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**Tarkhanyan et al.**

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(54) **SECURE COMPUTING ENVIRONMENT TO ADDRESS THEFT AND UNAUTHORIZED ACCESS**

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**G06F 7/04** (2006.01)

(52) **U.S. Cl.**  
USPC ..... **726/16**

(58) **Field of Classification Search**  
USPC ..... 726/16  
See application file for complete search history.

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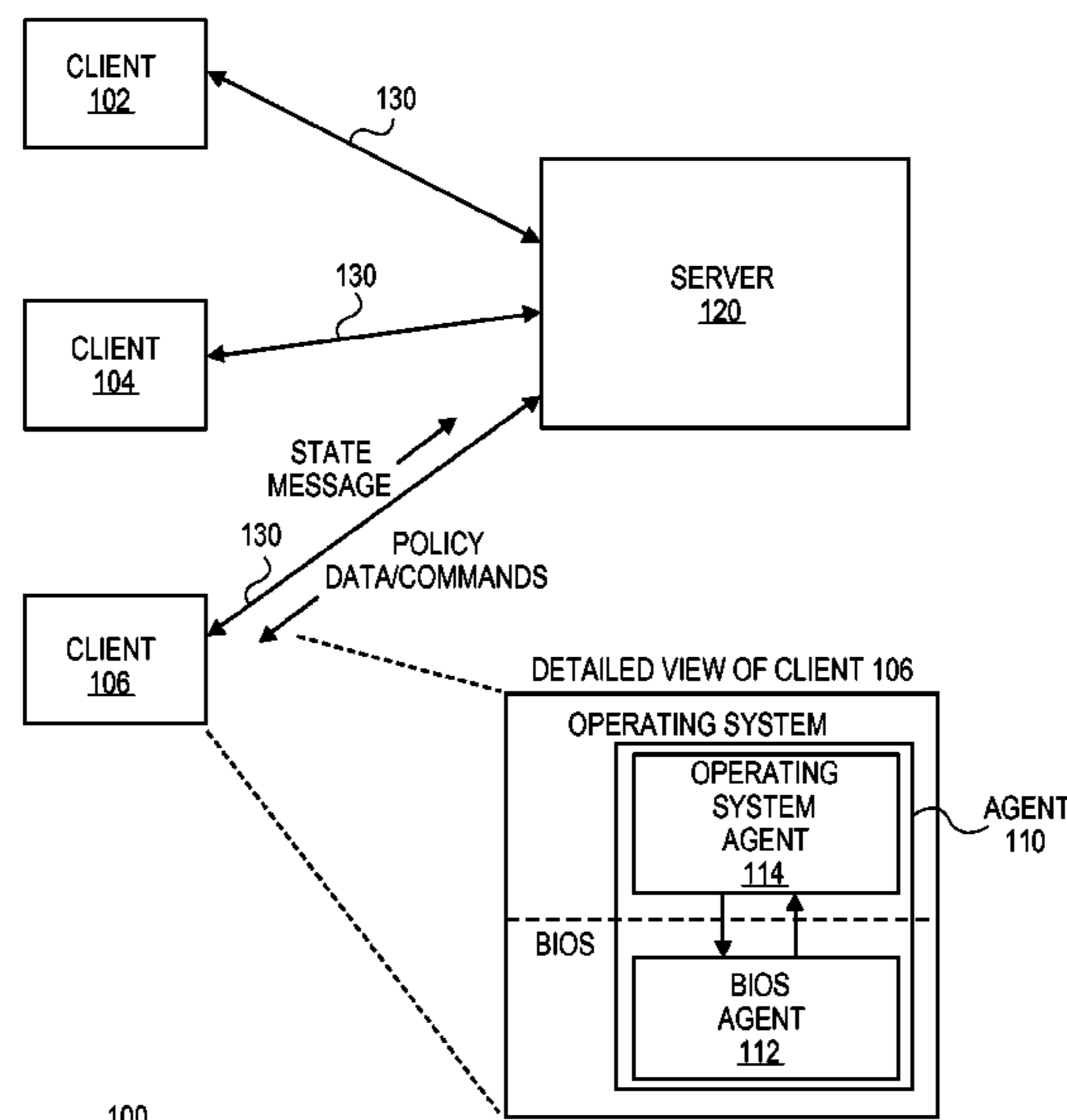
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(57) **ABSTRACT**

Techniques for securing a client. A BIOS agent stores policy data within a BIOS of the client. The BIOS agent is one or more software modules that execute in the BIOS of the client. The policy data describes one or more policies which the client should follow. When an operating system agent detects that a condition, specified by a particular policy of the one or more policies, has been met, the operating system agent performs one or more actions specified by the particular policy, such as disabling the client, retrieving a file from the client, erasing a file from the client, or encrypting a file on the client. The operating system agent is one or more software modules that execute in the operating system of the client.

**21 Claims, 12 Drawing Sheets**



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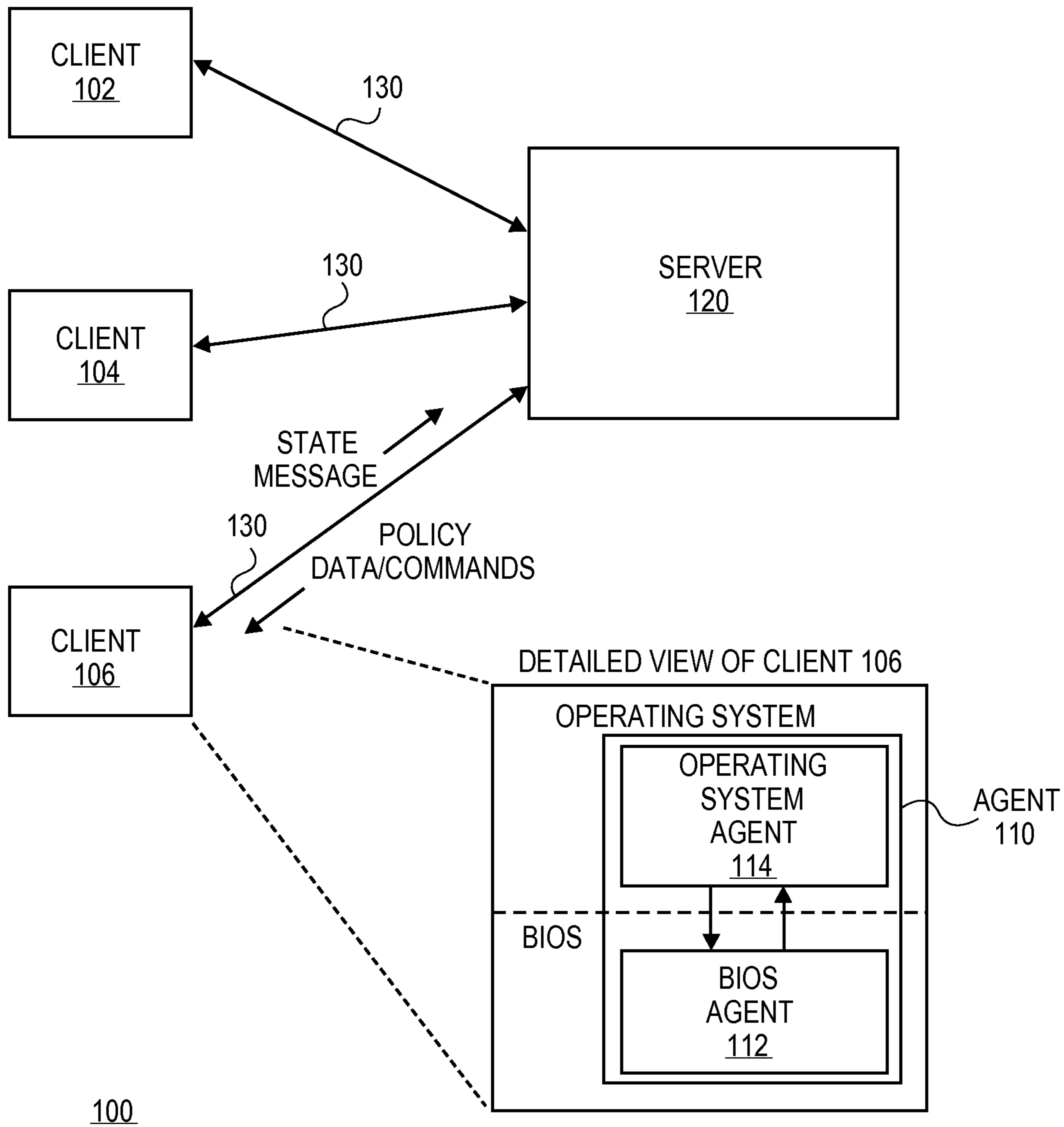
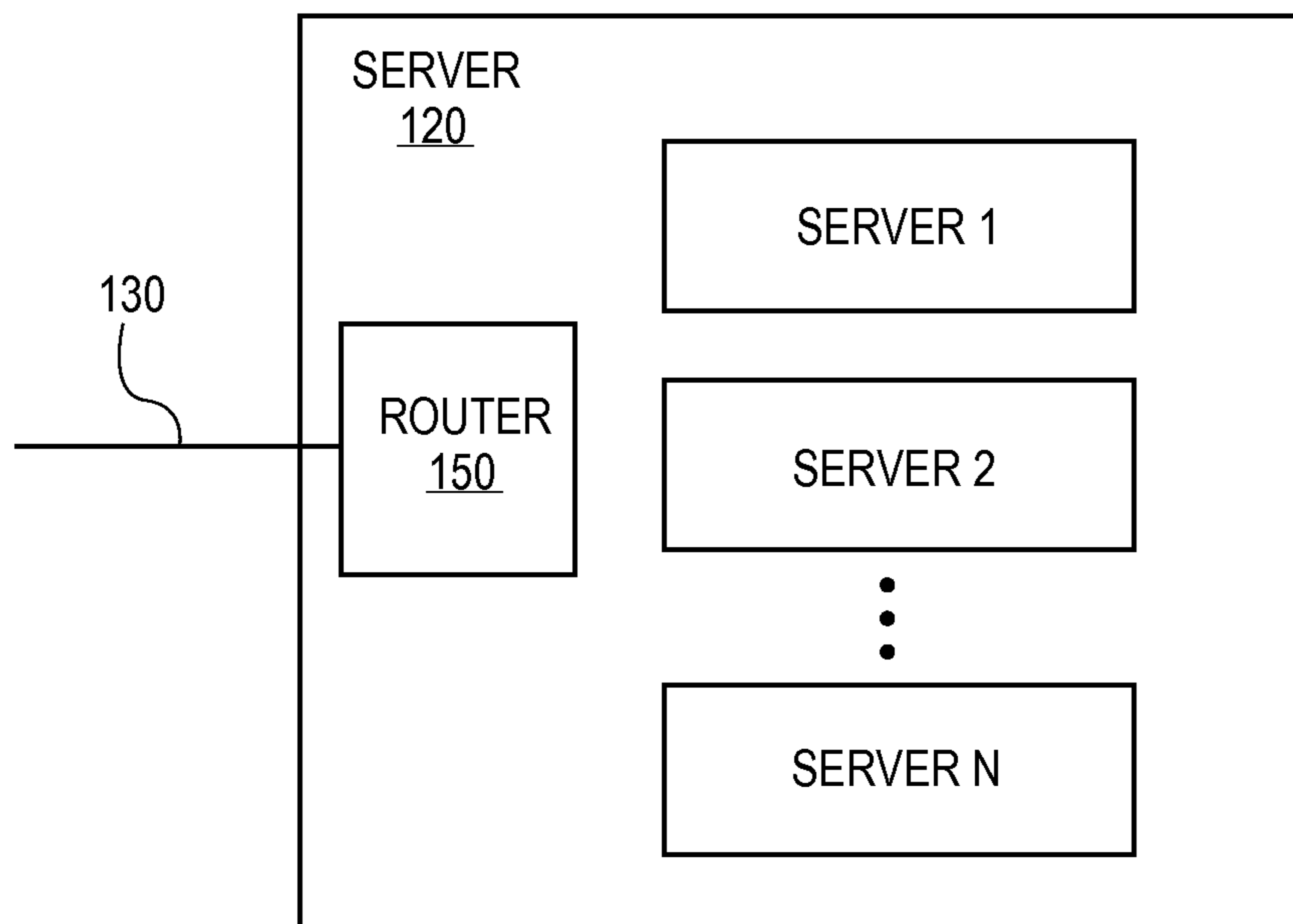


