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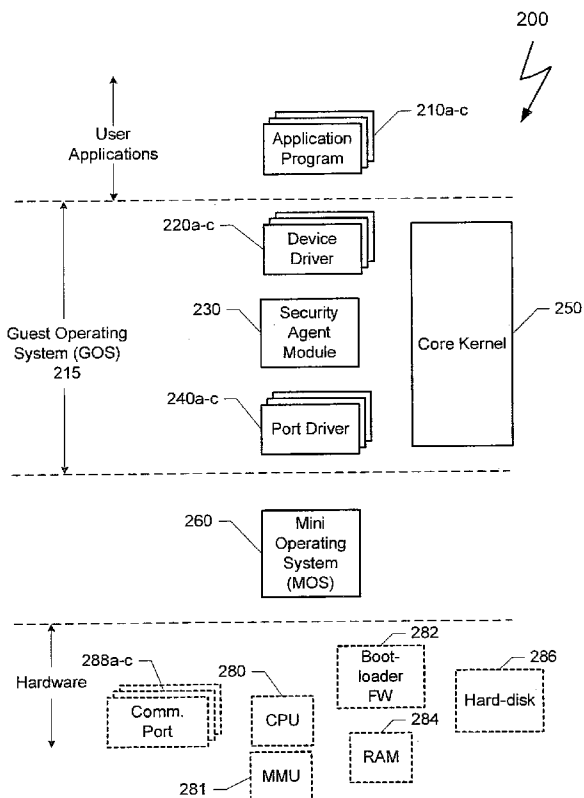
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(54) Title: METHOD AND SYSTEM FOR DEFENDING SECURITY APPLICATION IN A USER'S COMPUTER



(57) Abstract: Protecting the integrity and the effectiveness of a security agent that is installed in a user's device while the user's device operates online or offline. The security agent may be used for enforcing a security policy required by an organization or network to which the user's computer belongs. One aspect of exemplary embodiments of the present invention is to associate the content of one or more storage devices of the user's computer with the security agent and with a boot-loader program used by the user's computer.

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**METHOD AND SYSTEM FOR DEFENDING SECURITY  
APPLICATION IN A USER'S COMPUTER**

**FIELD OF THE INVENTION**

5 The present invention relates to the field of security of organizational private network and, more particularly, to protecting the integrity of one or more security applications that are installed in a user's computer.

**BACKGROUND OF THE INVENTION**

10 Commercial corporations, enterprises, organizations, such as government bodies, health care providers, military organizations, financial institutes, etc., face several computer security concerns. One of these concerns is the leakage of information from their internal computer network to the outside world. The threat of information leakage may come from outsiders attempting to hack into the organization's computers system as well as from disloyal, disgruntled or simply careless employees working inside the organization.

15 Internal employees, utilizing the permissions that have been granted to them, may gain access to the enterprise's information stored on the organization's computer system, download the information to their user's computer and then transfer the information to a hostile entity via an external storage device or any other method of data transferring. The external storage device may be a removable storage device (e.g. flash memory, such as but not limited to, DISK ON KEY provided by M-SYSTEMS or a other removable hard  
20 disk drives), a removable storage media (e.g., floppy disk, write able CD ROM or external hard drives), an internal hard drive (e.g., IDE hard drive or SCSI hard drive), a PDA with storage, a digital camera with storage, etc.

25 One common approach to deal with this type of security threat is by preventing access to all external storage devices from the computer system. This can be accomplished by blocking all the ports on which such external storage devices can appear on, or blocking the mount operation of a storage device. However, such drastic approaches adversely affect the productivity of the computer system users in that they prevent the employees from using any removable media.

Other common method is using one or more security agents that reside locally on each user's machine. A security agent is adapted to manage and enforce organizational security rules (policy) on its local user's computer. Usually a security agent can be effective when the user's computer is connected to the organizational network as well as when the user's  
5 computer is working offline far away from the organizational network. This agent monitors and controls the interaction of the local machine with other machines and devices. An exemplary security agent is disclosed in a PCT application number PCT/IL 2005/001367 and in a PCT application number PCT/IL 2004/001073, the contents of which are incorporated herein by reference. Usually an operating system is configured  
10 that the security agent is loaded as one of the first applications after the operating system.

However, there is a risk that a malicious employee, which "owns" the user's device, may try to remove or tamper the security agent in order to override the organizational security policy. An employee that "owns" the user's device has passwords, time and location in which he/she can access the user's device. Such a user may have some administrator's  
15 rights over her/his own machine, as well as some knowledge on the security policy. The malicious employee may try to bypass the security agent by installing a bypass, a detour application in both ends of the security agent for transferring the data over the bypass connection. Alternatively, in order to eliminate the operation of the security agent a malicious employee may reconfigure the operating system, by changing, for example, the  
20 operating system configuration file such as the Registry in Windows<sup>TM</sup> (Microsoft) operating system (OS).

A sophisticated malicious employee may use a CDROM having a boot program with an alternative operating system, such as Linux. The computer may be booted via the CDROM and loading the other operating system that does not include the security agent.  
25 Then the malicious user may copy the required confidential files or the entire content of the hard disk. Therefore, there is a need in the art for new method that can limit the ability of an employee to affect an installed security agent.

## SUMMARY OF THE DISCLOSURE

Exemplary embodiments of the present invention meet at least some of the above-described needs for protecting the integrity and the effectiveness of a security agent that is installed in a user's device while the user's device operates online or offline (connected or not-connected to the organization network, respectively). Usually, the security agent is used for enforcing a security policy that is required by a corporation to which the user's computer belongs. One aspect of exemplary embodiments of the present invention is to associate the content of one or more storage devices of the user's computer with the security agent and with a boot-loader program that is used by the user's computer. A storage device is a read/write persistent storage device such as but not limited to a hard disk drive or non-volatile memory (a flash memory), for example. Henceforth, the description of the present invention may use the term 'hard disk' as a representative term for any read/write persistent storage devices.

