage device $\mathbf{120}_1$. As an illustrative example, upon the second access control logic **335** determining that the data processing device **110** is authorized to access stored content therein, the locking logic **339** may be configured to receive signaling from the second access control logic **335** to alter its default operating state from a "locked" to an "unlocked" state.

According to another embodiment of storage device $\mathbf{120}_1$, although not shown, in lieu of storage within memory **220**, second access control logic **335** and/or keying material **337** may be implemented as part of processor(s) **320** or stored within non-volatile (NV) memory within the processor(s) **320**.

FIG. **4** is an exemplary embodiment of a message exchange between the data processing device **110** and at least one storage device (e.g. storage device $\mathbf{120}_1$ of FIG. **1**). Herein, as collectively illustrated in FIGS. **2-4**, in response to a state-changing event by storage device $\mathbf{120}_1$, such as a reboot operation or an operation after a prescribed number of access retries for example, the RNG **340** generates a random number (RN) and stores the random number within the first data store **332** for subsequent use. Of course, it is contemplated that the random number generation may be configured periodically in lieu of an aperiodic nature as described above. The keying material **337** is pre-stored within storage device $\mathbf{120}_1$ in an encrypted or plaintext format.

Upon receipt of an Access Request message (not shown) from the data processing device **110**, in the event that the data processing device **110** has not been authorized subsequent to the most recent random number generation, logic **415** within the storage device $\mathbf{120}_1$ generates a Challenge message **410**. The Challenge message **410** includes challenge data **420** that is based on both the keying material **337** and the random number (RN). According to one embodiment of the disclosure, the challenge data **420** is a result produced from operations conducted on the keying material (key) **337** and the random number (RN) in accordance with a first function (FN1( )) **430**. Herein, the first function (FN1( )) **430** is an XOR function to allow recovery of a value corresponding to the random number (RN) from the challenge data **420**. However, it is contemplated that the first function (FN1( )) **430** may be any function that obfuscates the keying material **337** and random number (RN) for transmission while allowing the random number to be recovered.

The Challenge message **410**, inclusive of the challenge data **420**, is transmitted to the data processing device **110**. Herein, the data processing device **110** relies on an inverse first function ($FN1^{-1}$( )) **435** to recover a return value (RV) **280** being equivalent to the random number (RN). According to one embodiment of the disclosure, where the first function (FN1( )) **430** is an XOR function, the inverse first function ($FN1^{-1}$( )) **435** is also an XOR function. Hence, by conducting a similar XOR operation on the challenge data **420** using the keying material **270**, that is equivalent to the keying material **337** stored in storage device $\mathbf{110}_1$ or derived from a key stored therein, the return value (RV) **280** is recovered.

As shown, according to one embodiment of the disclosure, the keying material **337** and the random number (RN) are obfuscated in accordance with the first function (FN1( )) **430**. As an illustrative example, the first function (FN1( )) **430** may represent an Exclusive OR (XOR) operation where the keying material (K) **337** and the random number (RN) undergo an XOR operation conducted in a bitwise manner or with greater granularity, namely K XOR RN, to produce the challenge data **420**. The challenge data **420** is part of the Challenge message **410** that is transmitted to the data processing device **110**.

Upon receipt of the Challenge message **410**, the data processing device **110** decrypts FN2(key) **275** in accordance with an inverse second function ($FN2^{-1}$( )) **440** to recover the key. Besides operating as a decryption function, $FN2^{-1}$( ) may also include functionality of producing the keying material **270** that is a derivative of the key **265** (e.g., $FN2^{-1}$( ) includes both decryption functionality and one-way hash functionality). Thereafter, logic **455** within data processing device **110** generates and transmits a Response message **450**.

The Response message **450** includes information **460** based on both (i) the keying material (K) **270** and/or (ii) the return value (RV) **280**. This information **460**, sometimes referred to herein as "response data **460**," may be the result of the keying material **270** and the return value (RV) **280** being obfuscated prior to transmission using a third function (FN3( )) **470**. According to one embodiment, the third function (FN3( )) **470** may be different from the first function (FN1( )) **430**. For instance, the third function (FN3( )) **470** may a mixture of arithmetic or logical functions that are stateful or stateless. Also, at different times and for generation of different response data **460**, FN3( ) **470** may operate differently so that the keys cannot be detected through analysis of multiple samples of the response data **460**. For example, different degrees of shifting may occur based on time, monitored count values, content within the return value (RV) **280**, or the like. Moreover, different logical functions (e.g. SHIFT, ADD, etc.) may be used depending on time, monitored count values, content within the return value (RV) **280**, or the like.