FIG. 1A

**FIG. 1B**



**FIG. 2**

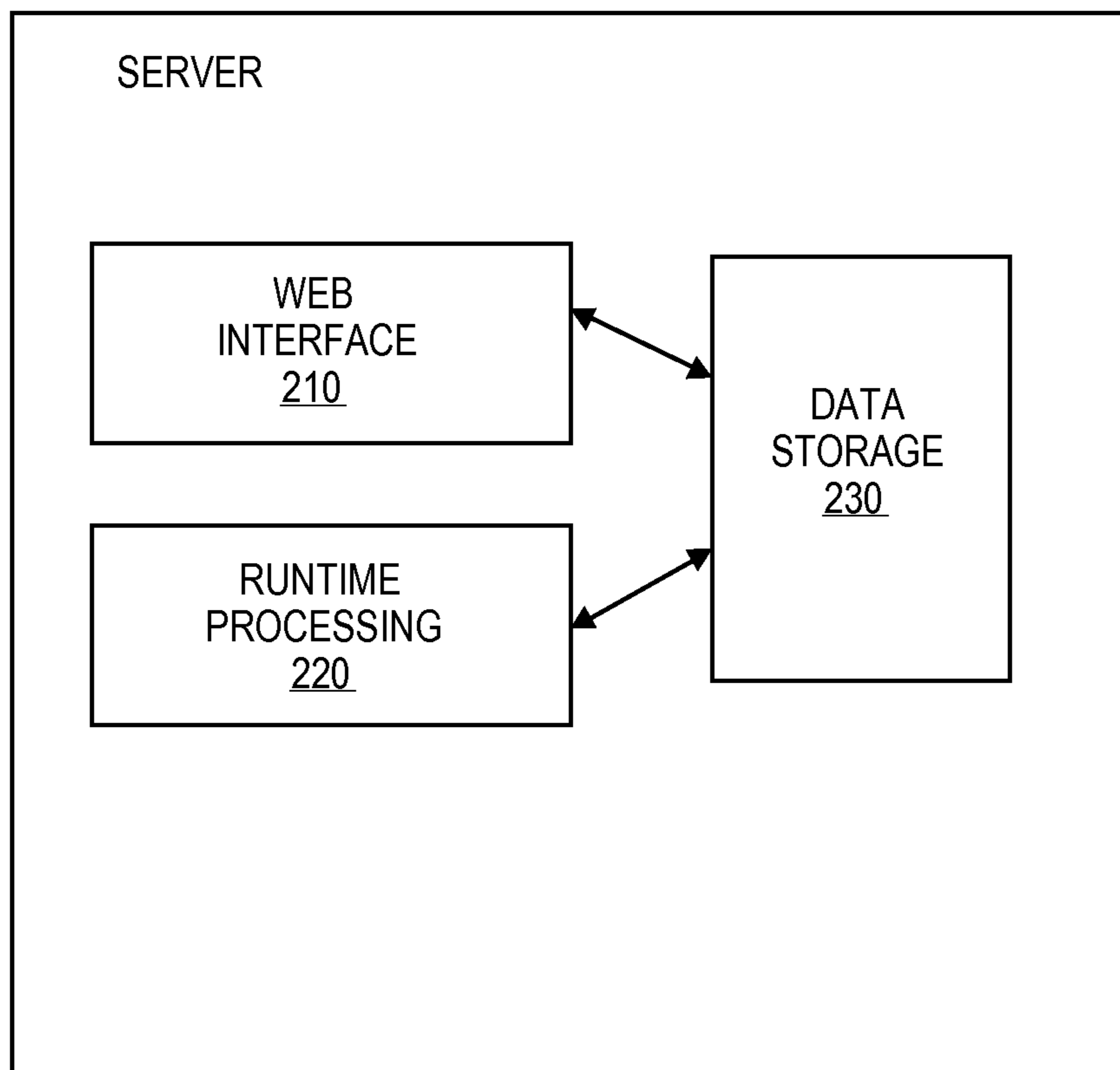


FIG. 3A

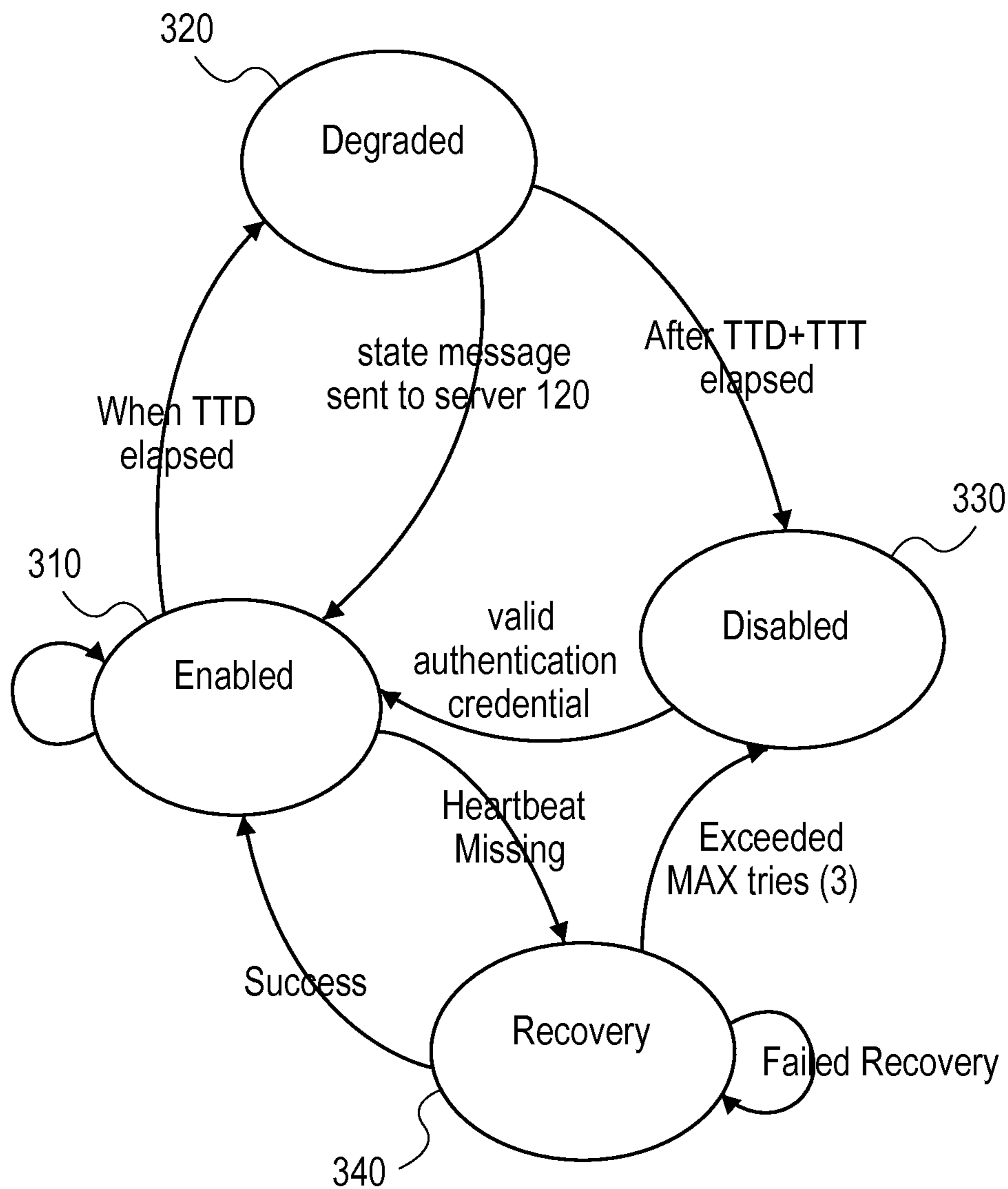
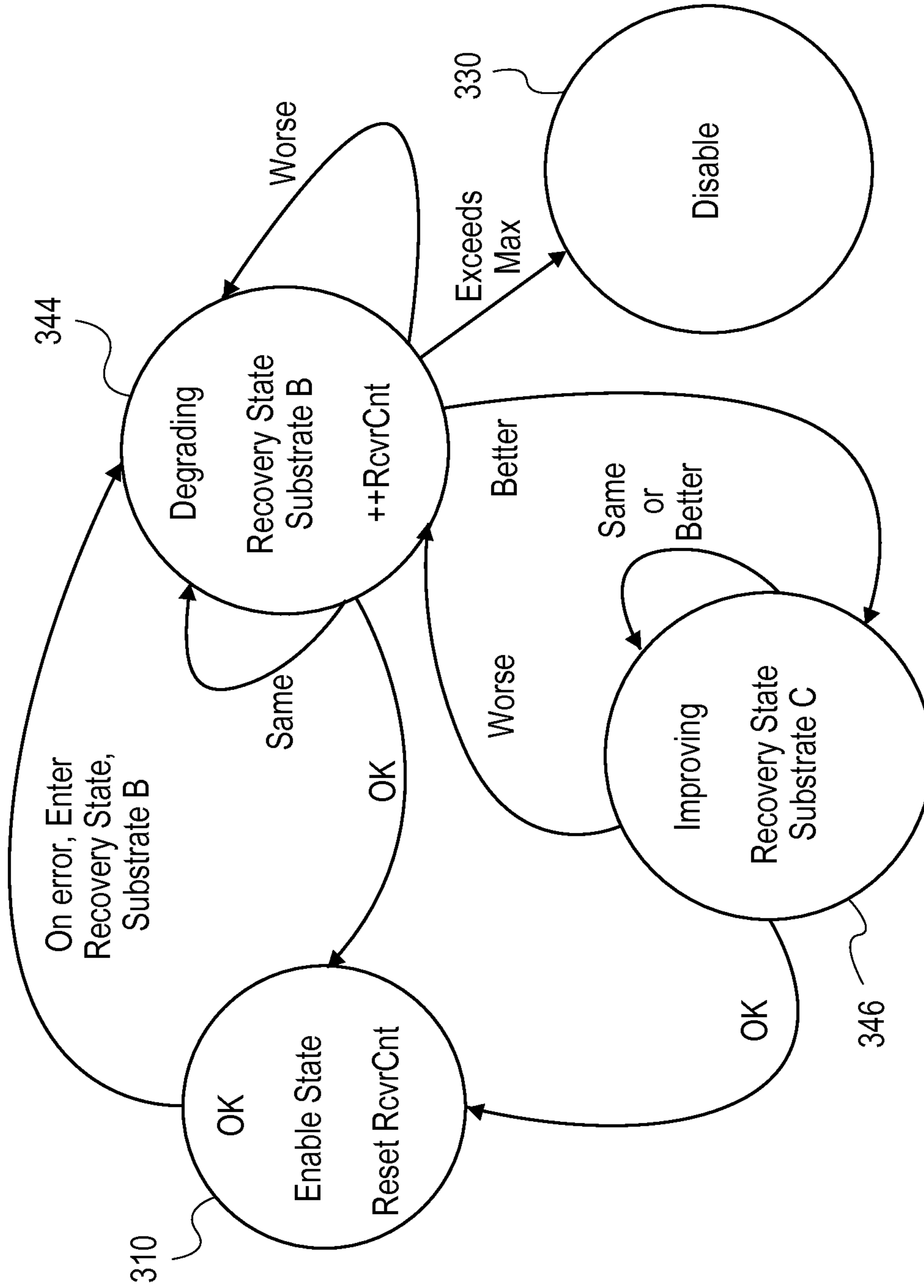
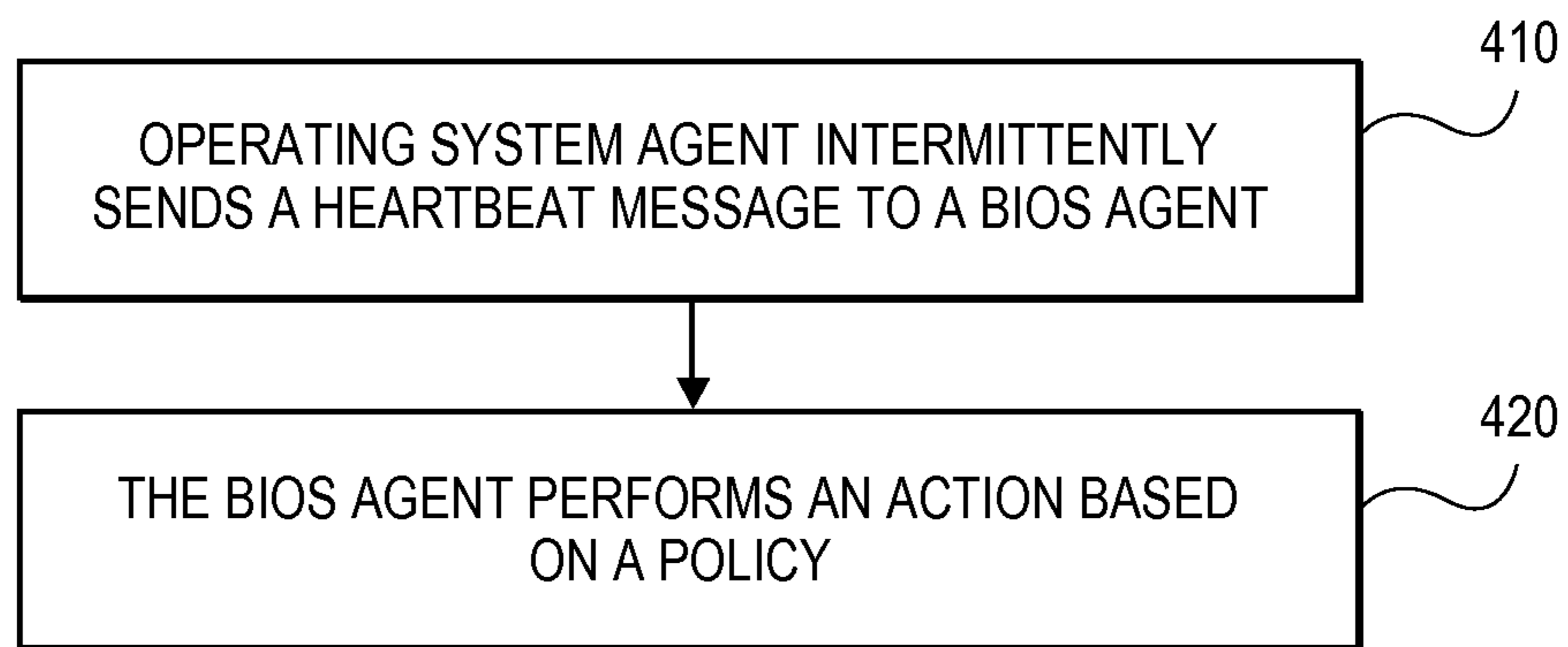