A boot-loader, or a bootstrap, program is a sequence of instructions for system initialization. This program is tailor-made to load enough other software from the hard disk for the operating system to start. Often, multiple-stage boot loaders are used, in which several small programs summon each other, until the last of them loads the operating system. Usually one or more of the first programs of the boot-loader process is maintained in "firmware", such as electrically-alterable or hard-coded read-only memory (ROM). The next one or more programs can reside on the hard disk in sectors that are associated to the boot loader process or in a flash memory, for example. Upon power-on or system reset, the boot-loader is executed by the central processing unit (CPU) of the user's device, to load an operating system user code from the hard disk into a system program memory section for execution by the CPU. The boot-loader then passes control to the operating system code.

In an exemplary embodiment of the present invention, the association between the content of the hard disk, the security agent and the boot-loader can be achieved by encrypting the content of the hard disk using an encryption key that is stored in the persistent memory of the boot-loader firmware. After the boot loader process the security agent may be adapted to retrieve the encryption key from the firmware memory and load it into an appropriate location in the system program memory to be used later on by the security agent during read/write cycles to the hard disk.

In an alternate exemplary embodiment of the present invention the boot loader program may be adapted to load the security agent from the hard disk into the operating system memory. In such an embodiment, the boot loader program may be adapted to load the encryption key to the program memory.

5 In addition to its common operation, the security agent may include an encryption/decryption engine. Furthermore the security agent may be adapted to intercept the data transportation from/to a user application to/from the hard disk. The data transferred to the hard disk can be encrypted and the data transferred from the hard disk can be decrypted by the security agent. The encryption engine can use a public key encryption algorithm or a symmetrical key algorithm. When using a public key algorithm, a block of program code or data is encrypted by the algorithm while using the public key. The encrypted data is decrypted by using a private key. RSA algorithm that is well known in the art can be an example of public key algorithm. When using the public key algorithm, the private key can be stored in the boot-loader firmware and while the public key can be stored in the hard disk with the software of security agent and may be loaded  
10  
15 by the boot-loader during power-on as part of the security agent code.

In an alternate exemplary embodiment of the present invention the encryption/decryption engine may use a symmetrical key algorithm such as but not limited to AES, DES, 3DES, RC4 that are well known in the art. In such algorithm a single encryption key is used to encrypt and decrypt the data or program code. In such an exemplary embodiment of the present invention the symmetrical key is stored in the boot-loader firmware.  
20

Furthermore, an exemplary embodiment of the present invention may use virtual machine architecture and uses a mini operating system (MOS) that hosts a common operating system such as Windows<sup>TM</sup> (a trademark of Microsoft) as a guest operating system (GOS). The MOS can be used as the host operating system and Windows<sup>TM</sup> as the guest operating system. The MOS may be loaded from the hard disk or from the boot-loader firmware by the boot-loader during power-on or reset and may be stored into system program memory of the user's device in a memory section that is below the memory section of the common operating system. The memory section of the MOS can be transparent to the operating system. The MOS may include drivers to the physical ports of the user's device to its RAM (Random Access Memory) and its hard disk. Therefore the data transportation from a user application via the operating system to and from the  
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30

RAM, the hard disk, any external device or network can be transferred through the MOS. After initiation the MOS can be adapted to continue the bootstrap process and to load the guest operating system (GOS) from the hard disk into the system program memory section, which can be above the section that is occupied by the MOS.

5 Furthermore, during loading the operating system and during ongoing operation, the MOS can be adapted to check the integrity of the security agent and/or the integrity of the operating system. An exemplary embodiment of the present invention may manipulate the virtual paging mechanism of the guest operating system and defining the pages of the operating system and/or the security agent code as read only. If a hostile application tries  
10 to write in one of those pages, then a page fault interrupt will occur and invoke the MOS. In case that the MOS suspects that the operating system and/or the security agent have been tampered the MOS may disable the operation of user's device, or destroy the content of the hard disk, etc. An exemplary MOS can be implemented by using commercial virtual machine such as but not limited to products of VMware Inc. California.

15 Another exemplary MOS can be implemented as a Virtual Machine Monitor (VMM). A virtual machine monitor is a thin piece of software that runs directly on top of the hardware and virtualizes all the resources of the machine. Since the exported interface is the same as the hardware interface of the machine, the operating system cannot determine the presence of the VMM. The VMM technique is well known in the art since 1970. A  
20 common VMM may utilize a memory manager unit (MMU) that is associated with the computer. The MMU may translate the virtual memory pages into physical memory addresses. The description of this application will not depict the operation of a common VMM.

On top of the VMM, the MOS may have a software module that follows the current  
25 activity of the computer in order to determine whether the current activity can violate the security agent and/or the operating system. Tracing the activity of the computer can be done by placing break-point in selected virtual memory pages that are relevant to the security agent or certain device driver or port driver. Some memory pages can be defined as read only pages. When a hostile code tries to write to one of those pages a page fault  
30 interrupt is invoked and the MOS may prevent the writing into the protected pages. By using its monitoring capabilities the MOS keeps the integrity of the security agent and the operating system.

Yet in an alternate exemplary embodiment of the present invention the MOS can be implemented by a common operating system, such as but not limited to Linux. The GOS, for example can be a Windows<sup>TM</sup> (Microsoft) that can be embedded as a folder in the disk and a process in the memory of the MOS.

- 5 Other objects, features, aspects and advantages of the present invention will become apparent upon reading the following detailed description of the embodiments with the accompanying drawings and appended claims.

**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING**

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

5 Fig. 1 is a block diagram depicting relevant elements of a computer system that uses an exemplary embodiment of the present invention for protecting the computer system;

Fig. 2 is a block diagram depicting relevant elements of a system that may be used in an exemplary user's computer;

10 Fig. 3 is a block diagram illustrating components of a security agent according to an exemplary embodiment of the present invention;

Fig. 4 is a block diagram illustrating components of a mini operating system (MOS) according to an exemplary embodiment of the present invention;

Fig. 5 is a memory map diagram illustrating the mapping of a system program memory space according to an exemplary embodiment of the present invention;

15 Fig. 6 illustrates a flowchart with relevant steps of an exemplary method for power-on;

Fig. 7 illustrate a flowchart with relevant steps of an exemplary method for associating the content of an hard disk with the security agent; and

Fig. 8 illustrates a flowchart with relevant steps of an exemplary method for verifying the integrity of the security agent and/or the operating system.