According to one embodiment of this disclosure, one "stateful" Challenge-Response scheme involves the data processing device introducing additional data (e.g. another random number) that is sent to the storage device. The additional data is saved for the next challenge event. The benefit of this stateful Challenge-Response scheme is that it will be increasingly difficult for the interloper to ever collect all the possible challenge-response combinations because the content within subsequent Challenge and Response messages will vary based on previous exchanges.

Another example of a "stateful" Challenge-Response scheme involves changing the response data based on previous history. In addition to returning the return value XOR'ed with the current key, the data processing device **110** generates a new key randomly (new_RN), which is XOR'ed with the current Return Value. The XOR'ed result is returned to the storage device $\mathbf{120}_i$. The storage device $\mathbf{120}_i$, in addition to verifying the current return value prior to place-

ment in an unlocked state to permit access thereto or continuing placement in the unlocked state, also saves the new random key (new_RN) to be used as the key for the next challenge and response cycle.

For failsafe reason, it is important to have a backup mechanism that allows both the data processing device **110** and the storage device $\mathbf{120}_i$ to revert back to the original saved keys. One method to consider is that if unlock fails after "j" retries, then restart everything with the original saved keys.

The return value (RV) **280** constitutes information produced by conducting an operation on the challenge data **420** in accordance with an inverse FN1 function ($FN1^{-1}(\ )$) **435**. For this illustrative example, the return value (RV) **280** should be equivalent to the random number (RN), which is recovered by conducting an inverse function ($FN1^{-1}(\ )$) **435** of the FN1 function conducted to produce the challenge data **420** from the keying material (K) **337** and the random number (RN).

In the event of a successful authorization (e.g. recovery of the return value (RV) by inverse function $FN3^{-1}(\ )$ **480** and comparison of the return value (RV) **280** with the random number (RN) and/or keying materials (K)), the data processing device is provided access to the storage device $\mathbf{120}_1$. This may be accomplished by the storage device $\mathbf{120}_1$ altering its operating state from a default "locked" state to an "unlocked" state. This "unlocked" state may remain for communications with the data processing device **110** until the next state-changing event occurs. Otherwise, in the event of an unsuccessful authorization, the data processing device **110** is precluded from accessing stored content within the storage device as the storage device $\mathbf{120}_1$ remains in a "locked" state.

Referring now to FIG. **5**, a general flowchart illustrating operations of a security mechanism for a storage device (e.g., storage device $\mathbf{110}_1$ of FIGS. **1** and **4**) to automatically determine whether a data processing device is permitted access thereto. Herein, in response to a state-changing event, the storage device is placed into a locked state and a count value (CNT) is set to an initial value (e.g. CNT=0) as set forth in blocks **500** and **505**. Also, a RNG within the storage device generates a random number that is subsequently stored by the storage device (block **510**).

Upon receipt of an Access Request message from the data processing device, the storage device generates and transmits a Challenge message to that data processing device (blocks **515** and **520**). Herein, the Challenge message includes challenge data that is based on both the random number (RN) and the keying material. For instance, the challenge data may be the result of a XOR operation conducted on both the random number and the keying material.

Upon receipt of a Response message from the data processing device, information associated the response data within the Response message is compared the random number and/or keying material used to produce the challenge data (blocks **525** and **530**). If no match is detected, a retry condition may be activated in which CNT is adjusted (e.g. incremented or decremented) and the adjusted CNT value is not greater (or lesser) than a prescribed retry threshold (X) as set forth in blocks **535**, **540** and **545**. In response to a retry condition, blocks **510-535** are repeated. Otherwise, an error is reported (block **550**). Of course, if a match is detected, the storage device is placed into an Unlocked state (block **555**).

FIG. **6** is a general flowchart illustrating operations by a data processing device for a security mechanism in automatically requesting and securely gaining access to a storage device. Herein, an Access Request message is sent to the electronic device associated with the storage device (block **600**). Subsequent to transmission of the Access Request message and in response thereto, the data processing device receives a Challenge message (block **605**). The return value (RV), which corresponds to the random number (RN), is extracted from the Challenge message (block **610**). Both the return RV along with the keying material undergoes a function to produce response data which is included to the Response message sent to the storage device (blocks **615** and **620**). If a match is determined between the return value (RV) and the random number (RN), the data processing device now has access to the stored content of the storage device in order to control operations of the storage device (blocks **625** and **630**)). However, if no match was detected, access to the stored content of the storage device is denied to the data processing device (block **625**). This may cause retry such as where the number of retries is less than a prescribed number (j, where $j \geq 1$) as set forth in blocks **635** and **640**. No further retries are provided, where the number of retries (RTRY) is greater than "j" (block **645**).