FIG. 3B



**FIG. 4**



400



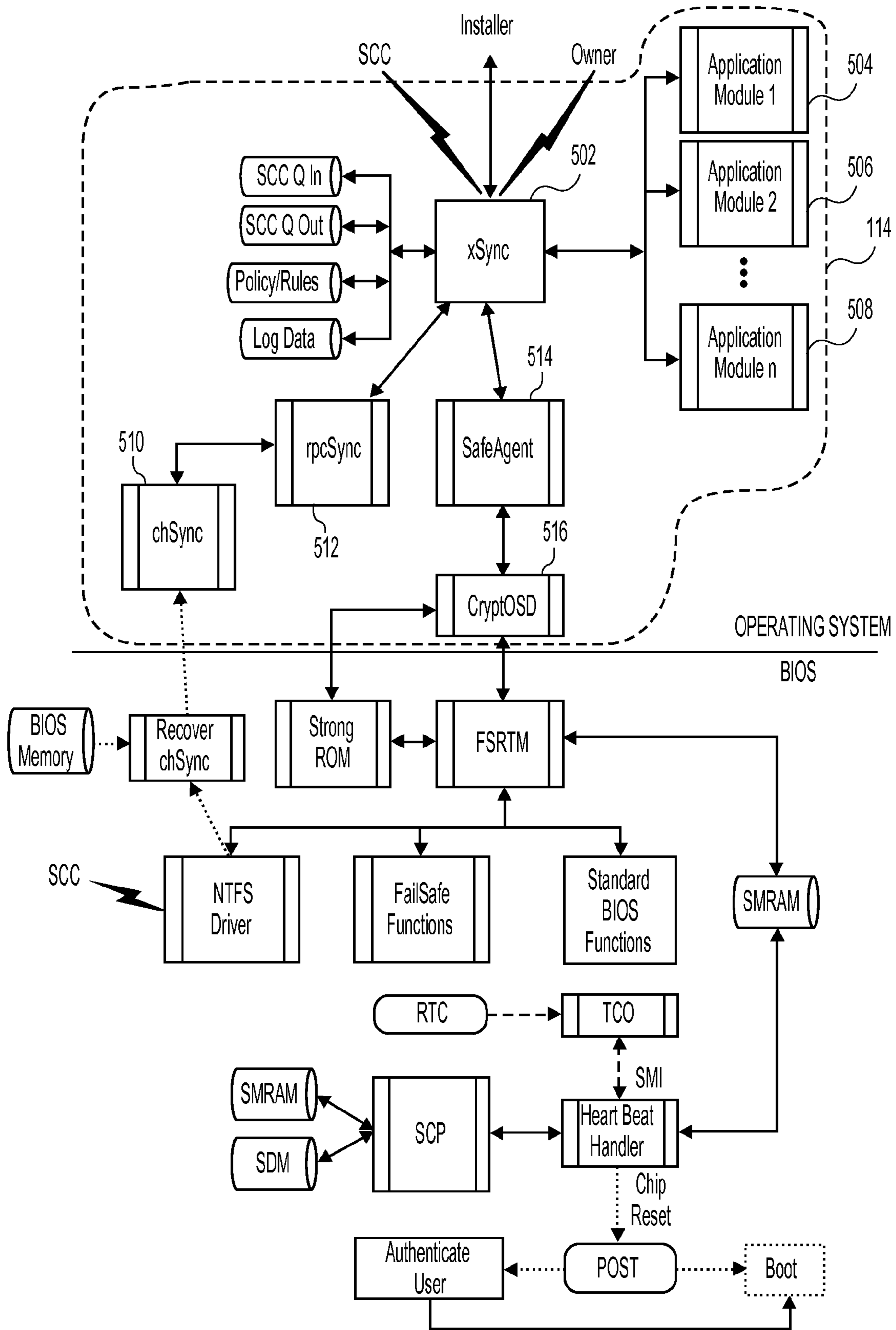


FIG. 5A

500

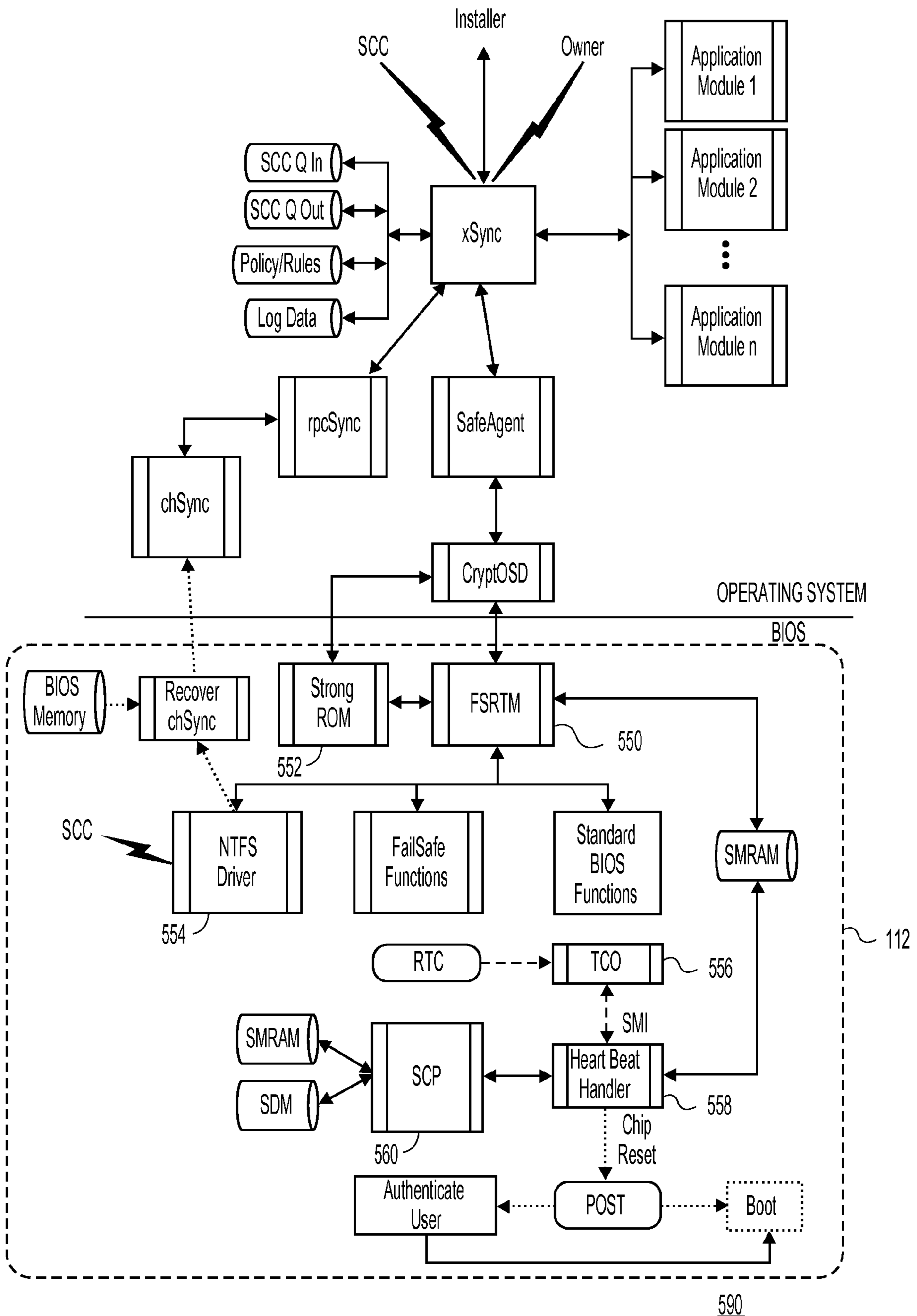
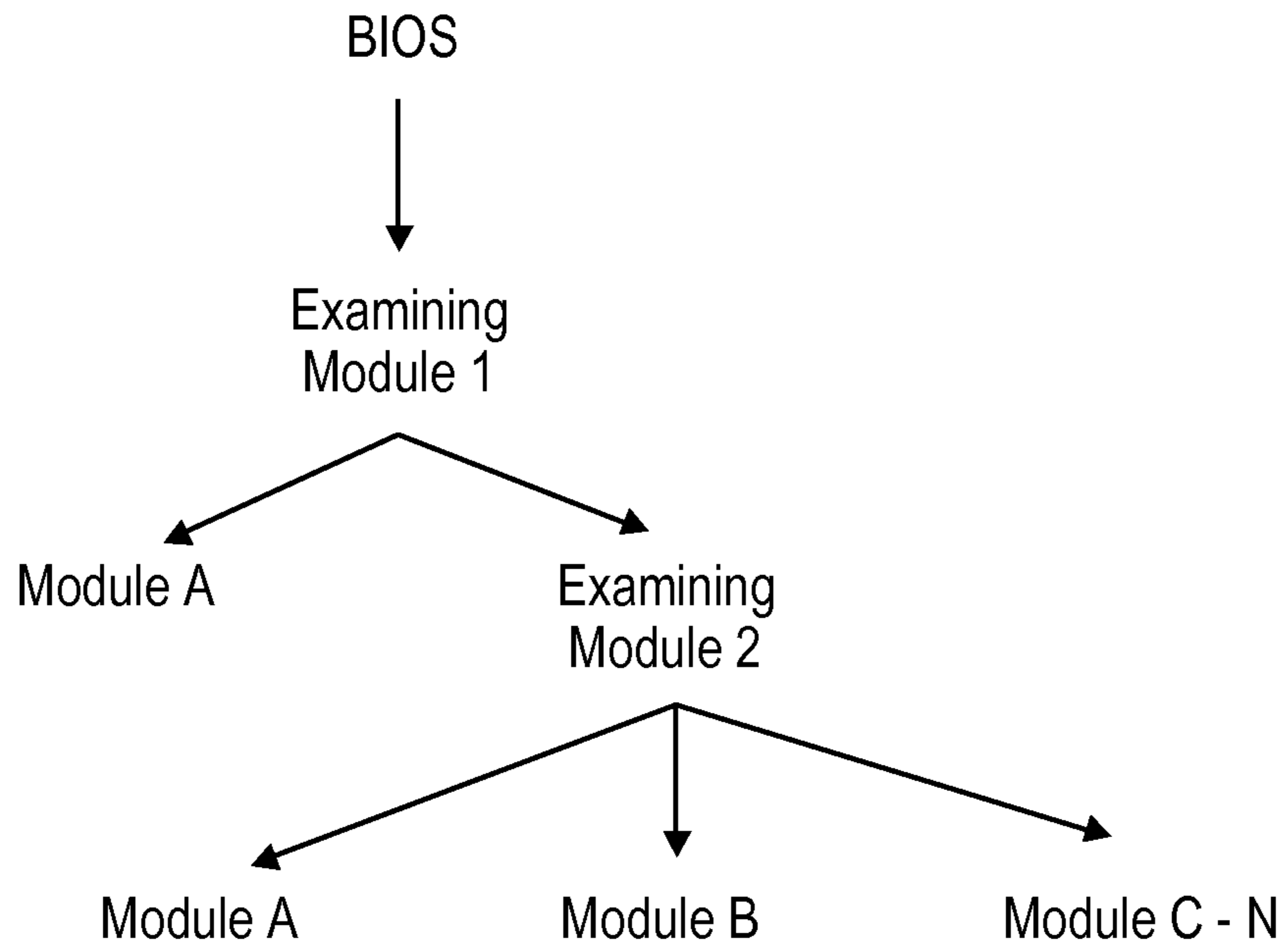


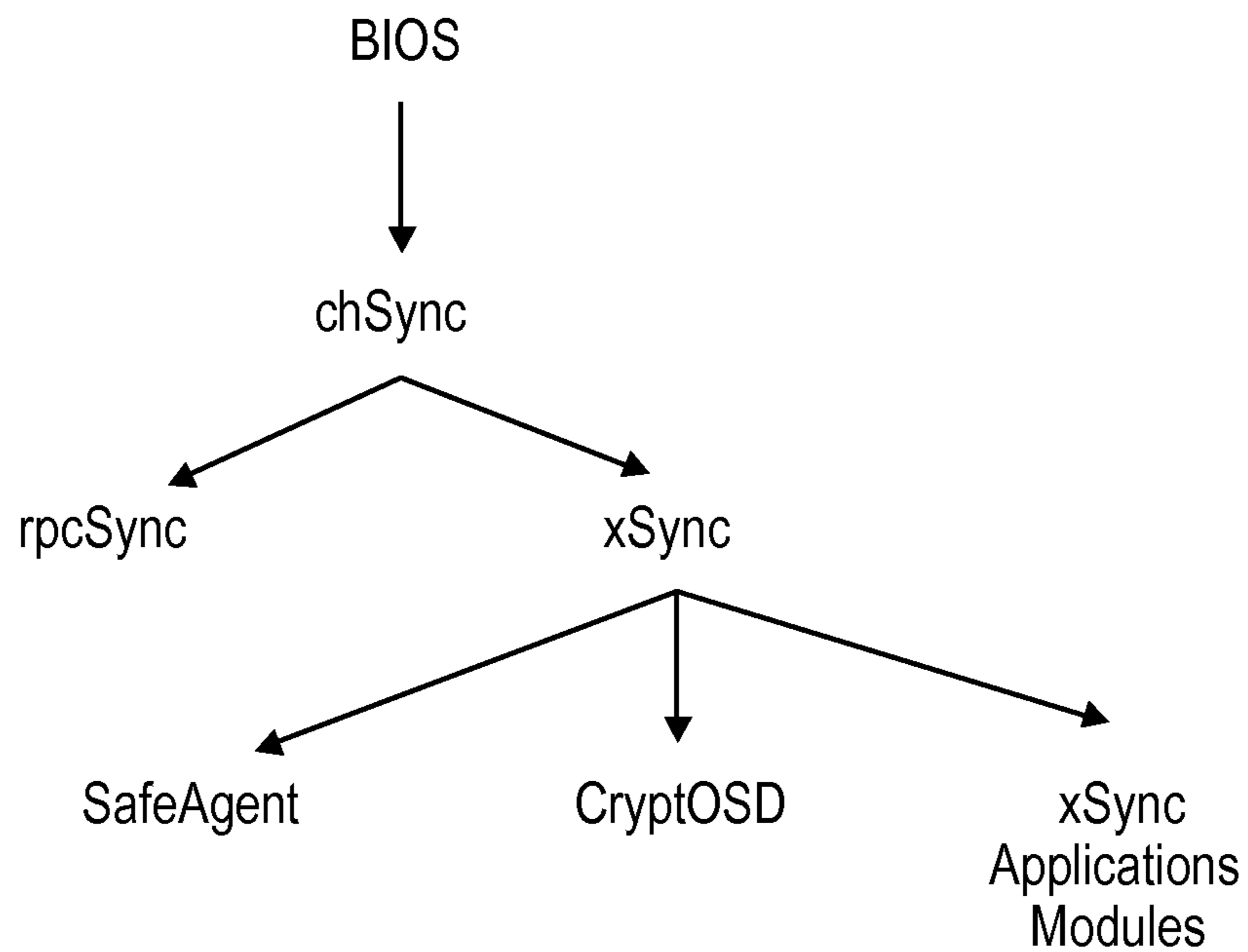
FIG. 5B

**FIG. 6A**

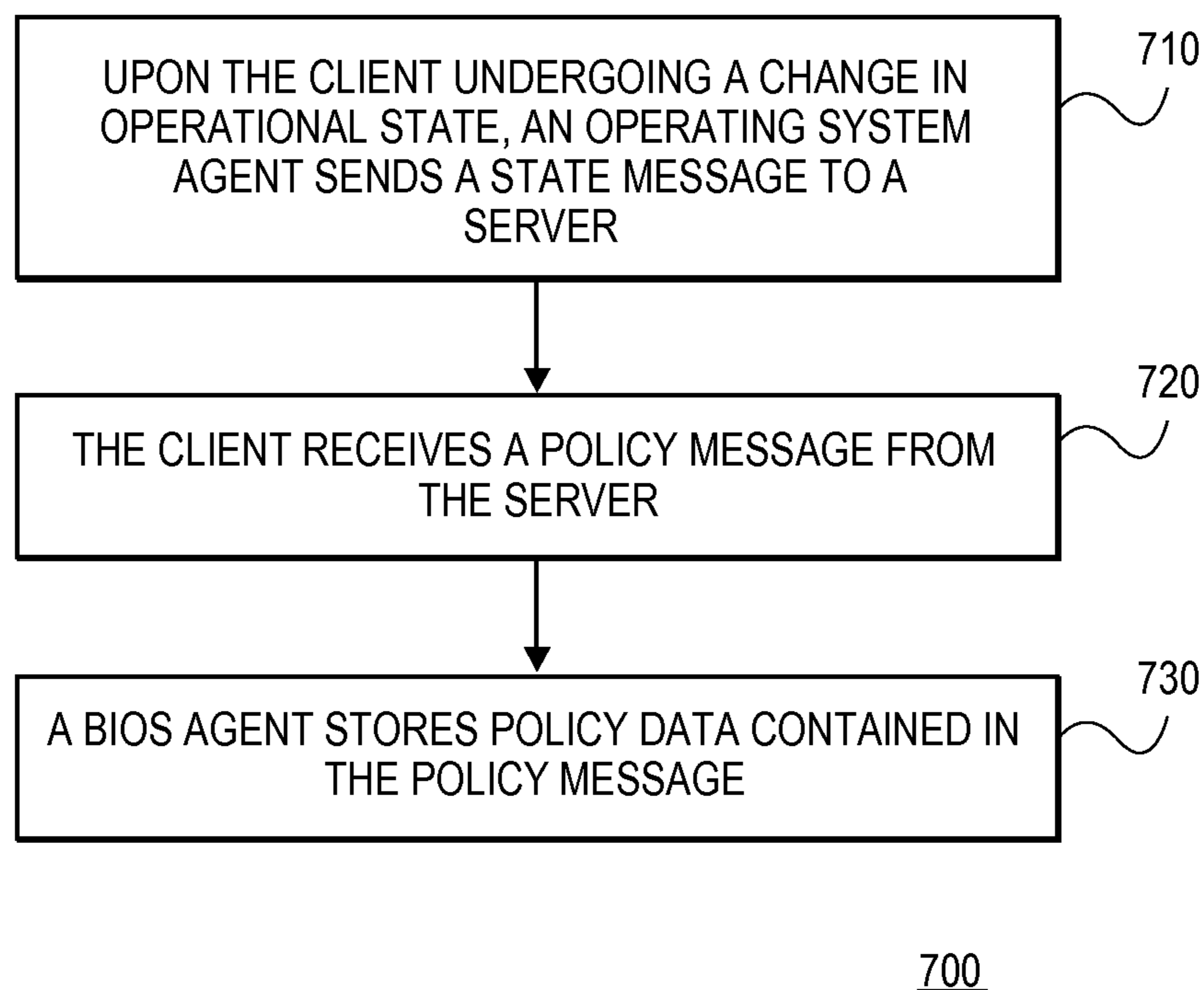
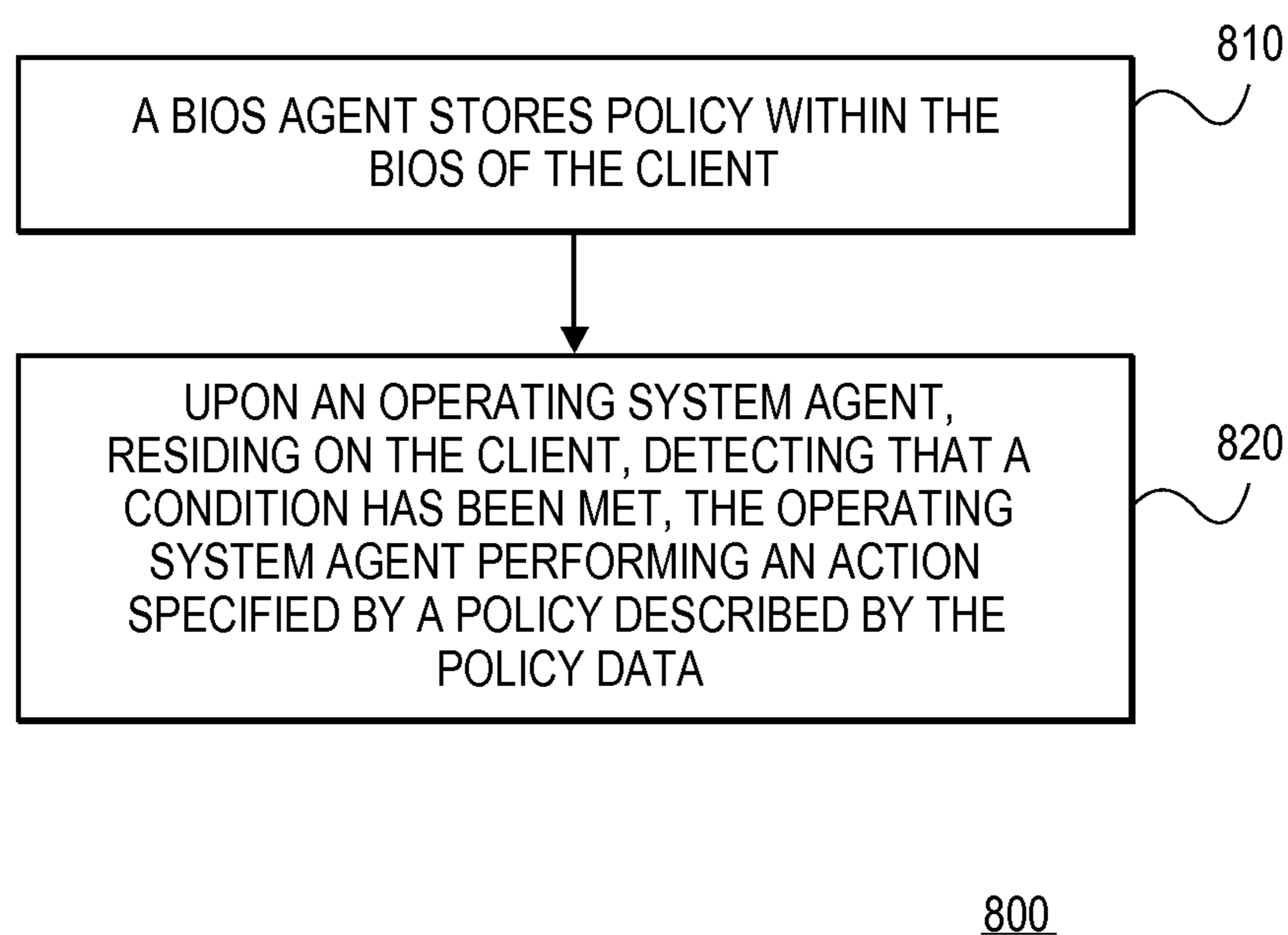