20 It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity.



## DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Turning now to the figures in which like numerals represent like elements throughout the several views, various aspects and exemplary embodiments of the present invention are described. For convenience, only some elements of the same group may be labeled with numerals. The purpose of the drawings is to describe exemplary embodiments of the present invention and not for production or limitation. Therefore, features shown in the figures are chosen for convenience and clarity of presentation only.

Fig. 1 is a block diagram depicting relevant elements of a computer system **100** that uses an exemplary embodiment of the present invention for forcing security policy of an organizational network as well as forcing the security policy on the user's devices. The computer system **100** may consist of a plurality of user's devices **110a-c**, a private or public network **120**, a plurality of communication channels **115a-c** between the private network **120** and the plurality of user's devices **110a-c**, and a security server **130**. Three instances of user's devices **110a-c** and communication channels **115a-c** are shown in Fig. 1 by way of example only, and it will be appreciated that any number other than three may also be used with various embodiments of the present invention. The private network **120** may be an Intranet, cellular network, a LAN, a VPN (Virtual Private Network) or any other type of communication network. Exemplary embodiments of the present invention can be implemented in a public network as well as in a private network.

Each of the user's computer **110a-c** may be a personal computer, a workstation, a desktop computer, mainframe computer, blade server (e.g. CITRIX), dumb terminal, etc. or any other type of computing device that can be connected over the private network **120**. In addition each of the user's devices **110a-c** may also be a portable device, such as but not limited to a laptop computer, notebook computer, a smart phone, a personal digital assistant (PDA), or any other type of mobile device. In this application, the terms "user's device" and "user's computer" may be used interchangeably.

From time to time, the user's computer **110a-c** may be connected to various networks, at home, at work, and at other locations. Communication channels **115a-c** may be permanent connections, temporary connections, and wire or wireless connections. A wireless connection can be an RF connection based on a protocol such as, but not limited

to, Bluetooth, GPRS, UMTS or WiFi. The wireless connection may also be an Infra Red (IR) connection.

An exemplary user's computer **110a-c** may be implemented as a virtual machine having a mini operating system (MOS) **140** that hosts a common operating system such as Windows OS as a guest operating system (GOS). In addition the user's computer **110a-c** includes a security agent **130**. The security agent is used for enforcing the security policy of the organization on the computer while the computer is working on-line or off-line. MOS **140** can be adapted to verify the integrity of the GOS as well as the integrity of the security agent **140**. More information about the user's computers **110a-c** is depicted below.

The security server **130** may be an element of network **120**. The security server **130** may be responsible for managing the one or more security policies that are used over the private network **120**. A plurality of policies may be used by each user's computer **110a-c**. The security policies may be based on the user's degree of security, the type of the devices that are connected to the user's computer, etc. The security policies can be updated from time to time and then be loaded or reloaded into the user's devices **110a-c**.

The security server **130** can operate to ensure that all user's computers comply with specified security policies. For example, if a trigger event occurs and a copy of a corporate security policy is not available on a user's computer **110a-c**, the user's computer **110a-c** may initiate a connection to the security server **130**. In response to such initiation, the appropriate policies may be downloaded to the user's computer **110a-c**. The security server **130** may periodically update the security policies that are installed in each one of the user's computers **110a-c**. The security agent **150** within the user's device **110a-c**, among other things, operates to enforce the security policy by monitoring events in accordance with the security policy and preventing types of activities according to organizational policies.

The security server **130** can be constructed in a variety of manners. One exemplary embodiment of the present invention may comprise the following relevant modules: client's communication module **132**, log analyzer module **133**, log server module **134**, policies database **135**, client database **136**, stamping user interface module **139** and a manager module **138**. Client communication module **132** is typically used to

communicate with the plurality of user's computers **110a-c** over the private network **120** while the user's computers **110a-c** are connected to the private network **120**. The communication between the user's computers **110a-c** and the security server **130** can be encrypted to create a secure connection between the user's computers **110a-c** and the security server **130**, over which data can be sent securely.

The communication from the security server **130** to the user's computer **110** may include: providing updated security policies, and/or periodically checking the security agent **150**, and/or the security policies that have been installed on the user's computer **110**, and/or periodically checking the MOS **140** to determine if they have been contaminated or have been tampered with by any hostile code. Security server **130** may communicate with the MOS **140** for collecting information on trials to affect the code of the security agent and/or the operating system. If a particular user's computer **110** does not have a required security agent **150** or security policy installed, or the security agent **150** and/or the MOS **140** were infected, the security server **130** can prevent further access to the private network until such user's computer **110** has installed and activated the required security agent, MOS or security policy. Technologies like network access control (NAC) of Cisco, Network Access Protection (NAP) of Microsoft, or changing routing tables can be used in order to prevent connection of an infected security agent to network **120**.

The communication from the user's computer **110** to the security server **130** may include: (a) a real-time indication that is used to inform the security server **130** when the user's computer **110** is connected to the private network **120**, (b) reports on events according to the security policy, (c) reports on trials to affect the host operating system and/or the security agent or the stored security policy, etc. The report may include information on any connection of the user's computer **110** to an external device, information on the data transfer, the timing of the event, the location, the device to which the data transfer was done, shadowing of the information that was transferred while the user's computer **110a-c** was not connected or connected to network **120**, etc.

The log server module **134** may be or may include a storage device. Any reports that have been sent from the user's computers within a certain period of time and/or pertaining to any policy violation event can be received by the log server module **134** and stored within the storage device. The reports may be retrieved and processed manually by an administrator of the private network **120** or automatically by the log analyzer module **133**,

which may run several statistical algorithms in order to monitor the security of the network. The process may uncover a careless user that may have connected or attempted to connect certain devices to the user's computer **110** or identify an attempt to access such certain storage devices or identify an attempt to tamper the security agent **150** and/or the GOS. The report may also identify a negative trend. As one example of a negative trend, the report may identify multiple user's computers in which the security agent has been tampered with, modified, etc. When a portable user's device is not connected to the network **120**, the events may be kept by the client agent operating within the user's computer and then sent to the security server **130** when the user's computer is reconnected to the private network **120**.