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as determined by the foregoing claims and their equivalents. The descriptions are thus to be regarded as illustrative instead of limiting.

What is claimed is:

1. A computerized method comprising:

transmitting, by a storage device, a first message to a data processing device, the first message comprises information generated internally within the storage device, wherein the information generated internally within the storage device is based on a random number generated by a random number generator residing in the storage device and a first keying material, the first keying material being either a key or information generated based on the key;

receiving, by the storage device, a second message in response to the first message, the second message comprises information generated using at least a portion of the information generated internally within the storage device;

recovering information from the second message by the storage device, the information from the second message comprises information generated using at least a portion of the information generated internally within the storage device;

comparing, by the storage device, the information recovered from the second message with at least the portion of the information generated internally within the storage device, wherein the storage device authenticates the data processing device upon determining that the information recovered from the second message compares to at least the portion of the information generated internally within the storage device; and

altering, by the storage device, an operating state of the storage device from a locked state to an unlocked state when the information recovered from the second message compares with at least the portion of the information generated internally within the storage device.

2. The computerized method of claim **1**, wherein the information is a result produced from operations conducted

on the random number and the first keying material in accordance with a first function.

3. The computerized method of claim **2**, wherein the first function is an Exclusive OR (XOR) function.

4. The computerized method of claim **2**, wherein the information associated with the second message is based on a return value that is equivalent to the random number generated by the random number generator and a second keying material that is equivalent to the first keying material and is recovered from a prestored cryptographic key encrypted in accordance with a second function by conducting an inverse of the second function on the prestored cryptographic key, the second keying material being either a key or information generated based on the key.

5. The computerized method of claim **4**, wherein the information associated with the second message is obfuscated prior to receipt using a third function.

6. The computerized method of claim **5**, wherein the third function is different than the first function.

7. The computerized method of claim **6**, wherein the third function is a logical function that includes a Shift function.

8. The computerized method of claim **5**, wherein the recovering of the return value and the second keying material comprises conducting an inverse of the third function.

9. The computerized method of claim **8**, wherein the comparing the information recovered from the second message with at least the portion of the information generated internally within the storage device comprises comparing the return value to the random number and the information recovered from the second message compares at least to the portion of the information generated internally within the storage device when the return value compares to the random number.

10. The computerized method of claim **1**, wherein the storage device, when placed in the unlocked state, allows one or more devices to control the storage device including accessing stored content within the storage device.

11. The computerized method of claim **1**, wherein the storage device is a hardware drive.

12. A storage device, comprising:

a processor;

a random number generator; and

a memory in communication with the processor and the random number generator, the memory comprises an access control logic that is communicatively coupled to the random number generator, the access control logic being configured, upon execution by the processor, to (i) transmit a first message that comprises information generated based on a random number generated by the random number generator and a first keying material being either a key or information generated based on the key, (ii) receive a second message in response to the first message, the second message comprises information generated based, at least in part, on at least the random number, (iii) recover information from the second message, the recovered information comprises information generated using at least pre-stored keying material and a return value being based on the random number, (iv) compare the return value from the recovered information with the random number to determine whether a first device providing the second message is authorized to access stored content within the storage device, and (v) alter an operating state of the storage device from a locked state to an unlocked state upon the return value matching the random number, the unlocked state allows the first device of one or more devices to access the stored content within the storage device while the locked state precludes a device of the one or more devices that is unauthorized from accessing the stored content.

13. The storage device of claim **12**, wherein the information associated with the random number and the first keying material includes a result produced from operations conducted on the random number and the first keying material in accordance with a first function.

14. The storage device of claim **13**, wherein the first function is an Exclusive OR (XOR) function.

15. The storage device of claim **13**, wherein the information from the second message is based on a return value that is equivalent to the random number and a second keying material that is equivalent to the first keying material and is recovered from a pre-stored cryptographic key encrypted in accordance with a second function that is different than the first function.

16. The storage device of claim **15**, wherein the information associated with the second message is further obfuscated based on a third function.

17. The storage device of claim **16**, wherein the third function is a logical function that includes a Shift function.

18. The storage device of claim **15**, wherein the access control logic to compare the return value from the recovered information with the random number and the information recovered from the second message and determines a comparison when the return value compares to the random number.

19. The computerized method of claim **11**, wherein the hardware drive corresponds to either a physical disk drive or a flash drive.

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