600

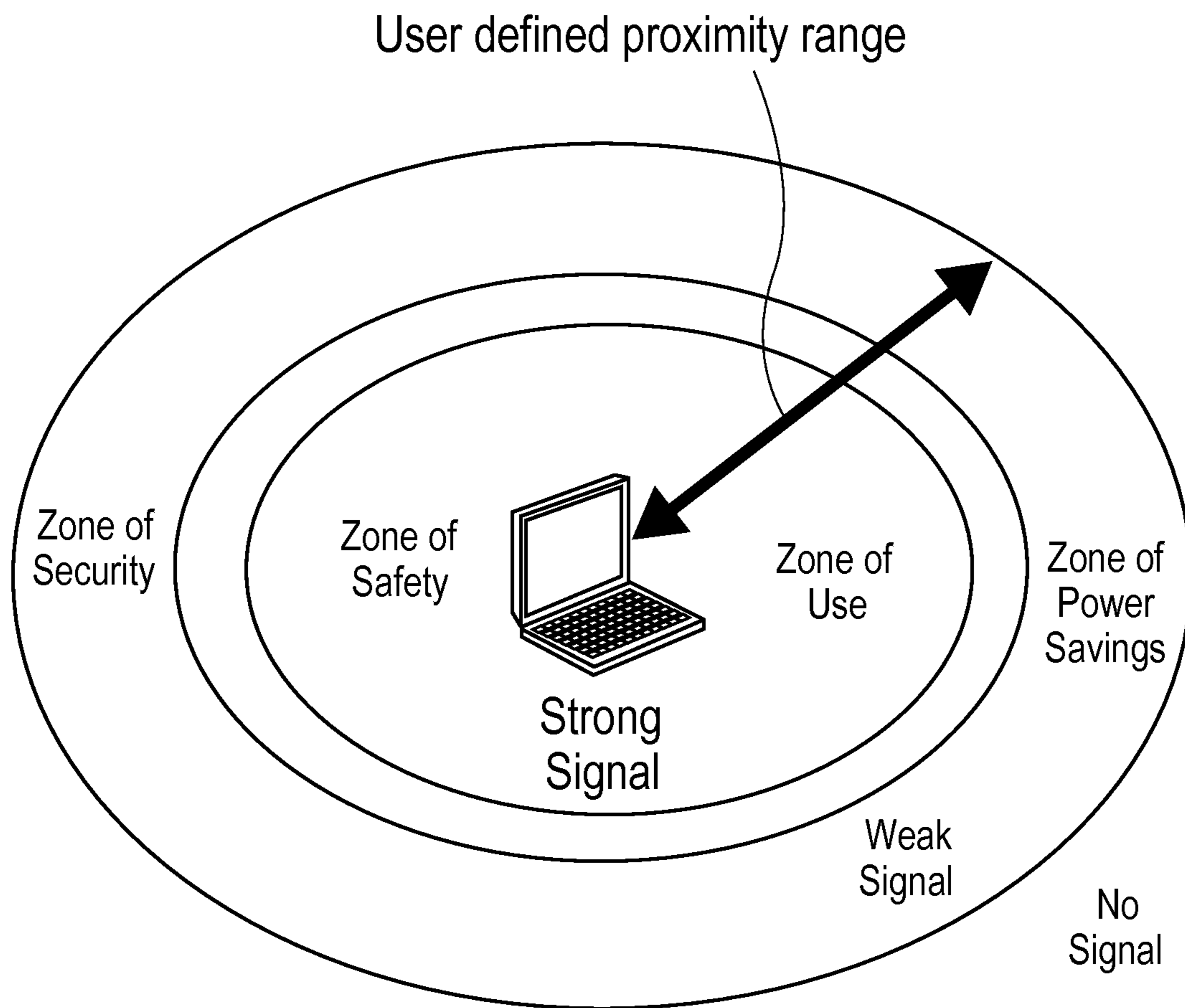
**FIG. 6B**



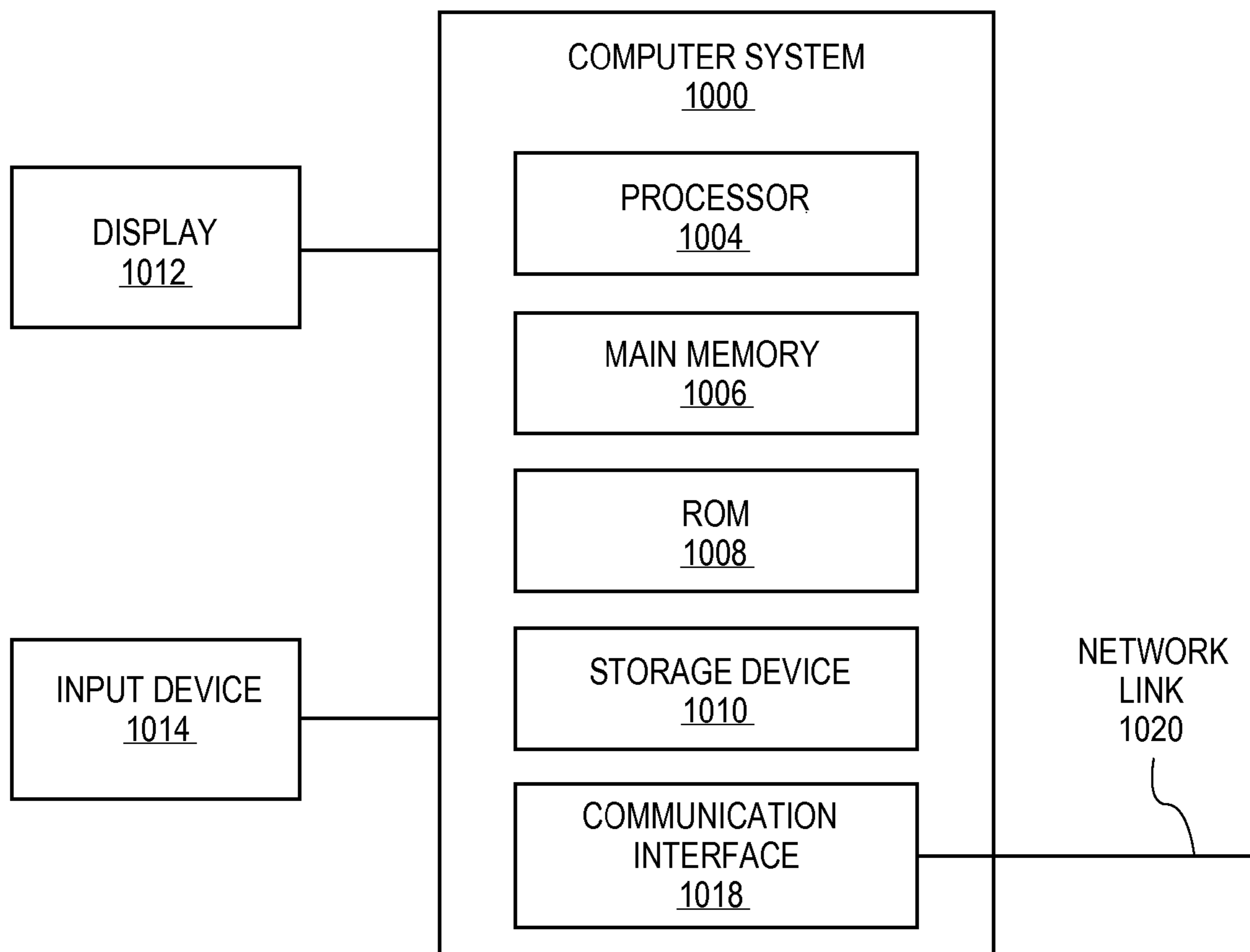
650

**FIG. 7****FIG. 8**

**FIG. 9**



**FIG. 10**





## SECURE COMPUTING ENVIRONMENT TO ADDRESS THEFT AND UNAUTHORIZED ACCESS

### CLAIM OF PRIORITY

This application claims benefit of Provisional Application Ser. No. 61/188,404, filed Aug. 8, 2008, entitled "Theft Deterrent and Secure Computing Environment," by Gaurav Banga et al., the entire contents of which are incorporated by reference as if fully set forth herein.

### RELATED APPLICATIONS

This application is related to U.S. patent application Ser. No. 12/321,504 (now U.S. Pat. No. 8,346,234), entitled "Secure Platform Management with Power Savings Capability," filed by Gaurav Banga et al. on Jan. 21, 2009, the entire contents of which are herein incorporated by reference as if fully set forth herein.

This application is also related to U.S. patent application Ser. No. 11/026,813, entitled "Secure Firmware Update," filed by Andrew Cottrell et al. on Dec. 29, 2004, the entire contents of which are herein incorporated by reference as if fully set forth herein.

This application is also related to U.S. patent application Ser. No. 12/538,044, entitled "Secure Computing Environment Using a Client Heartbeat to Address Theft and Unauthorized Access," filed by Anahit Tarkhanyan et al. on Aug. 7, 2009, the entire contents of which are herein incorporated by reference as if fully set forth herein.

This application is also related to U.S. patent application Ser. No. 12/538,040 (now U.S. Pat. No. 8,332,953), entitled "Receiving Policy Data From a Server to Address Theft and Unauthorized Access of a Client," filed by Jacques Lemieux et al. on Aug. 7, 2009, the entire contents of which are herein incorporated by reference as if fully set forth herein.

### FIELD OF THE INVENTION

The present invention relates to approaches for protecting resources, stored on a computerized device, from theft or unauthorized access.

### BACKGROUND OF THE INVENTION

The use of portable computers, such as laptops or personal digital assistants (PDAs), has become very popular in recent years. Many people store personal information or documents, such as social security numbers, credit card information, and family photos, on their laptops. Also, the use of portable computers is quite common in the modern business environment. Corporate laptops and PDAs often contain confidential or sensitive business information, such as confidential documentation, e-mail addresses, bank accounts, and trade secrets.

It has been estimated that one laptop is stolen every 53 seconds. Theft of portable computers and intellectual property is an increasing concern. Unfortunately, only a very small percentage of stolen laptops are ever returned. Even if a stolen laptop is recovered, the confidential, sensitive, or personal data that was stored thereon may have been accessed by malicious parties, which is undesirable.

### SUMMARY OF THE INVENTION

Approaches for securing a client, such as a portable computer, are provided. Embodiments of the invention secure the resources of a wide variety of clients from theft or unauthorized access.

In an embodiment, a client includes, among other components, an operating system agent and a BIOS agent. An operating system agent is one or more software modules that execute in an operating system of the client, while the BIOS agent is one or more software modules that execute in the BIOS of the client. Embodiments of the invention may implement the BIOS agent in a manner that prevents unauthorized users from deleting, overwriting, reading, or otherwise tampering with the BIOS agent. The BIOS agent, among other responsibilities, monitors the health of the operating system agent, which in turn, monitors the health of resources of the client.

The BIOS agent may store policy data within the BIOS of the client. The policy data describes one or more policies which the client should follow. When an operating system agent detects that a condition, specified by a particular policy of the one or more policies, has been met, the operating system agent performs one or more actions specified by the particular policy, such as disabling the client, retrieving a file from the client, erasing a file from the client, or encrypting a file on the client. Advantageously, the policies stored by the BIOS agent may be customized to accommodate a wide variety of contexts in which a client may be employed.

The approaches described herein are not meant to describe all the embodiments of the invention, as other embodiments of the invention may differ in their operation compared to the illustrative approaches discussed in this section.

### BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

FIG. 1A is a high level block diagram of a system for protecting resources of a client from theft or unauthorized access according to an embodiment of the invention;

FIG. 1B is a block diagram of a system employing multiple servers according to an embodiment of the invention;

FIG. 2 is a high level block diagram of a server according to an embodiment of the invention;

FIG. 3A, which is a state diagram of an agent according to an embodiment of the invention;

FIG. 3B is a state diagram that includes additional details of the recovery state according to an embodiment of the invention;

FIG. 4 is a flowchart illustrating the functional steps of protecting resources of a client according to an embodiment of the invention;

FIG. 5A is a block diagram of the functional components of an operating system agent according to an embodiment of the invention;

FIG. 5B is a block diagram of the functional components of a BIOS agent according to an embodiment of the invention;

FIG. 6A is an illustration of a high-level approach for implementing examining modules according to an embodiment of the invention;

FIG. 6B is an illustration of another example of implementing examining modules according to an embodiment of the invention;

FIG. 7 is a flowchart illustrating the functional steps of communicating a policy from a server to a client according to an embodiment of the invention;

FIG. 8 is a flowchart illustrating the functional steps of securing a device according to an embodiment of the invention;



FIG. 9 is an illustration of a proximity condition according to an embodiment of the invention; and

FIG. 10 is a block diagram that illustrates a computer system upon which an embodiment of the invention may be implemented.

#### DETAILED DESCRIPTION OF THE INVENTION

Approaches for protecting resources, stored on a computerized device, from theft or unauthorized access are described. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the embodiments of the invention presented herein. It will be apparent, however, that the embodiments of the invention presented herein may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the embodiments of the invention presented herein.

#### System Overview

FIG. 1A is a high level block diagram of a system 100 for protecting resources of a client from theft or unauthorized access according to an embodiment of the invention. In an embodiment, system 100 includes clients 102, 104, and 106, server 120, and communications link 130. System 100 may be used to implement security policies to ensure that data stored on clients 102, 104, and 106 is protected from theft and authorized access. While FIG. 1A depicts three clients, there are no restrictions on the number of clients that an embodiment of the invention may have. Thus, embodiments of the invention may employ a single client or may employ a plurality of clients.

Clients 102, 104, and 106, as broadly used herein, refer to any computerized device which is capable of executing a BIOS and an operating system. Typically, a client will be a portable device, such as, for example, a laptop, a personal digital assistant (PDA), a cell phone, a game system (such as an Xbox available from Microsoft Corporation of Redmond, Wash. or a Playstation 3 available from Sony Corporation of Park Ridge, N.J.), or a tablet computer, although there are no size or weight restrictions of what may constitute a client. Thus, a client may be implemented using a relatively large, immobile, or cumbersome computerized device, such as a vending machine, a computerized gasoline dispenser, or an automatic teller machine (ATM).