Policies database **135** may include a database of a plurality of policies, including security policies that may be used by the organization that uses the private network **120**. A security policy may include a set of rules that are used to determine whether a given user's computer can be permitted to gain access to a specific storage device. The security policy may depend on a variety of factors, such as but not limited to, the size of the storage device, the manufacturer of the storage device, whether the device is "stamped", "stamp" security ascriptions, etc. In addition, different security policies may be allocated to different users, groups of users, computers working hours, etc.

User Database **136** is a database that may include information regarding the various user's computers **110a-c** that may be connected over private network **120**. This information may include items such as but not limited to: the user's level of security, the type of equipment that the user possesses, the external devices to which the user's computer is allowed to be connected, information about the different environments in which the user's computer may work, a rescue key that can be use in order to rescue the content of a persistence storage device in case that the a boot-loader firmware, the security agent or the MOS that are used by the user's computer have been damaged.

The manager module (MM) **138** manages the operation of the security server **130**. It may initiate tasks to check the status and configuration of each one of the security agents **150**, MOS **140** and the security policies installed within the various user's computers. In alternate exemplary embodiment of the present invention MM **138** can be adapted to communicate with the MOS **140** in order to verify the integrity of the GOS. The MM **138** may create and send the appropriate policies to each one of the user's computers. Based

on the information that is stored in the policies database **135** and the client database **136**, the MM **138** may create one or more policies for a particular user **110a-c**. For example, a user that has a portable computer may need three policies. One of the policies may be used while the particular user's computer is connected to the private network **120**.  
5 Another policy may be used when the user's computer is operating in a known environment, such as but not limited to a home environment or home network. The third policy may be used when the user's computer is operating in an unknown environment or location. One example of such an unknown environment would include a hotspot or a WiFi access zone.

10 The MM **138** and the stamping UI module **139** cooperatively may be used for signing a "stamp" on each one of the boot-loader firmware and or each one of the security agent **150**. An exemplary method for signing the "stamp" or a digital certificate may be based on a certification standard, including but not limited to ITU.T standard X.509. Signing may be done by using cryptographic techniques such as but not limited to MD5, SHA-1  
15 for calculating a hash value and RSA for encryption and decryption. In an exemplary embodiment of the present invention, the security server has a cryptographic private key, while each of the user's devices has a public key. This public key can be stored in the boot-loader firmware of the user's device **110**. The ITU is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization  
20 Sector (ITU-T) is a permanent organ within the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing recommendations on them with a view to standardizing telecommunications on a worldwide basis. Additional information regarding the ITU can be found at the website address of [www.itu.int](http://www.itu.int).

The stamping user interface module (SUIM) **139** may have a graphical user interface  
25 (GUI) that may be used by the administrator of the system to "stamp" an external device and/or the boot-loader firmware. In an alternate exemplary embodiment of the present invention SUIM **139** may be distributed over one or more computers that are used by one or more administrators for interfacing with the security server. The SUIM **139** may gather parameters from the storage device, and allow the administrator to choose a security  
30 ascription, to which a user's device will be associated, size of the security agent, etc. The parameters and the ascription are used in the process of creating the new stamp. This information is transferred to the MM **138**. The MM **138** may retrieve the parameters and

the ascription of the "stamp" to be written on the boot-loader firmware of the user's device. The "stamp" can be processed and then written onto the boot-loader firmware.

Fig. 2 is a block diagram depicting relevant elements of an exemplary user's computer **200**. The user's computer **200** can be divided into four levels: a user applications level, a guest operating system (GOS) **215**, a mini operating system (MOS) and the hardware level. The user application level comprises one or more application programs **210a-c**. The application level operates via the GOS **215**. An exemplary guest operating system level can be implemented by a common operating system such as but not limited to Microsoft Windows (a trademark of Microsoft), Unix, MAC OS, VMS; LINUX, SYMBIAN, PALM-OS, Windows CE etc. The GOS **215** can comprise one or more device drivers **220a-c**, one or more communication port or bus drivers (stack) **240a-c**, a core kernel module **250**. In addition an exemplary GOS **215** may comprise a security agent module **230**. In an exemplary embodiment of the present invention the GOS **215** can be isolated from the hardware level of the computer system **200** by MOS **260**. Yet in an alternate embodiment of the present invention the GOS **215** may not be isolated from the hardware level but may be monitored and controlled by the MOS **260**.

The MOS **260** can be a code added to computer system **200** in order to validate the pureness and the operation of Security Agent (SA) **230** while the computer system **200** is running. MOS **260** may verify that the SA **230** was not bypassed by another code, and/or that the SA **230** has not been modified to skip or ignore some limiting policies, and/or that the encrypting/decrypting engine (if exist) has been disabled. Disabling the encrypting/decrypting engine may enable copying data from the network **100** (FIG. 1) to the hard disk **286** of computer system **200** to be latter transferred to an hostile entity, etc.

An exemplary MOS **260** can run on top of the hardware and virtualizes some or all the resources of the computer system **200**. The operation of MOS **260** is transparent to GOS **215**. GOS **215** cannot determine the presence of MOS **260**. An exemplary MOS **260** can be implemented by using a virtual machine monitor (VMM) technique that is well known in the art. In addition to typical VMM software modules the MOS **260** may comprise one or more logical modules that are adapted to verify that the SA **230** has not been tampered and that it operates properly. Furthermore, the MOS may control the operation of the computer **200** based on decisions relevant to the operation of the SA **230**.

An alternate exemplary embodiment of the present invention, which can be used in a user's computer that has a virtual memory pages system, the MOS 260 may be implemented by a transparent software module that traces the physical pages of the program memory addresses. The MOS 260 may include an Addressing Inspection  
5 Module (AIM) and a Physical to Virtual Translating Module (PtVTM). The AIM may use tracing technique such as breakpoint technique and/or page-fault interrupt as identification for attempting to violate the security agent or the MOS itself. Traces can be placed in sensitive addressing spaces of the program memory 284. When a code requests an access to a traced (marked) physical memory page, then MOS 260 can be invoked.  
10 Determining the location for placing the traces can be done after the termination of the boot-loader process. The location of the SA 230 in RAM 284 can be verified by utilizing features of the GOS. In an exemplary embodiment of the present invention in which the GOS 215 is Windows and the SA 230 is implemented in a way that includes a kernel driver, then the "Driver Object Structure" can be checked for the relevant pages by using  
15 DriverStart and DriverSize values in the driver's device object. These values determine the memory pages where the SA 230 driver is found.

Yet an alternate exemplary embodiment of the present invention MOS 260 may be implemented by a debugger application that is modified to be transparent and automatic. The debugger technique is well known in the art. The MOS may be adapted to use  
20 breakpoint to determine when an execution should be interrupted. A breakpoint can indicate reading, writing, modification of a specific area in RAM 284, or at a particular time (non-working hours, for example). The interrupt may invoke additional software modules that automatically analyzes the situation, may proceed by running code step by step and reach a decision whether the operation is legal or not. Based on this decision the  
25 GOS 215 may be enabled to continue or disabled. MOS 260 may initiate counter measures methods to prevent the violation.

Yet in an alternate exemplary embodiment of the present invention, MOS 260 can be implemented by a commercial operating system, such as but not limited to Linux, Windows CE, etc. In such an embodiment the GOS 215 can be embedded as a  
30 process/application of the MOS 260. During the boot-loader process the MOS is loaded and initiated first from the hard-disk 286 to RAM 284. Then the MOS 260 loads the GOS 215 from the hard-disk to the RAM. The additional functionalities of MOS 260 that are

relevant to the communication with the security server **130** (FIG. 1) and to checking the integrity of the SA **230** and/or the GOS can be implemented as another one or more applications/processes of MOS **260**. The application/process of MOS **260** that runs the GOS **215** may also include methods that simulate the hardware of system **200** for virtualization of the hardware of system **200**. More information on the operation of MOS **260** is disclosed below in conjunction with FIG. 4, FIG. 6 and FIG. 8.

Among other hardware modules, the hardware level can comprise a CPU **280**, a Boot-loader firmware **282**, a random access memory (RAM) **284**, a hard disk **286**, and one or more physical communication ports or buses **288a-c**. CPU **280** can be a processor that is capable of using virtual paging memory system, for example Intel-x86 compatible processors, Motorola 68030, etc.

Boot-loader firmware **282** can be an electrically-alterable or hard-coded read-only memory (ROM) that stores a boot-loader program. The exemplary Boot-loader firmware **282** can be modified, by the administrator of network **100** (FIG. 1), to load the code of the MOS **260** from the hard-disk to the appropriate location in RAM **284**. The location of the MOS **260** can be in memory addressing section (memory addressing space **520**, FIG. 5) adjacent and above the memory addressing section of the Boot-loader program (memory addressing space **510**, FIG. 5).

The boot-loader program can be adapted to verify the validity of the loaded MOS **260**. Checking the validity of the MOS **260** can be done by using cryptographic technique such as but not limited to MD5, SHA-1 for calculating a hash value for each block of MOS **260** code that is loaded. The signing of the MOS **260** can be done by the administrator of system **100** via security server **130** (FIG. 1). The boot-loader program may use a private key that can be stored in the firmware **282** by the security server prior to the installation of the firmware **282** in the user's computer **200**.

After authenticating the MOS **260**, the CPU **280** may proceed according to the boot-loader program and may load the GOS **215** with its drivers and the security agent **230**. The boot-loader firmware may be adapted to include a validation process for the security agent **230** using a similar method to the one that is depicted above in conjunction with loading of MOS **260**. In an exemplary embodiment of the present invention in which the content of the hard disk is encrypted/decrypted by the security agent. During the boot-



loader process an encryption key, which is stored in the firmware **282**, is transferred to the security agent **230**. The encryption key may be stored in the boot-loader firmware **282** by the administrator of system **100** using the security server **130** (FIG. 1). At the end of the boot-loader program the instruction pointer of CPU **280** is set to the first address of the MOS **260** to initiate it.

In an alternate exemplary embodiment of the present invention the firmware **282** may include a small program that loads portion of the MOS **260** from the hard disk **286** to RAM **286**. This portion of MOS **260** is sufficient for continue loading the MOS **260** from the hard disk. MOS **260** is adapted to load GOS **215** with the SA **230** and to validate the integrity of the loaded SA **230**. In such an embodiment of the present invention the boot-loader firmware **282** may get one or more verification parameters such as but not limited to encryption/decryption keys that are used by the security agent **230**. Loading the verification parameters into the firmware can be done by the security server **130** (FIG. 1) More information on the boot-loader program is depicted below in conjunction with FIG. 6.

RAM **284** is a random access read/write memory. An exemplary RAM **284** may be divided into pages of address. A page is a minimum portion of the memory that can be allocated to an entity. RAM **284** can be used to store the software program that is executed by computer system **200** as well as data and parameters that are currently used. An exemplary physical memory addressing map **500** of CPU **280** is illustrated in FIG. 5. The mapping includes the memory space of the boot-loader firmware **282** and RAM **284**. It can be seen that the storage of the boot-loader firmware is using the first space of addresses **510**, contiguous and above it is the addresses space **520** that is allocated to MOS **260**, contiguous and above is the addresses space **530** of GOS **215** which includes also the address space of the security agent **230** (not shown in the map). The address space **520** and **530** can be part of RAM **284**. The rest of RAM **284** can be used for data.

In some exemplary embodiment of the present invention RAM **284** can be managed by a memory management unit (MMU) **281**. The MMU **281** can be a class of computer hardware components responsible for handling memory accesses requested by the CPU **280**. Some CPUs **280** may comprise the MMU **281**. Common functions of an MMU **281** are the translation of virtual addresses to physical addresses (i.e., virtual memory management), memory protection, cache control, bus arbitration. The MMU **281**

normally translates virtual page numbers to physical page numbers via an associative cache called a TLB. The MMU may be used by MOS **260** in order to trace the operation of the GOS **215**.

5 Hard disk **286** can be a read/write persistent storage device such as but not limited to a hard-disk drive or non-volatile memory (a flash memory) that stores data and software program that are used by the computer system **200**.

10 Generally, data transportation in the user's computer **200** can flow from/to an application **210a-c** to/from a physical communication port **288a-c** or RAM **284** or hard disk **286** via the appropriate device driver **220a-c**, security agent **230**, core kernel **250**, the appropriate port driver **240a-c**. In some embodiments the data can be transferred also via the MOS **260**.