FIG. 1A depicts a detailed view of client 106. As illustrated by FIG. 1A, each client in system 100 executes a BIOS and an operating system. In an embodiment, each client includes an agent 110 (the client may have many other components in addition to agent 110). Agent 110 is a set of software components that operate to ensure that resources on the client upon which agent 110 resides are protected from theft and unauthorized access. Each agent 110 comprises two portions, namely a BIOS agent 112 and an operating system agent 114. BIOS agent 112 may be implemented by one or more software modules that execute in the BIOS of a client, while operating system agent 114 may be implemented by one or more software modules that execute in the operating system of the client.

Among other functions that operating system agent 114 performs, operating system agent 114 monitors the resources of the client to ensure that the resources are not subject to theft or unauthorized access. After analyzing resources of a client for signs of theft, unauthorized access, or otherwise malicious activity, operating system agent 114 generates a heartbeat

message that describes the operational state of the operating system agent 114, and thereafter sends the heartbeat message to BIOS agent 112. BIOS agent 112 stores security policies which the client receives from server 120. These security policies instruct BIOS agent 112 to perform certain actions based on the content of the heartbeat message or whether the heartbeat message was received within an expected duration of time.

Server 120, as broadly used herein, refers to any mechanism capable of communicating with a client. Server 120 may be used to receive status information from clients as well as transmit policy data and commands to clients. For example, an owner of a set of clients may interact with server 120 to define one or more security policies, and thereafter server 120 may disseminate those defined security policies to the set of clients belonging to the owner.

In an embodiment, server 120 may be implemented as a server executing on a single computer system. In other embodiments of the invention, such as the embodiment depicted by illustration 180 of FIG. 1B, server 120 may be implemented using two or more servers that are executing on two or more different computer systems. In illustration 180, communications from clients, sent over communications link 130, may be received by application router 150, which may subsequently route the communication to an appropriate server for processing. As the number of clients in system 100 increases, it may be advantageous to implement server 120 using a plurality of different server instances to promote scalability and fault tolerance. Also, one or more servers depicted in FIG. 1B may be dedicated for a particular task, such as processing requests from a single entity or business. For example, to ensure availability and speed of processing, one or more servers depicted in FIG. 1B may be dedicated to communicate with clients associated with a particular entity, such as a business or a logical business unit of a company.

FIG. 2 is a high level block diagram 200 of a particular server 120 according to an embodiment of the invention. The server shown in FIG. 2 may correspond to server 120 depicted in FIG. 1A or one of the many servers (such as server 1, server 2, or server N) depicted in FIG. 1B. As shown by FIG. 2, in an embodiment, a server comprises a web interface 210, a runtime processing component 220, and data storage 230.

Web interface 210 refers to a functional component which enables a person to define and record one or more security policies that govern the behavior of clients in system 100. For example, an owner of one or more clients may use a web browser to record policy data that describes or defines a security policy, and thereafter use the web browser to submit the policy data to web interface 210. Additional description about security policies, which may be defined and submitted to web interface 210, is provided below in the section entitled "Security Policies."

Runtime processing component 220, as broadly used herein, refers to any mechanism for processing communications, such as state messages, received from clients as well as communicating security policies and/or commands to one or more clients in system 100. Runtime processing component 220 may be implemented using software that is configured to perform the runtime functions of server 120.

Data storage 230, as broadly used herein, refers to any mechanism for persistently storing data. For example, data storage 230 may be implemented using a database management system (DBMS) which comprises one or more database servers and one or more databases.

Communications link 130 may be implemented by any medium or mechanism that provides for the exchange of data between a client, such as clients 102, 104, and 106, and server



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120. Non-limiting, illustrative examples of communications link 130 include, without limitation, a network such as a Local Area Network (LAN), Wide Area Network (WAN), Ethernet or the Internet, one or more terrestrial, satellite or wireless links, and serial or parallel printer cables.

For a variety of reasons, the communications link 130 between a particular client, such as client 102, and server 120 may become intermittently unavailable. In particular, if the communications link 130 between client 102 and server 120 is implemented as a wireless link, at certain times the wireless link may be available and at other times the wireless link may not be available. For ease of explanation, in FIG. 1A communications link 130 is depicted between each client to server 120. However, those in the art shall appreciate that each client in system 100 may communicate with server 120 over a different type of communications link, e.g., client 102 may communicate with server 120 over a wireless link, client 104 may communicate with server 120 over a wired WAN, and client 106 may communicate with server 120 over a satellite link. Further, those skilled in the art will appreciate that, at times, a communications link between a particular client and the server may be unavailable at the same time that a communications link between another client and the server is available.

As shall be explained in further detail below, clients may use communications link 130 to transmit, to server 120, status messages, while server 120 may use communications link 130 to transmit, to one or more clients of system 100, security policies and/or commands. Having described an illustrative system 100 according to an embodiment of the invention, additional description about the possible operational states of agent 110 shall now be presented.

## Agent States

Agent 110 operates to ensure that resources on the client upon which agent 110 resides are protected from theft and unauthorized access. Agent 110 may operate in a variety of different states. Each operational state of agent 110 reflects a different perceived threat level with respect to the theft and unauthorized access to resources of the client upon which agent 110 resides. To illustrate, consider FIG. 3A, which is a state diagram of agent 110 according to an embodiment of the invention. The operational state of agent 110 may change from time to time in response to differences in the perceived threat level to the client as perceived by agent 110. The actions performed by agent 110 may differ based on the current operational state of agent 110.

Initially, agent 110 may start in an enabled state 310. Enabled state 310 is a state that indicates that the client upon which agent 110 resides is operating as expected and no threats of theft or unauthorized access have been detected by agent 110. Thus, if the intended user of a client is using the client, then the client should be in enabled state 310.

If agent 110 determines that a condition is satisfied which suggests it would be appropriate for the current user of the client upon which agent 110 resides to authenticate him or herself to agent 110, then agent 110 will enter degraded state 320. An example of such a condition may be the expiration of an amount of time (referred to as the "Time to Disable" or "TTD"), determined by server 120, after which the current user of the client upon which agent 110 resides must authenticate him or herself to agent 110, e.g., by supplying a valid username/password combination or other such authentication credential. Degraded state 320 is a state that indicates that the client upon which agent 110 resides should prompt the user to authenticate himself to the client by submitting an

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authentication credential. If agent 110 is in degraded state 320, it does not necessarily follow that the client upon which agent 110 resides has been stolen or access in an unauthorized manner, degraded state 320 simply means that it is a possibility. Thus, in degraded state 320, agent 110 will attempt to determine whether the current user of the client is authorized to access the client by instructing the current user of the client to submit authentication credentials to agent 110. The amount of time that agent 110 should wait before entering degraded state 320 from enabled state 310 may be based on a security policy or may be based on a random or semi-random duration of time determined either by agent 110 or by server 120.

If the current user of the client is able to authenticate himself as an authorized user of the client when agent 110 is in degraded state 320 after the expiration of a period of time, then agent 110 may, but need not, send a state message to server 120 to inform server 120 that the current user of the client has successfully authenticated himself to agent 110. The amount of time to allow the client to report and authenticate with server 120 when agent 110 is in degraded state 320 before agent 110 enters disabled state 330 is referred to as "Time to Trust" or "TTT." The specific amount of time that corresponds to the "Time to Trust" or "TTT" time may change based on the security policies provided by server 120 and stored by BIOS agent 112 on the client, as the amount of time may be adjusted to reflect the sensitivity of the data stored by the client. A shorter TTT time provides greater security than a longer TTT time; however, a shorter TTT time also increases the risk that a legitimate user may be inconvenienced because the client entered disabled state 330 before the legitimate user could authenticate himself to agent 110. The TTT time may be established by recording the TTT time in a policy stored by BIOS agent 112 at the client. After the current user of the client authenticates himself as an authorized user of the client when agent 110 is in degraded state 320, agent 110 returns to enabled state 310.

When agent 110 is in degraded state 320, the user may be challenged to prove his identify at a certain frequency. The frequency at which the user is challenged to prove his identity when agent 110 is in degraded state 320 is referred to as "Time to Challenge" or "TTC." As with the TTT time, the TTC time may be established by a policy stored by BIOS agent 112 at the client. The TTC time is independent of the TTT time. During the interval of time measured by the TTT value established by policy, the user of the client may be prompted to submit a valid authentication credential (for example, by submitting a valid operating system password) after each expiration of a period of time corresponding to the TTC time.

If the current user of the client is unable to authenticate himself as an authorized user of the client to agent 110, when agent 110 is in degraded state 320, then agent 110 will enter the disabled state 330. Disabled state 330 is a state that indicates that agent 110 has determined the client upon which agent 110 resides has been the subject to theft or an unauthorized access, and consequently, agent 110 disables the client. When a client is disabled, the client is unable to boot. Thus, if a malicious user attempts to operate a client having an agent 110 in disabled state 330, the malicious user will not be able to boot or otherwise use the client. In order for agent 110 to switch from disabled state 330 to enabled state 310, it may be necessary for an authorized user of the client, and/or personnel associated with the owner of the client, to supply, to agent 110, a key, digital certificate, authentication credential, or otherwise establish the fact that the client is in possession of an authorized party.



If agent **110** determines that a condition is satisfied which might indicate the client has been compromised in some fashion when agent **110** is in enabled state **310**, then agent **110** will enter recovery state **340**. An example of such a condition may be BIOS agent **112** not receiving a heartbeat message from operating system agent **114** after an expected period of time. Recovery state **340** is a state that indicates that agent **110** has detected a condition that suggests the client upon which agent **110** resides is stolen or being accessed in an unauthorized manner, but agent **110** is not yet ready to conclude so. In recovery state **340**, the current user of the client may be provided an opportunity to authenticate him or herself to agent **110**; additionally, agent **110** will monitor resources of the client when agent **110** is in recovery state **340**, and if additional evidence surfaces to suggest that the client has been stolen or compromised, then agent **110** will enter disabled state **330**. In recovery state **340**, the user may be provided a limited opportunity to authenticate him or herself to agent **110**. For example, as depicted in FIG. 3A, after three failed attempts by the user to authenticate him or herself, agent **110** enters disabled state **330**. Note that the maximum number of failed attempts to allow before agent **110** moves from recovery state **340** to disabled state **330** may be established by a policy stored at the client. While FIG. 3A depicts a maximum number of three failed attempts before agent **110** moves from recovery state **340** to disabled state **330**, this number is merely exemplary, as other embodiment of the invention may establish a different number of maximum failed authentication attempts before agent **110** moves from recovery state **340** to disabled state **330**.

Embodiments of the invention may implement the operational states of agent **110** differently than that discussed above with reference to FIG. 3A. For example, certain embodiments may implement agent **110** such that one or more operational states discussed above with respect to FIG. 3A may contain two or more sub-states. To illustrate, consider FIG. 3B, which is a state diagram that includes additional details of recovery state **340** according to an embodiment of the invention. In the embodiment depicted by FIG. 3A, when agent **110** enters recovery state **340**, agent **110** enters recovery sub-state **344** shown in FIG. 3B. When agent **110** enters recovery sub-state **344**, agent **110** monitors the resources of the client and determines if the conditions that suggest a theft or unauthorized access has occurred improve, stay the same, or grow worse. If such conditions improve, then agent **110** may move to recovery sub-state **346** as shown in FIG. 3B, and if such conditions improve further, then eventually agent **110** enters enable state **310**. However, if agent **110** is in recovery sub-state **344**, and if conditions that suggest a theft or unauthorized access have occurred stay the same or grow worse, then a counter is incremented, and agent **110** remains in recovery sub-state **344**. If the counter exceeds a threshold value, then agent **110** enters disable state **330**. As the threshold value for the counter may be set by policies provided by server **120** and stored by agent **110**, the operation of agent **110** (for example, how many opportunities agent **110** is provided before moving from recovery sub-state **344** to disable state **330**) may be adjusted accommodate different balances between the need to provide a secure environment and the need to not be overly restrictive with user behavior.

The particular operational state which agent **110** is currently in reflects the current perceived threat level to the client. To ensure that malicious users cannot compromise agent **110**, agent **110** has been designed to resist tampering

and interference from unauthorized users, as shall be explained in more detail in the next section.

#### Securing the BIOS Agent from Unauthorized Access

Embodiments of the invention protect resources, stored on a client, from theft and unauthorized access. Advantageously, the BIOS of each client in system **100** comprises BIOS agent **112**. The BIOS is responsible for booting the client and starting the client system and its components, such as CPU and memory. The BIOS has two portions, a boot portion and a runtime portion. The boot portion of the BIOS is responsible for activities involved in booting the client, while the runtime portion of the BIOS is responsible for ongoing activities after the client has booted. In an embodiment, BIOS agent **112** communicates and interacts with the runtime portion of the BIOS.

By implementing BIOS agent **112** within the BIOS of each client of system **100**, it is very hard for a party to circumvent, disable, or disengage the protection offered by embodiments of the invention. As shall be explained below, BIOS agent **112** is implemented in a manner that protects a party from circumventing, disabling, or disengaging BIOS agent **112**. Further, BIOS agent **112** performs functions which protect resources of the client as well as the operating system agent **114**.

It is important to secure BIOS agent **112** from tampering and interference from unauthorized users, as BIOS agent **112** stores policy data that describes the security policies which agent **110** follows. In an embodiment, the BIOS, and therefore BIOS agent **112**, may be stored on a special microchip located on the motherboard of a client. The microchip is designed to ensure that the BIOS cannot be accessed by unauthorized parties. To achieve this goal, the microchip may be designed such that data stored on the microchip is (a) encrypted and (b) cannot be overwritten.

In an embodiment, BIOS agent **112** securely stores certain types of data in a manner that preserves the data through power cycles, disk re-formatting, software reinstallation, BIOS reflashing, and the like. For this purpose, BIOS agent **112** may maintain a small database, referred to as a Secure Data Memory (SDM), in the BIOS Flash Memory (EEPROM). Information stored in the SDM includes information about client provisioning from the manufacturing process, the BIOS agent **112** installation process, and the BIOS agent **112** registration process with server **120**, including but not limited to a unique client identifier generated by server **120**, password(s) for authentication and session keys, server identifier, application router domain name, and timeout limits. Additionally, the SDM may store information about the current operating state of BIOS agent **112**, the status of recovery of the client, and/or information about the heartbeat message(s) communicated from operating system agent **114** to BIOS agent **112**.

To maintain security, data in the SDM must be protected from intentional and unintended disclosure. BIOS agent **112** may encrypt data stored in the SDM which must not be disclosed. Similarly, none of the data stored in the SDM should be capable of being altered by a rogue software application. The BIOS Flash Memory meets these requirements, as it is a secure data storage area which may only be accessed and altered by authorized BIOS programs.

SDM may be implemented in a reserved area of Flash Memory and afforded the protection that it offers. Flash Memory is different from normal RAM memory in two significant ways. First, memory access is much slower. Second, there are a finite number of times that flash memory can be rewritten. To compensate, certain flash memory microchips



have built-in means for “moving” data to different areas of memory. In an embodiment, BIOS agent 112 may further address the limit on the number of times flash memory may be rewritten by allocating multiple records, and when the limit is about to be reached in a first record, the contents of the first record are copied to a second record and the current-record pointer is updated to reference the second record.

In an embodiment, to ensure that BIOS agent 112 is implemented such that (a) BIOS agent 112 is prevented from being overwritten and/or deleted, and (b) BIOS agent 112 encrypts data to prevent unauthorized parties from reading the code and/or data that comprises BIOS agent 112, BIOS agent 112 may be implemented using an approach referred to as “SecurePhlash,” which is described in U.S. Pat. No. 11/026,813, entitled “Secure Firmware Update,” filed by Andrew Cottrell et al. on Dec. 28, 2004, the contents of which are herein incorporated by reference as if fully set forth herein. SecurePhlash may be used to ensure that BIOS agent 112 cannot be disabled without manually altering or changing the physical components of the client upon which BIOS agent 112 resides. SecurePhlash requires that a user to provide not only the contents (i.e., bit patterns) to be reflashed, but the proper certificates of signature to ensure that the BIOS can only be reflashed by authorized parties. Passing this hurdle allows re-flashing to process in a system/chip mode that is only available to the BIOS, and thus, applications are unable to gain the necessary access to overwrite the contents of a portion of Flash Memory. SecurePhlash also provides the capability for excluding blocks of BIOS Flash Memory from being re-flashed, thereby providing a one-time only flash capability.