15 The example illustrated in Fig. 2 shows the use of three application programs **210a-c**, three device drivers **220a-c**, three port drivers **240a-c**, and three physical communication ports **288a-c**; however, it will be appreciated that any number other than three may be used with the present invention. The software of user's computer **200**, or aspects of the client software, may be stored in a fixed storage medium (e.g. a disk, flash memory, a read-only memory (ROM) etc.).

20 During operation one or more application programs **210a-c** may be transferred from a fixed storage medium into a RAM **284** of client **200** for execution by the GOS **215**. The application programs **210a-c** may be a program such as, but not limited to, (a) synchronization applications for a PDA, (b) Java applications for synchronization with external Java devices, such as but not limited to cellular telephones, backup storage applications, (c) office applications, including but not limited to word processing applications, presentation applications, file utilities, etc., and (d) communication applications, such as but not limited to, applications that utilize Bluetooth or WiFi protocols, Internet browser, etc.

25 When the core kernel **250** and/or one or more application programs **210a-c** operate to communicate with a device, the appropriate device driver **220a-c** may be invoked. The device driver **220a-c** is used as an intermediary node between the core kernel **250** and/or one or more application programs **210a-c** and the device itself. Exemplary devices can include external devices such as but not limited to a removable storage device, a printer, a

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PDA, a WiFi dongle, etc; or internal devices such as but not limited to the internal the internal hard disk **286** RAM **284**, etc. An exemplary embodiment of the present invention may associate the content of the hard disk **286** with the boot-loader firmware **282** and the security agent **230**. The association is needed for preventing a disloyal owner of the computer system **200** to bypass the security agent and copy the content of the hard disk.

Usually a device driver **220a-c** is supplied by the vendor of the device itself. In addition to the device driver **220a-c**, a port driver **240a-c** may also be invoked. The port driver/bus driver **240a-c** is used to organize the communication according to the protocol that is used over the physical communication port **250a-c**. For example, if communication port **250** is a USB port, then a USB driver (USB stack) is needed. The above-described computer software is for illustrating the basic software components that may be employed by a user's computer **110a-c** (Fig. 1). In addition to those elements, a security agent **230** is added by an exemplary embodiment of the present invention.

The security agent **230** may be stored in hard disk **286** and be loaded to RAM **284** during the power-on cycle of the user's computer **200**. The SA **230** can be validated by the MOS **260** or the boot-loader program and remain active for the entire operation of the system **200**. In other embodiments of the present invention, the security agent **230** may be burned onto a physical memory, such as the ROM, PROM, BIOS (the boot-loader firmware **282**), etc. The security agent **230** may be installed as a section of the GOS **215** and can be handled by an administrator having the appropriate permissions. The security agent **230** may be installed above the one or more communication port/bus drivers **240a-c**.

In an alternate exemplary embodiment of the present invention the SA **230** can be a section of MOS **260** or an application that is executed in the MOS. In such an embodiment of the present invention, during the bootstrap process SA **260** is loaded from the hard-disk (HD) **286** by the MOS and is stored in program memory section **520** (FIG. 5) of RAM **284**. This memory section **520** is transparent to GOS **215** and therefore it is not vulnerable to attacks that occur on the level of GOS **215**.

An exemplary security agent **230** may emulate a kernel device driver and will receive the communication between the device driver **220a-c** and the appropriate port driver **240a-c**. During the installation and/or periodically, from time to time, the security agent **230** may

register in the appropriate location in the core kernel as the first device driver for receiving the communication from/to the different physical communication port/bus drivers. For example, if GOS 215 is a Microsoft product, than the security agent 230 may register in the Registry as the first device driver to get the communication. The registration may be done in a class level or in a device level. Exemplary classes may be USB, CD-ROM drivers, Disk Controller, etc.

In some operating systems, the device driver may be constructed from a stack of two or more sub-device-drivers. In such architecture, an exemplary embodiment of the security agent 230 may operate to collect information from at least one of the two or more sub-device-drivers. For example, in the scenario of using a USB flash storage device, such as but not limited to, DISKONKEY (DiskOnKey is a trademark of M Systems) in the WINDOWS (Windows is a trademark of Microsoft) environment, the stack of the relevant sub-device-drivers can include: VolSnap.sys; Disk.sys; UsbStor.sys; and Usbhub.sys. The security agent may collect information from any of the four sub-device-drivers.

In an exemplary embodiment of the present invention, the security agent 230 may emulate a filter procedure but, instead of providing the functionality of a common storage filter driver, the security agent performs security checking. A filter may perform device-specific functionality that is not provided by a class device driver. The security agent 230 may emulate more than one type of filter driver. The number of types of filters that may be emulated by the security agent 230 can be configured according to the number of physical communication ports and devices of which their transportation may be checked by the security agent 230.

Security agent 230 may be activated when a physical communication port is requested. The security agent 230 may pull the transportation to and from the physical communication port, processes the information and may reach a decision regarding the legality of the requested connection and/or data transfer. An exemplary embodiment of the security agent 230 may act as a proxy for both sides. The security agent 230 may be transparent to the user; it may not have any icon or indication to indicate its existence to the user. More information about the operation of security agent 230 is depicted in PCT application number PCT/IL 2005/001367 and in a PCT application number PCT/IL 2004/001073, the contents of which are incorporated herein by reference.

In addition to the above functionality of the security agent **230** as the executer of the security policies of the organization in the user's computer **200**, the security agent **230** may include cryptographic engine for associating the data that is written to the hard disk **286** with the SA **230** and with the boot-loader firmware **282**. The cryptographic engine may use an encryption key that is stored in the boot-loader firmware **282** and is loaded to the program memory section of the security agent **230** in RAM **284** during power-on or reset. The combination of the encrypted data of the hard disk, the cryptographic engine in the security agent and keeping the encryption key in the firmware **282** bonds the three entities into an association that is mandatory for understanding the content of the hard-disk.