In another embodiment of the invention, the BIOS, and by extension BIOS agent 112, may be encrypted using a published specification called Trusted Platform Module (TPM) by Trusted Computing Group. Other embodiments of the invention may employ different approaches for encrypting data in the BIOS, as SecurePhlash, TPM, or other methods known to those skilled in the art may be employed.

As described above, BIOS agent 112 is implemented within the BIOS of each client of system 100, thereby making it very hard for a party to circumvent, disable, or disengage the protection offered by embodiments of the invention. The next section describes, at a high-level, how the protection offered by system 100 operates.

#### Protecting Resources of the Client

FIG. 4 is a flowchart illustrating the high-level functional steps of protecting resources of a client according to an embodiment of the invention. In step 410, operating system agent 114 intermittently sends a heartbeat message to BIOS agent 112. A heartbeat message is a communication that describes the operational state of operating system agent 114. As operating system agent 114 monitors resources of the client to detect any malicious or unauthorized activity, the operational state of operating system agent 114 reflects whether any resources of the client has been subjected to any unauthorized activity. The process of operating system agent 114 generating the heartbeat message is explained in further detail below in the section entitled “Examining Modules and Forming the Heartbeat Message.”

Thereafter, in step 420, BIOS agent 112 performs an action based on a policy. The one or more policies which BIOS agent 112 follows are described by data (denoted “policy data”) that is stored within the BIOS. A policy may specify that BIOS agent 112 is to perform a certain action in response to either (a) a particular operational state described by the heartbeat

message, or (b) BIOS agent 112 not receiving the heartbeat message after an expected period of time.

As an example of the type of policy which BIOS agent 112 may follow, if the heartbeat message received by BIOS agent 112 indicates that a module of operating system agent 114 has been deleted, then the policy may interpret that as an indication of a malicious attack, and the policy may instruct BIOS agent 112 to perform one or more actions to address the malicious attack, such as disabling the client upon which BIOS agent 112 resides, emitting a loud sound to alert nearby persons that an unauthorized use of the client is occurring, and/or requiring the user of the client upon which BIOS agent 112 resides to resubmit authentication credentials to the client to continue use of the client. As another example of an illustrative policy which BIOS agent 112 may follow, if no heartbeat message is received by BIOS agent 112 after an expected period of time, then the policy may interpret that as an indication that operating system agent 114 has been compromised and is unable to send the heartbeat message, and the policy may instruct BIOS agent 112 to perform one or more actions to address the situation. Additional description of the nature of the policies of which BIOS agent 112 may follow is provided below in the section entitled “Security Policies.”

Having described the high-level functional steps of protecting resources of a client according to an embodiment of the invention, additional details about how operating system agent 114 monitors resources of the client and how operating system agent 114 generates the heartbeat message in step 410 will now be presented.

#### Operating System Agent Operation

Operating system agent 114 may be responsible for, among other functions, monitoring the resources of the client upon which it is implemented, generating a heartbeat, and sending the heartbeat to BIOS agent 112. There are a variety of ways in which operating system agent 114 may be implemented. To provide a description about how operating system agent 114 may operate according to one embodiment of the invention, reference will be made to FIG. 5A, which is a block diagram 500 of the functional components of operating system agent 114 according to an illustrative embodiment of the invention. Note that in other embodiments of the invention, operating system agent 114 may comprise a different set of functional components, as certain functional components of operating system agent 114 depicted in FIG. 5A are optional or may be combined with one or more other functional components.

As shown in FIG. 5A, in an embodiment, operating system agent 114 comprises xSync module 502. xSync module 502 operates as a communications hub for operating system agent 114. xSync module 502 communicates with all of application modules 504, 506, and 508. xSync module 502 also handles all communications with server 120, the owner of the client, and the user of the client. xSync module 502 is also responsible for the installation and updating of the components of operating system agent 114. xSync module 502 is also responsible for periodically forming a portion of the heartbeat message, generated by operating system agent 114; xSync module 502 checks the status of application modules 504, 506, and 508, and subsequently generates a portion of the heartbeat message that reflects the status of application modules 504, 506, and 508.

In an embodiment, operating system agent 114 comprises one or more application modules, such as application modules 504, 506, and 508. While three application modules are depicted in the embodiment shown by FIG. 5A, operating system agent 114 may comprise any number of application



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modules. An application module performs a functional operation, such as a command and/or control operations sent from server **120** and received by operating system agent **114** or an action that is dedicated by a policy.

Non-limiting, illustrative examples of the functions which a particular application module may perform include (a) encryption and backup services, (b) fetching the client's hardware and software configuration and identification information, (c) taking pictures or video with the client's webcam, (d) performing anti-theft functionality, such as disabling the client, emitting an alarm, and/or displaying a stolen alert screen, (e) deleting or removing files or resources stored on the client, (f) gathering forensic data, such as capturing the user's keystrokes, (g) retrieving files and/or resources from the client and bundling the files and/or resources (for example, by creating a .zip file) for xSync module **502** to upload to server **120** (possible via the FTP protocol), (h) preparing and registering components of operating system agent **114** (such as xSync module **502** or a particular application module) with server **120**, and (i) detecting and fetching global positioning service (GPS) information.

chSync module **510** periodically forms a portion of the heartbeat message. chSync module **510** is also responsible for determining whether rpcSync module **512** is installed and uncorrupted, and if not, chSync module **510** is responsible for installing rpcSync module **512**. The operation of chSync module **510** is explained in more detail below in the section entitled "Examining Modules and forming the Heartbeat Message."

rpcSync module **512** starts executing at boot time and monitors for the presence of xSync module **502**. If xSync module **502** is not running, then rpcSync module **512** will install and/or restore xSync module **402**. rpcSync module **512** may form a portion of the heartbeat message based upon whether xSync module **502** is present and/or executing.

SafeAgent module **514** periodically forms the heartbeat message from the portions of the heartbeat message that are created by other components of operating system agent **114**. After forming the heartbeat message, SafeAgent module **514** stores the heartbeat message, in SMRAM, which is part of BIOS agent **112**.

CryptOSD module **516** the main interface of all components of operating system agent **114** with BIOS agent **112**.

Note that the above discussion of the embodiment of operating system agent **114** depicted in FIG. **5A** is merely illustrative of one embodiment. Other embodiments of the invention may implement operating system agent **114** differently. For example, other embodiments of the invention may implement modules or functions described herein as being performed by operating system agent **114** such that they are performed by BIOS agent **112**, and vice-versa.

Additional details about how operating system agent **114** monitors the resources of the client upon which it is implemented, generates a heartbeat, and sends the heartbeat to BIOS agent **112** will now be presented.

#### Examining Modules and Forming the Heartbeat Message

The heartbeat message, generated by operating system agent **114** and communicated to BIOS agent **112**, describes an operational state of operating system agent **114**. As operating system agent **114** monitors the health of resources of the client, the operational state of operating system agent **114** is a reflection of the health of resources of the client. The content of the heartbeat message reflects whether normal operations of the client have been compromised or degraded. Agent **110**

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is a self-monitoring system which dynamically and continuously ensures that resources of the client are present and have not been subject to tampering and that agent **110** is operating correctly, and if not, is able to repair or recover itself. The heartbeat message, as shall be explained in more detail below, informs BIOS agent **112** about the operational state of operating system agent **114**. As a result, BIOS agent **112** may take an appropriate action, using upon one or more security policies, based upon the content of a heartbeat message or upon not receiving a heartbeat message after an expected duration of time (which suggests that operating system agent **114** is unable to send the heartbeat message to BIOS agent **112**).

The heartbeat message comprises several parts that are derived independent of each other. Periodically, various modules (denoted "examining modules") of operating system agent **114** examine the condition of other modules, and their associated files, of operating system agent **114** to determine if they are present as installed and operating as intended. This may be the only function performed by a particular examining module or the function may be performed in addition to other functions for which the examining module is also responsible. Each examining module of operating system agent **114** performs these checks for a subset of modules of operating system agent **114** and, for redundancy purposes, some modules of operating system agent **114** may be checked by more than one examining module. Furthermore, an examining module is treated like any other module of operating system agent **114**, and therefore, may be examined by other examining modules of operating system agent **114**. The number of examining modules in operating system agent **114** is a design decision based on the implementation of operating system agent **114**. If there are too few examining modules in operating system agent **114**, then it is potentially easier to defeat the protection provided by operating system agent **114**; on the other hand, too many examining modules in operating system agent **114** may make implementation cumbersome.

A high-level approach for implementing examining modules according to an embodiment of the invention is depicted in illustration **600** of FIG. **6A**. In the approach depicted by FIG. **6A**, the BIOS checks an examining module, namely examining module **1**, capable of restoring the entire operating system agent **114**. In the embodiment depicted in FIG. **6A**, operating system agent **114** consists of modules A-N. Examining module **1** is capable of restoring module A and examining module **2**, which is capable of restoring modules A, B, and C-N.

A more specific example of implementing examining modules, based on the operating system agent shown by FIG. **5A**, is illustrated by FIG. **6B**. In the embodiment of FIG. **6B**, the BIOS will check to see that chSync module **410** is operating correctly and all of its associated files are present and uncorrupted. If the BIOS determines that chSync module **410** does not pass this examination, then agent **110** enters recovery state **340**. However, if the BIOS does determine that chSync module **410** passes this examination, then chSync module **410** checks the process and file status of rpcSync module **412** and xSync module **402** and records their status for SafeAgent module's **414** use in forming the heartbeat message. xSync module **402** also checks the process/file status of SafeAgent module **414**, CryptOSD module **416**, and all xSync applications modules **404**, **406**, and **408** and records their status for SafeAgent module's **414** use in forming the heartbeat message.

An examining module will check a number of other modules to ensure their processes and associated files are present and have not been corrupted. If a process is determined to be absent or corrupted, the examining module will re-establish it



from its associated file if possible. If the associated file is absent or corrupted, a request will be made to server 120 to recover the appropriate file. The result of this examination, made by all examination modules, is summarized, saved, and becomes part of the heartbeat message. The details of the examination are recorded in a module status table (MST) which contains an entry for each examination module. SafeAgent module 414 assembles the heartbeat message using the information in the module status table and sends the heartbeat message to BIOS agent 112 for storage in the SMRAM.

Thus, the only way to circumvent the protection provided by agent 110 is to physically alter the client, because if portions of agent 110 are deleted or corrupted, they will be reinstalled or recovered by portions of agent 110 that reside in a portion of the BIOS which cannot be accessed except by authorized personnel.

#### The Content of the Heartbeat Message

A healthy client is a client that exhibits no signs or evidence of theft or unauthorized access. A healthy client has all of appropriate processes executing in an uncorrupted manner as well as has all of its files (particularly its executable files, such as a file with an ".exe" extension) present and uncorrupted. An uncorrupted process or file is one that passes a security check, such as having a valid digital signature or a valid cyclic redundancy check (CRC). The heartbeat message generated by operating system agent 114 may identify the "health" of the client upon which operating system agent 114 resides.

A heartbeat message may be implemented in a variety of different ways. According to one embodiment, the heartbeat message contains information that identifies, for a particular module or component of operating system agent 114, whether the module or component is present and uncorrupted. Such an embodiment may indicate whether a particular module or component of operating system agent 114 is executing and is uncorrupted as well as indicating whether all files associated with the module or component are present and uncorrupted.

According to another embodiment, additional information that describes the nature of the potential security threat(s) may be contained in the heartbeat message. For example, if a particular module of operating system agent 114 is moved or deleted every five minutes, then this additional information may be contained within the heartbeat message. Such additional information may provide additional insight into potential security threats, and may be referenced by a security policy. For example, a particular security policy may be established that states that if the same file or resources is deleted three times in a particular time period (which is suggestive of a malicious attack on the client), then agent 110 should enter the disable state 330.

If the heartbeat identifies any evidence of theft or unauthorized access, then when BIOS agent 112 receives the heartbeat, BIOS agent 112 follows security policies stored by BIOS agent 112 to address the potential theft or unauthorized access. The security policies followed by BIOS agent 112 may strike a balance between maintaining the integrity of agent 110 (and by extension the resources of the client upon which it resides) and the convenience of the user of the client, as locking the client due to the accidental deletion of a file could be a major inconvenience for the user.

In an embodiment, if a process or file is removed, then agent 110 will follow security policies stored by BIOS agent 112 to determine how to address the situation. For example, a particular security policy may instruct agent 110 to enter recovery state 340 if a process or file is removed or corrupted.

In recovery state 340, agent 110 may attempt to communicate with server 120 to restore the particular process or file that has been removed. For example, server 120 may be able to provide agent 110 with a new version of the process or file that has been corrupted or removed. If the missing resources is a low priority resource, and a connection to server 120 cannot be established by agent 110, a security policy may instruct agent 110 to continue and to defer recovery of the missing resource; however, care should be given to defining security policies, as when a process and its corresponding executable file are missing, it is unlikely to be accidental.

While agent 110 is in recovery state 340, agent 110 monitors resources of the client for further degradation. Any further degradation of resources of the client is most likely an indication of malicious intent, as a consequence, it is addressed by agent 110 in accordance with the security policies stored by BIOS agent 112 and established by the owner of the client. For example, according to an exemplary security policy, if agent 110 determines that resources of a client have continued to degrade while agent 110 is in recovery state 340, then agent 110 may enter disable state 330. Although the behavior of agent 110 when agent 110 is in disable state 330 may differ according to the particular security policies stored by agent 110, a typical behavior of agent 110 when agent 110 is in disable state 330 is to "lock" the client by preventing anyone to access the client without providing two or more levels of authentication to "unlock" the client.

Additional details will now be provided about the operation of BIOS agent 112.

#### BIOS Agent Operation

FIG. 5B is a block diagram of the functional components of BIOS agent 112 according to an embodiment of the invention. BIOS agent 112 receives the heartbeat message from operating system agent 114 and stores security policies which agent 110 receives from server 120. Additionally, BIOS agent 112 performs one or more actions in accordance to the security policies. For example, BIOS agent 112 may perform an action, dictated by a security policy, in response to either (a) the contents of a received heartbeat message, or (b) BIOS agent 112 not receiving the heartbeat message after an expected period of time.

BIOS agent 112 may be implemented in a variety of different ways. To illustrate how BIOS agent 112 may be implemented according to an embodiment of the invention, consider FIG. 5B, which is a block diagram of BIOS agent 112 according to an embodiment of the invention. As illustrated by FIG. 5B, in an embodiment BIOS agent 112 includes FSR™ module 550. FSR™ module 550 serves as the primary interface for modules of operating system agent 114 to communicate with BIOS agent 112. FSR™ module 550 evaluates all communications received from modules of operating system agent 114 to ensure that the communications originated from a valid module of operating system agent 114 as well as routes valid communications, from modules of operating system agent 114, to their appropriate destination within BIOS agent 112.

Strong ROM 552 provides security services for the BIOS of the client upon which it resides. In particular, Strong ROM 552 may be used to provide encryption/decryption functionality as well as authentication functionality. Strong ROM 552 may be implemented as a binary module which executes in system management mode (SMM) inside SMRAM. Strong ROM 552 provides authentication and cryptographic services, including authentication of binary modules and caller validation for applications that access firmware services.



Strong ROM **552** is an illustrative example of BIOS security services, but it is contemplated that other security services may be used by other embodiments of the invention. For example, a client may be implemented with other approaches for performing encryption/decryption and/or authentication.

NTFS Driver **554** is a module that is responsible for copying chSync module **510** and other associated files to the operating system.

TCO **556** is a timer which is used to determine when BIOS agent **112** will examine the recent heartbeat message received from operating system agent **114**.

Heartbeat handler **558** is responsible for examining the heartbeat message received from operating system agent **114**. Heartbeat handler **558** may either reset the heartbeat message or take remedial action depending on the nature of the changes in the heartbeat message.

State change processor (SCP) **560** is a module which examines the changes in the heartbeat message received from operating system agent **114**, the current state of agent **110**, and takes appropriate action depending on the security policies established by the owner of the client.