Fig. 3 is a block diagram depicting relevant elements of an exemplary security agent (SA) module **300** that may be used by an exemplary security agent **230** (Fig. 2). Exemplary security agent **300** is adapted to verify that data transportation to/from the user's computer **110** (FIG. 1) from/to storage device complies with the security policy of the organization. Other type of security agent may be adapted to verify other type of operation of the computer device. In addition to its security activity, the SA **300** is configured to include a mechanism that bonds the SA **300** with the content of the hard disk **286** (FIG. 2) and the boot-loader firmware **282** (FIG. 2) of the same computer. Security agent module **300** may comprise a parameter gathering module (PGM) **310**, a manager and decision maker (MDM) **320**, a log module (LM) **330**, a bank of security policies (BOSP) **340**, a cryptographic module (CM) **350**, an encryption/decryption engine (EDE) **360** and a communication module **370**.

The PGM **310** detects a newly connected device, such as a storage device. The parameters can include information that is relevant to the device. For example if the device is a disk, the parameters may include, for example: the disk's size, its geometry parameters (such as number of cylinders, tracks per cylinder, etc.), a serial number if one exists, etc. Those parameters can be used during the process of creating and writing the stamp, as well as for verifying stamps. Moreover, the parameters may be used in order to check whether the connection to the device is allowed according to a relevant security policy that is currently in used. For example, if allowing the device depends on its volume of storage, the device may not be allowed unless it falls within the threshold requirements.

There are cases in which parameters of the storage device are not accessible to the security server. In those storage devices, exemplary embodiments of the present invention may use only the information that was written by the security server onto the external storage device.

5 Another role of the PGM **310** is to retrieve the content of a "stamps" from the storage device (if exist). These stamps are examined with an algorithm that is described below in conjunction with the description of the cryptographic module **350**. During this examination, the "stamp" is revealed and checked for authenticity. The parameters of the stamp, which can include the stamp name and ID, are then moved to the manager and  
10 decision maker **320**. The manager and decision maker **320** then operates to check the applicable policy according to all of the information given by or pertaining to the storage device, such as but not limited to, a USB vendor id, product id, disk size, stamp name (security ascription), stamp ID as well as other parameters and values for determining to permit or deny data transportation to/from the storage device.

15 The cryptographic module (CM) **350** may be invoked by the MDM **320** upon connecting the system **200** (Fig. 2) to a device that includes storage capabilities. The cryptographic module **350** may get, via the PGM **310**, the parameters of the device as well as the current "stamp" that is written on or associated with the device. The CM **350** may verify the validity of the stamp and then update the MDM **320** with the result of the verification. In  
20 addition, the CM **350** may update the "stamp". The updated "stamp" is written back to the device replacing the previous stamp.

The log module **330** may be a storage area for storing communication events and/or any policy violation event that have been detected by the SA **300**. In addition the log module **330** can keep track of the "stamped" devices (devices with digital certificates) used in or  
25 connected to the user's computer **110**. When the user's computer **110** is connected to the network **120**, the logged events may be sent to the security server **130** (FIG. 1).

The communication module **370** operates to deliver logs from the user's computer **110** to the security server **130**, and one or more policies from the security server **130** to the user's computer **110**. This communication is preferably secured and includes  
30 authentication, so that it will be difficult for a system to mimic a policy. The communication can be based on Internet Protocol, for example.

The BOSP **340** manages one or more security policies that are installed from time to time by the administrator of the private network **120** (Fig. 1), while the user's computer **110** is connected over the private network **120**. Moreover, the policy may be dependent upon the time of operation, the type of network, capabilities and types of external storage devices, the number of external devices, etc.

Each security policy may comprise a plurality of rules that may operate to control the behavior or availability of a storage device based on various parameters. The parameters may include, but are not limited to, the device's parameters, hardware parameters, the stamp name and the stamp ID. The rules within the security policy can be positive (i.e. allowances) or negative (i.e. restrictions). An exemplary rule that could exist in a security policy is as follows: a storage device that is stamped with a stamp name = "PR", can be used accessed by a user's computer named PR1 only if the stamp ID of the storage device is not one of the following ID numbers (1563 or 2317).

From time to time, the content of the BOSP **340** may be checked and updated manually by the administrator of network **120** or automatically by the security server **130** (Fig. 1). From time to time, the MDM **320** may perform an integrity check on the BOSP **340** to determine if it has been tampered with or modified by hostile code. If the BOSP **340** has been damaged or otherwise altered, the MDM **320** may prevent any data transportation to/from any external device. More information on the operation of the security agent **300** can be found in PCT application PCT/IL 2005/001367 the contents of which is incorporated herein by reference.

In addition to the above mentioned modules, SA **300** can comprise the EDE **360**. The EDE is activated each time an application **210a-c** (FIG. 2) is willing to read or write to the hard disk **286** (FIG. 2). The data to the hard disk can be encrypted and the data from the hard disk can be decrypted by EDE **360**. EDE **360** can use a public key encryption algorithm or a symmetrical key algorithm. When using a public key algorithm, a block of program code or data is encrypted by the algorithm that uses a public key. The encrypted data is decrypted by using a private key. RSA algorithm that is well known in the art can be an example of public key algorithm. When using the public key algorithm, the private key can be stored in the boot-loader firmware **282** (FIG. 2) and may be retrieved by the boot-loader during power-on or reset and be stored in the RAM **284** (FIG. 2), while the public key can be stored in the hard disk **286** with the software of security agent **300** and

may be loaded by the boot-loader during power-on as part of the security agent code. Alternatively, the SA 300 may be adapted, upon initiation, to load the private key from the boot-loader firmware and store it in the RAM 284 (FIG. 2).

5 In an alternate exemplary embodiment of the present invention the EDE 360 may use a symmetrical key algorithm such as but not limited to AES, DES, 3DES, RC4 that are well known in the art. In this algorithm a single encryption key is used to encrypt and decrypt the data or program code. In such an exemplary embodiment of the present invention the symmetrical key is stored in the boot-loader firmware 282.

10 Yet another exemplary embodiment of SA (not shown in the drawings) may not have an EDE. In such a case the boot-loader firmware 282 with the MOS 260 (FIG. 2) may force the necessity of the SA 230 for the operation of computer system 300. However a disloyal employee, in order to read the content of the hard disk 286 may remove the hard-disk 286 from the user's computer and connect it to an unsecured computer. The previous exemplary embodiments with the EDE 360 deliver a tighter protection than the one  
15 without an EDE, but may affect the read/write speed to the hard disk.