As BIOS agent **112** acts upon policies and instruction received from server **120**, additional detail will now be provided about how a client and server **120** may interact.

#### Interactions Between Clients and the Server

FIG. 7 is a flowchart illustrating the functional steps of communicating a policy from server **120** to a client according to an embodiment of the invention. The steps of FIG. 7 may be used to ensure that agent **110**, residing on a client, possesses the latest security policies issued by the owner of the client. Additionally, the steps of FIG. 7 also ensure that a party external to each client in system **100**, namely server **120**, maintains accurate information about the status of each client so that the owners of each client may be apprised. For purposes of providing a clear explanation, the steps of FIG. 7 shall be explained below with reference to agent **110** executing on client **106**.

In step **710**, upon client **106** undergoing a change in operational state, operating system agent **114**, executing on client **106**, sends a state message to server **120**. The state message describes a new operational state of client **106**. Clients in system **100** periodically contact server **120** whenever the client undergoes a change that may affect its operation or present a change in the risk of theft or unauthorized access of the client. Non-limiting, illustrative changes which may result in client **106** sending a state message to server **120** include a change in the IP address of client **106**, a change to the hardware configuration of client **106**, a change to the software configuration of client **106**, a toggling of the power supplied to client **106**, a change to a configuration setting of client **106**, a change in client **106** physical location (such as a global position service (GPS) indicating that client **106** has moved outside of a bounded geographical region), and a change in the heartbeat message received by BIOS agent **112** from operating system agent **114**.

Server **120** stores the information contained in the state message. Server **120** also examines any policies that affect client **106** to determine what, if any, action(s) should be performed by server **120** in response to receiving the state message from client **106**. An applicable policy may result in a command being sent from server **120** to client **106** that affects the mode of operation of client **106**, such as disabling some function of client **106** (for example, the USB ports of client **106**). In more serious situations, server **120** may instruct agent **110** executing on client **106** to change its state

to disable state **330**, and force client **106** to reset, reboot, and enter a mode that requires multi-level user authentication.

Server **120** may periodically determine if there are any pending policy changes to send to a client, and if so, send a policy message containing the new policies to the client. In an embodiment, server **120** may determine if there are any pending policy changes to send to client **106** in response to receiving a state message from client **106**.

In step **720**, client **106** receives a policy message from server **120**. The policy message is a communication, sent over communications link **130**, which contains policy data which identifies one or more security policies which client **106** is to follow. In an embodiment, the owner of client **106** may establish the security policies using web interface **210** of server **120**.

In step **730**, agent **110** of client **106** stores the policy data, received from server **120**, in the BIOS of the device. As a result, the security policies which client **106** is to follow is stored in a secure location which is protected from unauthorized access.

#### Clients May Follow Security Policies without Aid of the Server

Client **106** is not dependent on server **120** for protecting the clients' data from loss and/or disclosure. Without being connected to server **120** the client is able to determine its state, changes to its state, and according to the policies established by the owner, react to those changes, which may include entering a disable state which requires multi-level authentication before the client can re-boot and resume operations.

FIG. 8 is a flowchart illustrating the functional steps of securing a device according to an embodiment of the invention. By performing the steps illustrated by FIG. 8, a client may protect its resources from loss and/or disclosure by following security policies stored in the BIOS of the client. For ease of explanation, the steps of FIG. 8 shall be described below with reference to client **106**.

In step **810**, client **106** stores policy data within the BIOS of client **106**. The policy data describes one or more security policies which client **106** should follow. Client **106** may receive the policy data in a policy message from server **120** as described above with reference to step **720**.

In step **820**, upon operating system agent **114** of client **106** detecting that a certain condition, specified by a particular security policy, has been met, operating system agent **114** of client **106** performs one or more actions specified by the particular security policy. Advantageously, if a malicious user steals client **106** or accesses client **106** in an unauthorized manner, operating system agent **114** may protect resources of client **106** without any assistance or communication from server **120**. For example, the security policies stored in the BIOS of client **106** may indicate that, upon detecting signs that client **106** has been stolen, operating system agent **114** should turn client **106** "into a brick," that is to say, prevent client **106** from being able to boot, thereby rendering client **106** inoperable but protecting the data stored thereon from unintended disclosure to a malicious party.

Security policies are discussed in greater detail below in the section entitled "Security Policies." Additional information about the types of actions that a client may perform is presented below in the section entitled "Illustrative Commands that a Client may Perform." Also, discussion about the types of conditions that a security policy may reference is



presented below in the section entitled “Illustrative Conditions that may be Referenced by a Security Policy.”

#### Security Policies

A security policy, as used herein, refers to a policy which a client of system **100** may follow to protect the resources of the client from theft and/or unauthorized access. A client in system **100** may follow any number of security policies. The security policies which a client of system **100** follows are stored in the BIOS of the client.

A security policy may initially be defined using web interface **210** of server **120**. For example, the owner of a client (which may correspond to a company and may be, but need not be, different than the intended user of a client) may use a web browser to define one or more security policies, and may submit the defined one or more security policies to server **120** via web interface **210**.

In an embodiment, a security policy specifies that one or more actions are to be performed by a client if one or more conditions are met. A condition referenced by a security policy serves to indicate when a particular action is performed. As such, a condition referenced by a security policy may reference any quantum of evidence that, when present, would motivate one to perform the action specified by the policy. Illustrative examples and further discussion about the types of conditions that a security policy may reference is presented below in the section entitled “Illustrative Conditions that may be Referenced by a Security Policy.”

In an embodiment, a security policy may be performed in a “1-click” fashion. That is to say, the owner of one or more clients may use web interface **210** of server **120** to, with the click of one mouse button or keystroke, instruct server **120** to either send one or more predefined policies to one or more clients of the owner or send one or more predefined commands to one or more clients of the owner. For example, the owner of a plurality of clients may use web interface **210** to organize the plurality of clients into one or more logical groupings, such as by division, department, or type of client. Such logical groupings may aid the owner of the plurality of clients in managing the security policies followed by a large number of clients. After the owner has defined a set of one or more commands and/or a set of one or more security policies, the owner may disseminate the set of one or more commands and/or the set of one or more security policies to a logical grouping of clients by sending a single instruction (a “1-click”) to web interface **210** of server **120**.

Using embodiments of the invention, a corporate IT department may manage the security policies of thousands of clients. The IT department may establish different security policies for clients used by personnel in the engineering department than clients used by personnel in the sales department. For example, the IT department may establish a policy, only to be used by clients operated by personnel in the sales department that will erase the hard-drives of stolen clients that are used by sales personnel under the rationale that the data stored on a client used by someone in the sales department may be very sensitive, but easy to re-create. On the other hand, the IT department may establish another policy, only to be used by clients operated by personnel in the engineering department, that will encrypt the data stored on the hard-drives of stolen clients operated by engineering personnel under the rationale that the data stored on a client used by someone in the engineering department may be hard to re-create. In this way, a centralized entity (such as an IT department) may establish a different set of security policies for various groups of clients, and the centralized entity may

instruct server **120** to implement security policies or send commands to each client in a group of clients by issuing a single instruction to server **120**.

In an embodiment of the invention, the owner of a client (such as a company) may communicate with server **120** to send commands or policy data to one or more clients owned by the owner; however, the user of a client may not modify the policy data stored on the client. In this way, a company or other centralized entity that manages a large number of clients may ensure that each client is implementing the same security policies. In this way, the user of a client cannot configure the client in a manner that disables or otherwise reduces the security protection afforded by the securities policies stored by BIOS agent **112** on the client.

#### Illustrative Commands that a Client May Perform

In an embodiment, server **120** may issue a command to a particular client for immediate performance. Additionally, a client may store a security policy which instructs the client to perform a particular command when a particular condition is met. Embodiments of the invention may implement a variety of different commands, such as retrieve, erase, encrypt, and disable. Each of these commands shall be explained in detail below.

The retrieve command instructs a client to retrieve a particular resource, such as a file, and send a copy of the resource to server **120** over communications link **130**. The retrieve command is useful when the owner of a missing or stolen client would like to retrieve a limited number of resources from the lost or stolen client. In an embodiment, resources that are retrieved using the retrieve command are then deleted from the missing client, as the client may be in possession of a malicious user.

In an embodiment, to issue a retrieve command to a client, the name of the resource (which may be a file or folder, for example) is included as an argument to the retrieve command. In another embodiment, the name of the resource to be retrieved and the path to the resource is included an argument to the retrieve command.

There may be limitations to the size of resources that are able to be retrieved using the retrieve command, as it would not be desirable to inundate server **120** with a large volume of incoming data.

The erase command instructs a client to erase one or more resources, such as a file. The erase command is use to erase sensitive or confidential data from a client. In many cases, data stored on a client may be backed-up or stored in another location on a regular basis; consequently, the real concern when a client is stolen may be that sensitive or confidential data may be accessed by a malicious party, rather than a concern that the client itself may not be retrieved. Thus, the erase command may be used to affirmatively erase data stored on client, thereby preventing the data from being accessed by unauthorized parties. In an embodiment, the path to the resources that are intended to be erased and well as information identifying the resources to be erased should be identified as arguments to the erase command.

In an embodiment, when a client performs the erase command, if the client is able, the client sends a confirmation, to server **120**, that the data identified by the erase command was erased. In this way, the owner of the client may have some assurance that sensitive or confidential data on the client was not accessed by a malicious party.

The disable command instructs a client to shut down and become unable to boot. Thus, a client that has been disabled by performing the disable command is unable to reboot. For



this reason, a client may be said to “turn into brick” by via the disable command, because the client, after performing the disable command, is unable to operate, and becomes “as useful as a brick” to an unauthorized user.

In an embodiment, a client that has been disabled by performing the disable command may be able to return to operational status if one or more authentication credentials are provided to the client. Presumably, a thief who stole a client would not know the proper authentication credential(s) to submit to the client to return the client to an operational state. In such an embodiment, it may be necessary to obtain an authentication credential from two or more parties, such as the current user of the client and the owner of the client. The user of the client may be prompted to submit an authentication credential to the client if a blank screen or a screen displaying a warning is shown by the client. In such an embodiment, the client would not necessarily have to be powered down, but instead, would not respond to any input to the client (such as mouse movements or keystrokes) except for a secret sequence of input (such as holding two or more keys together at the same time). If a user is unfamiliar with this procedure, then the user will likely believe the client is broken, and may not attempt any further action to retrieve data from the client. However, if the user is familiar with this procedure, the user may quickly submit the secret sequence of input to the client to enable the user to gain access to the client.

In an embodiment, when a client is disabled by performing the disable command, the client may emit a loud alarm. Such an approach may be useful for notifying of nearby people the client may be stolen. In an embodiment, when a client is disabled by performing the disable command, the client may display a message on a screen indicating the client has been stolen or is being accessed in an authorized manner. The message may also contain information to assist in unlocking the client. For example, the message may instruct the user of the client call a particular telephone number to unlock the client. When the user calls the telephone number, the user’s identity may be confirmed, and the user may be given a password or other authentication credential to provide to the client to unlock the client.

The specific actions taken by a client that has been instructed to perform a disable command may be defined either by the disable command itself or by a security policy stored by the client. For example, the client may store policy data that describes a policy that indicates that, when the client receives a disable command, the client is only to emit an alarm if the physical location of the client is outside of a particular geographical area.

Other illustrative commands which may be referenced by a policy or be conveyed to a client from a server include an instruction to record the keystrokes of the user of the client and an instruction to take one or more pictures or video using a web cam or other digital camera associated with the client.

The commands discussed above may be sent from server **120** to a particular client for immediate execution by the client. Alternately, as discussed below, the commands may be referenced by policy data, which defines one or more security policies, sent from server **120** to a particular client. When a condition referenced by a policy is met, then a command referenced by a policy may be performed. For example, server **120** may send a command to client **104** to enter disable state **330**. Alternately, server **120** may send policy data to client **104** which contains a policy that states the client should enter disable state **330** when a condition is met by the client, such as

the client’s IP address changing or the client physically moving outside of a bounded geographical area identified by the policy.

#### Illustrative Conditions that may be Referenced by a Security Policy

In an embodiment, a security policy specifies that one or more actions are to be performed by a client if one or more conditions are met. A condition referenced by a security policy serves to indicate when a particular action is performed. Security policies may reference a wide variety of conditions. Non-limiting, illustrative examples of conditions which may be referenced by a security policy, as an indication of when a particular action is to be performed, includes: (a) when a IP address of the client changes, (b) when the name of the client changes, (c) when the client does not connect to server **120** for a predefined length of time, (d) when the client does not receive a heartbeat message from the operating system agent executing thereon after an expected period of time, and (e) when the user of the client is not able to supply valid authentication credentials.

In an embodiment, a security policy may specify that the client may reboot a certain number of times without receiving a heartbeat message from the operating system agent residing on the client. While allowing a client to reboot without receiving a heartbeat message may introduce an element of risk to the resources of the client, it may be necessary to reboot the client without receiving a heartbeat message when the client is being repaired. As a result, a security policy that specifies, as a condition to the perform of a security action, number of times the client may reboot without receiving a heartbeat message from the operating system agent residing on the client should balance convenience versus security.

Two other conditions that may be referenced by securities policies of embodiments of the invention involve geofencing and the proximity of the client to a wireless device. Each of these techniques is described in greater detail below.

#### Geofencing

In an embodiment, a client of system **100** may be designed to perform an action or command whenever the client physically moves outside of one or more bounded geographical areas. An owner of a client may define one or more bounded geographical areas using web interface **210** of server **120**. The owner may then define one or more policies that instruct a client to perform an action or command whenever the client physically moves outside of one or more bounded geographical areas. The defined policies, which reference the one or more bounded areas, may be communication from server **120** to one or more clients.

A client storing a security policy that references one or more bounded geographical areas may employ an application module, of operating system agent **114**, to detect and fetch global positioning service (GPS) information for the client. Thus, if the client physically moves outside of the one or more bounded geographical areas referenced by the security policy, the client may be apprised and perform the one or more actions specified by the security policy.

To illustrate an example, a security policy may be stored on a client that instructs the client to enter a disabled state if the client is physically moved outside of one or more bounded geographical areas. As another example, another security policy may be stored on the client that instructs the client to perform a different action, such as erasing all data stored on the client, if the client is physically moved into one or more



bounded geographical areas, such as a bounded geographical area corresponding to a country that has weak intellectual property locations or to a location associated with a competitor.

There is no limit to the size, shape, or number of bounded geographical areas which may be referenced by a security policy. For example, a security policy may define a bounded geographical region around a particular building or physical property of the owner of the client. In this way, if the client is taken outside of a building or off the property of the owner, the client may perform a certain action, such as disabling itself or erasing sensitive or confidential information.

#### Proximity to Wireless Device

In an embodiment, a client of system **100** may be designed to perform an action or command whenever the user of the client moves his or her mobile device (such as a cell phone) beyond a specified distance from the client. For example, client **106** may immediately lock and/or power down the client and put the client in sleep mode when the user of client **106** walks with his cell phone further than a specified distance from client **106**. Further, when the user of client **106** moves his cell phone within the specified distance to client **106**, client **106** may unlock and/or power on client **106**. This approach advantageously allows a client to become secure and/or save power whenever the user walks away, with a mobile device, from the client.

FIG. **9** is an illustration of a proximity condition according to an embodiment of the invention. As shown by FIG. **9**, a zone of use is established around the client. If the user of the client leaves the zone of use with a mobile device, such as a Bluetooth cell phone, a security policy, stored by the client, may instruct the client to perform a certain action or command. The distance between the user's mobile device and the client is determined by evaluating the strength of the Bluetooth signal between the user's mobile device and the client.

Additional details about the approach depicted in FIG. **9** may be found in U.S. Pat. No. 12/321,504, entitled "Secure Platform Management with Power Savings Capability," filed by Gaurav Banga et al. on Jan. 21, 2009, the contents of which are herein incorporated by reference as if fully set forth herein.

#### Facilitating Legitimate use of Clients

Embodiments of the invention not only prevent the theft and unauthorized access of resources of a client, but also accommodate the legitimate use of clients by authorized users. An authorized user may have a legitimate need to remove a hard-disk drive or other persistent storage medium from a client and install a new hard-disk drive or other persistent storage medium in the client. The new hard-disk drive or persistent storage medium would not have operating system agent **114** installed, whereas the client would have BIOS agent **112** installed in the BIOS of the client. As the new hard-disk drive or persistent storage medium does not have operating system agent **114** installed, BIOS agent **112** on the client would not receive a heartbeat. In response to not receiving a heartbeat after an expected period of time, BIOS agent **112** checks to see if modules of operating system agent **114** are installed and uncorrupted; consequently, BIOS agent **112** would soon discover that operating system agent **114** is not installed in the new hard-disk drive or persistent storage medium. Thereafter, BIOS agent **112** copies chSync module **410** to the operating system of the client and communicates with server **120** to obtain data necessary to install operating

system agent **114** in the operating system of the client. In this process, BIOS agent **112** sends information identifying the client to server **120**, such as the serial number of the client. In this way, BIOS agent **112** may cause operating system agent **114** to be installed upon the new hard-disk drive or persistent storage medium and may repopulate operating system agent **114** with all the appropriate modules using the data obtained from server **120**.

If a user removes a persistent storage medium (such as a hard-disk drive) from a first client of system **100** and installs the persistent storage medium into a second client that is the same make and model of the first client, data stored in the persistent storage medium will still not be accessible by a user operating the second client. This is so because the second client would either be lacking a BIOS agent **112** or would not be installed with a BIOS agent **112** that is configured to operate with operating system agent **114** installed on the persistent storage medium.

When the new persistent storage medium is powered on, it would try to send a state message to server **120**, and, working in conjunction with server **120**, would attempt to repopulate BIOS agent **112** in the BIOS of the second client. The user of the second client may be asked by operating system agent **114** if the user would like to transfer a license to agent **110** from the first client to the second client. The owner of the first client may receive an email from server **120** notifying the owner about the request to transfer the license from the first client to the second client. The owner of the first client would need to approve of the transfer of license from the first client to the second client before data may be accessed from the persistent storage medium using the second client. In an embodiment, each agent **110** requires a license to operate, and if either BIOS agent **112** or operating system agent **114** resides on a client for which it does not have a license, it will not operate. To uninstall agent **110** from a client, one needs to submit appropriate authentication credential to do so.

#### Composite Tracking Algorithm (CTA)

In an embodiment, there may be a variety of different classes of data sent by a client to server **120**. Such different classes of data may include IP trace information, global positioning system (GPS) coordinates, surrounding Wifi access points, and webcam picture and video data. Server **120** may collect such information for purposes of tracking the geographical location of clients in system **100**. These different classes of data shall be discussed below.

IP trace information may include the public IP address of the client and the set of IP addresses that data packets sent from the client pass through to reach server **120**. The public IP address of the client may be determined by gathering the source IP address from the server socket receiving the client connection. The list of hops through which the data packets sent from the client go through may be determined by sending adaptive TTL (time to live) UDP packets to server **120** from the client. In order to determine if the client is being an IP proxy, server **120** may correlate the list of hops with the public IP of the client. In this way, server **120** may effectively discover the real public IP address of the client. The real public IP address of the client is then matched against a database of Internet Service Providers (ISPs) which returns the probable address of the originating client message. This address may be translated to a set of longitude and latitude coordinates.

GPS coordinate data comprises coordinates, namely longitude and latitudes, gathered by the GPS service provided by the client as well as other information, such as accuracy factors.



Surrounding Wifi Access point data may include a list of all public Wifi access points surrounding the client. The list of surrounding wifi access points is formatted and correlated with a database of public wifi access points, which may be used by server **120** to determine a probable set of longitude and latitude coordinates for the client using triangulation.

Each class of data has a weighted value in the composite tracking algorithm (CTA). For example, in an embodiment, GPS coordinate data may have the highest weight in the CTA when the client is in a position to gather relevant and accurate longitude and latitude coordinates from its GPS service. IP trace information may have the lowest weight and Wifi triangulation may have an average weight. The result of the CTA is that a geographical position is mapped to a mapping service.

In an embodiment, webcam shot data may provide visual information about the operator of the client. Webcam shots may be taken at boot time and on demand, and sent to server **120**, where the webcam shots are associated with the geographical location of the client at the time the shot was taken. Webcam shot data may include one or more digital pictures, digital video, or both.

In an embodiment, server **120** may provide an interface which visually depicts webcam shot data on a map. For example, a map may depict the five most recent geographical locations of the client on the map, and at each location, may depict webcam shot data to visually display the operator of the client at that location.

#### Location Aware Client

In an embodiment, by receiving CTA data from server **120**, a client may become self-aware as to its geographical location. By employing the predefined security policies the client obtains from server **120**, the client is able to perform actions based on the CTA data and its securities policies. Such actions that a client may take in response to a security policy referencing the client's current geographical location may include disabling the client, degrading the client, and increasing the frequency of the reports the client makes to server **120**. For example, a client may recognize that it is in an area that is unknown (e.g. a coffee shop) versus a known area (such as the home of the user or at the office). The client may determine what action to take based on the CTA data that describes its geographical location and the security polices stored on the client by BIOS agent **112**. As an example, a client may enter degraded state **320** if the client detects that the client is in an unknown network. Advantageously, embodiments of the invention enable the client to raise its level of security automatically based on its current geographical location and its surroundings.

#### Instant Command

In an embodiment, commands may be sent by server **120** to a particular client for execution in real-time. Thus, if a user wishes a particular client to immediately perform a particular command, the user may access an interface provided by server **120** to issue a command, for immediate execution, to a particular client. In order for a client to be instructed in real time of commands or special tasks (such as to disable, to retrieve a file, to erase one or more files) that are initiated using a user interface provided by server **120**, a communication channel is kept open between the client and server **120** at all time where there is network connectivity. This communication channel enables server **120** to initiate a connection to the client on demand, which cannot be accomplished in a

natural way in today's network environments with network address translation and firewalls.

The communication channel effectively enables a command to be sent from server **120** to the client for immediate execution upon receipt. For example, a user that wishes to disable his lost laptop may access the user interface provided by server **120**, and initiate an instant lock command on his lost laptop, which would effectively disable his laptop in real time. Likewise, the user could initiate other commands to be performed on his laptop immediately upon receipt, such as a retrieve command or an erase command.

#### BCOI (BIOS Connect Over Internet)

In an embodiment, agent **110** of a client may include a component (referred to as BCOI Failsafe BIOS component) which is configured to directly communicate with server **120** from the BIOS level of the client using the network stack. This transport mechanism is configured to allow (a) obtaining policy updates and/or commands on the BIOS level directly from server **120**, (b) download and update modules of agent **110**, such as those modules required for persistency, (c) support one-time password authentication methods to unlock the system, and (d) support a "remote unlock" feature, which enables a user to access a user interface provided by server **120** to unlock a particular client from server **120**.

#### Persistence

In an embodiment, agent **110** may check a heartbeat recovery flag in the BIOS and initiate a restore process for the client upon which agent **110** resides if the heartbeat recovery flag so indicates. The restore process can be initiated when the client is booted and/or when the client resumes from sleep mode or hibernate mode. One or more modules of agent **110** may copy a module (referred to as a "FailSafe Windows module" or "FailSafe OS module") from a secure location (such as BIOS Flash Memory) to an appropriate partition of the operating system of the client (which may be, but need not be, MS Windows from Microsoft Corporation of Redmond, Wash.). The one or more modules may be recovered to a particular partition specified during provisioning or to all applicable partitions. All modules that are recovered may be authenticated before they are loaded and executed.

#### Data Protection

In an embodiment, locking mechanisms allows integration with data protection solutions such as the standard ATA-based HDD and Full Disk Encryption. One may create a policy that not only locks the client, but also enforces disk data encryption. For example, when a user sends the lock command to the client, the FDE secure data (encrypt) callbacks may be called to enable the "data protection" first and thereafter, the lock will be performed. Thus, even if the hard-disk drive is removed from the client, a malicious user cannot access the data stored on the hard-disk drive. Agent **110** may store a key to perform such encryption and decryption in a secure location, such as in the BIOS of the client.

#### Implementing Mechanisms

In an embodiment, one or more of clients **102**, **104**, and **106** may each be implemented using a computer system. FIG. **10** is a block diagram that illustrates a computer system **1000** upon which an embodiment of the invention may be implemented. In an embodiment, computer system **1000** includes



processor **1004**, main memory **1006**, ROM **1008**, storage device **1010**, and communication interface **1018**. Computer system **1000** includes at least one processor **1004** for processing information. Computer system **1000** also includes a main memory **1006**, such as a random access memory (RAM) or other dynamic storage device, for storing information and instructions to be executed by processor **1004**. Main memory **1006** also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor **1004**. Computer system **1000** further includes a read only memory (ROM) **1008** or other static storage device for storing static information and instructions for processor **1004**. A storage device **1010**, such as a magnetic disk or optical disk, is provided for storing information and instructions.

Computer system **1000** may be coupled to a display **1012**, such as a cathode ray tube (CRT), a LCD monitor, and a television set, for displaying information to a user. An input device **1014**, including alphanumeric and other keys, is coupled to computer system **1000** for communicating information and command selections to processor **1004**. Other non-limiting, illustrative examples of input device **1014** include a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor **1004** and for controlling cursor movement on display **1012**. While only one input device **1014** is depicted in FIG. **10**, embodiments of the invention may include any number of input devices **1014** coupled to computer system **1000**.

Embodiments of the invention are related to the use of computer system **1000** for implementing the techniques described herein. According to one embodiment of the invention, those techniques are performed by computer system **1000** in response to processor **1004** executing one or more sequences of one or more instructions contained in main memory **1006**. Such instructions may be read into main memory **1006** from another machine-readable medium, such as storage device **1010**. Execution of the sequences of instructions contained in main memory **1006** causes processor **1004** to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement embodiments of the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

The term “machine-readable storage medium” as used herein refers to any medium that participates in storing instructions which may be provided to processor **1004** for execution. Such a medium may take many forms, including but not limited to, non-volatile media and volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device **1010**. Volatile media includes dynamic memory, such as main memory **1006**.

Non-limiting, illustrative examples of machine-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, a RAM, a PROM, and EPROM, a FLASH-EPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

Various forms of machine readable media may be involved in carrying one or more sequences of one or more instructions to processor **1004** for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a network link **1020** to computer system **1000**.

Communication interface **1018** provides a two-way data communication coupling to a network link **1020** that is connected to a local network. For example, communication interface **1018** may be an integrated services digital network (ISDN) card or a modem to provide a data communication connection to a corresponding type of telephone line. As another example, communication interface **1018** may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface **1018** sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

Network link **1020** typically provides data communication through one or more networks to other data devices. For example, network link **1020** may provide a connection through a local network to a host computer or to data equipment operated by an Internet Service Provider (ISP).

Computer system **1000** can send messages and receive data, including program code, through the network(s), network link **1020** and communication interface **1018**. For example, a server might transmit a requested code for an application program through the Internet, a local ISP, a local network, subsequently to communication interface **1018**. The received code may be executed by processor **1004** as it is received, and/or stored in storage device **1010**, or other non-volatile storage for later execution.

In the foregoing specification, embodiments of the invention have been described with reference to numerous specific details that may vary from implementation to implementation. Thus, the sole and exclusive indicator of what is the invention, and is intended by the applicants to be the invention, is the set of claims that issue from this application, in the specific form in which such claims issue, including any subsequent correction. Any definitions expressly set forth herein for terms contained in such claims shall govern the meaning of such terms as used in the claims. Hence, no limitation, element, property, feature, advantage or attribute that is not expressly recited in a claim should limit the scope of such claim in any way. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. A machine-readable medium storing one or more sequences of instructions for securing a client, which when executed, cause:

a BIOS agent storing policy data within a BIOS of the client, wherein the policy data describes one or more policies which the client should follow after the operating system has loaded, wherein the BIOS agent is one or more software modules that execute in a runtime portion of the BIOS of the client; and

upon an operating system agent detecting that a condition, specified by a particular policy of the one or more policies, has been met, the operating system agent performing one or more actions specified by the particular policy, wherein the operating system agent is one or more software modules that execute in the operating system of the client.

2. The machine-readable medium of claim 1, wherein the condition is a determination as to whether the client is physically located outside of one or more bounded geographical areas.

3. The machine-readable medium of claim 1, wherein the condition is a determination as to whether the client is located within a certain distance from a mobile device associated with a user of the client.



4. The machine-readable medium of claim 1, wherein the condition is a determination as to whether a user of the client has submitted valid authentication credentials within a configurable period of time.

5. The machine-readable medium of claim 1, wherein the one or more actions includes powering down the client and preventing the client from rebooting.

6. The machine-readable medium of claim 1, wherein the one or more actions includes the client emitting a loud noise.

7. The machine-readable medium of claim 1, wherein the one or more actions includes causing the client to take a picture or video of a user of the client.

8. The machine-readable medium of claim 1, wherein a policy, of the one or more policies, indicates that the client should enter a degraded state after a configurable period of time, wherein the degraded state requires that the user of the client authenticate himself to the client by submitted valid authentication credentials to the client, and wherein the configurable period of time is specified by the policy.

9. The machine-readable medium of claim 8, wherein execution of the one or more sequences of instructions further cause:

in response to the user being unable to authenticate himself to the client by submitting valid authentication credentials to the client when the client is in a degraded state, the client entering a disabled state, wherein the disabled state prevents the user from accessing resources of the client.

10. The machine-readable medium of claim 9, wherein execution of the one or more sequences of instructions further cause:

in response to the user submitting valid authentication credentials to the client when the client is in a degraded state, the client entering an enabled state, wherein the enabled state enables the user to access resources of the client.

11. A method for securing a client, comprising:

a BIOS agent storing policy data within a BIOS of the client, wherein the policy data describes one or more policies which the client should follow after the operating system had loaded, wherein the BIOS agent is one or more software modules that execute in a runtime portion of the BIOS of the client; and

upon an operating system agent detecting that a condition, specified by a particular policy of the one or more policies, has been met, the operating system agent performing one or more actions specified by the particular policy, wherein the operating system agent is one or more software modules that execute in the operating system of the client.

12. The method of claim 11, wherein the condition is a determination as to whether the client is physically located outside of one or more bounded geographical areas.

13. The method of claim 11, wherein the condition is a determination as to whether the client is located within a certain distance from a mobile device associated with a user of the client.

14. The method of claim 11, wherein the condition is a determination as to whether a user of the client has submitted valid authentication credentials within a configurable period of time.

15. The method of claim 11, wherein the one or more actions includes powering down the client and preventing the client from rebooting.

16. The method of claim 11, wherein the one or more actions includes the client emitting a loud noise.

17. The method of claim 11, wherein the one or more actions includes causing the client to take a picture or video of a user of the client.

18. The method of claim 11, wherein a policy, of the one or more policies, indicates that the client should enter a degraded state after a configurable period of time, wherein the degraded state requires that the user of the client authenticate himself to the client by submitted valid authentication credentials to the client, and wherein the configurable period of time is specified by the policy.

19. The method of claim 18, further comprising:

in response to the user being unable to authenticate himself to the client by submitting valid authentication credentials to the client when the client is in a degraded state, the client entering a disabled state, wherein the disabled state prevents the user from accessing resources of the client.

20. The method of claim 19, further comprising:

in response to the user submitting valid authentication credentials to the client when the client is in a degraded state, the client entering an enabled state, wherein the enabled state enables the user to access resources of the client.

21. An apparatus for securing resources stored thereon, comprising:

one or more processors; and

a machine-readable medium storing one or more sequences of instructions, which when executed by the one or more processors, cause:

a BIOS agent storing policy data within a BIOS of the apparatus, wherein the policy data describes one or more policies which the apparatus should follow after the operating system has loaded, wherein the BIOS agent is one or more software modules that execute in a runtime portion of the BIOS of the apparatus; and

upon an operating system agent detecting that a condition, specified by a particular policy of the one or more policies, has been met, the operating system agent performing one or more actions specified by the particular policy, wherein the operating system agent is one or more software modules that execute in the operating system of the apparatus.