There are other exemplary embodiments in which the decision, on the whether to use or not to use the EDE 360 while writing to the hard disk, can be depended on the type or the file as well as the owner of the computer device. This decision can be made by the MDM 320 according to an appropriate policy from the BOSP 340.

20 In an alternate exemplary embodiment of the present invention the EDE 360 can encrypt/decrypt the directory of the hard disk 286. Yet in an alternate exemplary embodiment of the present invention SA 300 can be implemented as a module in the GOS 210.

25 Fig. 4 is a block diagram depicting relevant elements of an exemplary mini operating system (MOS) module 400 that can be implemented in computer system 200 (Fig. 2). Exemplary MOS 400 is adapted to verify that the SA 230 and/or GOS 215 (Fig. 2) have not been contaminated during ongoing operation of the computer system 200. The operation of MOS 400 can be transparent to the GOS 215 as well as to the user of the computer system 200. During power-on or reset MOS 400 can be loaded by the boot-  
30 loader program, which is stored in firmware 282 (FIG. 2). MOS 400 can be stored in addressing space 520 (FIG. 5) above the memory space 510 of the boot-loader program



and below the memory space **530**, which is used by the GOS. After initiation by the boot-loader program MOS **400** can continue the bootstrap process and load the GOS **215** (FIG. 2) from the hard-disk **286** and store it in memory section **530**.

5 Exemplary MOS **400** operates to protect addressing space **530** in which the GOS **215** is stored or at least to protect a portion of this memory space of addresses, which is used by SA **230**. In order to do so MOS **400** may communicate with MMU **281** (FIG. 2), set traces, uses single step mode, etc. MOS **400** may comprise a MOS log module (MLM) **420**, a MOS manager and decision maker (MMDM) **430**, a bank of MOS security policies (BOMSP) **440**, an integrity checker module (ICM) **450** and a MOS communication  
10 module (MCM) **470**.

MOS Log module **420** may be a storage area in memory space **520** for storing events of trials to violate the SA **230** (FIG. 2) and or the GOS **215**. The content of the MOS log module **420** may be used by MMDM **430** in order to decide on the type of action that MOS **400** has to take. Each entry in MOS LOG module **420** may include several fields.  
15 Exemplary field can be the time of the event, user's ID, type of the event, action that was taken, etc. In addition the MOS log module **420** can keep track of users of the computer that frequently try to violate the SA, problematic hours in which the trials are more frequent than the other hours etc. Based on this data MMDM may decide which policy will be used with certain user and/or time, etc.

20 The BOMSP **440** manages one or more security policies that are used by MOS **400**. MOS security policies can be stored in the hard disk **286** and be loaded to RAM **284** after power-on or reset. From time to time the security policies may be updated by the administrator of the private network **120** (Fig. 1), while the user's computer **110** is connected over the private network **120**. The updated policy may include updated  
25 information on certain user's ID that are not allowed to do certain activities, new user's, new devices, new rules, etc. After power-on or reset the integrity of the data stored in BOMSP **440** can be checked by the Boot-loader program that is stored in firmware **282** (FIG. 2). Checking the integrity can be done during loading the BOMSP **440** from the hard disk to RAM **284** (FIG. 2) by using cryptographic techniques such as but not limited  
30 to MD5, SHA-1 for calculating a hash value and comparing the calculated hash value to the one stored in the boot-loader firmware **282** (FIG. 2). In another exemplary

embodiment of the present invention one or more policies can be stored in the boot-loader firmware **282**.

Each security policy may comprise a plurality of rules that may operate to monitor and control read/write access to certain physical addresses of RAM **284** (FIG. 2). The rules  
5 within a security policy can be positive (i.e. allowances) or negative (i.e. restrictions). An exemplary rule that could exist in a security policy can be as follows: allow write access to certain addresses only if the current user is the administrator, and the current time is within a certain period (working hours, for example), if not reboot the machine. Another exemplary policy may define time intervals for triggering the ICM **450** to start an  
10 integrity test on the memory addressing space **220** and **230**, which are associated with SA **230** or GOS **215**, etc. For example, during the working period (8:00 am to 8:00 pm the time interval can be every five minutes, between 8:00 pm to 8:00 am the time interval can be shorter, one minute for example, etc.

From time to time, the stored content of the BOMSP **440** in the hard disk **286** (FIG. 2)  
15 can be checked and updated manually by the administrator of network **120** or automatically by the security server **130** (Fig. 1). From time to time, the MMDM **430** may perform an integrity check by using cryptographic technique, for example. The cryptographic technique can be such as but not limited to MD5, SHA-1 for calculating a hash value. The cryptographic algorithm may compare the calculated hash value to a  
20 stored hash value in the boot-loader firmware **282** and has been loaded by the boot-loader to a memory address in space **520** (FIG. 5). If the BOMSP **440** has been damaged or otherwise altered, the MMDM **430** may reboot the machine.

The MOS manager and decision maker (MMDM) **430** manages the operation of MOS **400**. It can be initiated at the end of one of the earlier stages of the boot-loader process.  
25 After initiation MMDM **430** may proceed with the bootstrap process and start loading the GOS **215** (FIG. 2) and the SA **230** (FIG. 2). The MMDM **430** may start a setup mode. During set up mode ICM **450** can be triggered to check the integrity of the program stored in the memory addressing space **530** (FIG. 5) in the physical pages that have been allocated to the SA **230** (FIG. 2).

30 In other embodiments of the present invention the integrity of the entire memory space **530** is checked. If the response is positive then MMDM **430** may instruct MMU **281** to

set break-point in selected memory pages that are relevant to the security agent **230** or certain device driver **220a-c** (FIG. 2) or port driver **240a-c**; to define certain memory pages as read only pages, etc. MMDM **430** can have a timer module that can be set to invoke the MMDM to start a checking process. Setting the period of the timer is depending on a relevant security policy that matches the current time and user for example. At the end of the setup mode MMDM may invoke the GOS **215** (FIG. 2). Initiating the GOS can be done by pointing the MMU **281** to the starting address page of space **530** in FIG. 2, for example. During the operation of GOS, MMDM **430** can be invoked from time to time by an interrupt from its timer or in case of a security event by an interrupt from MMU **281**. The MMDM **430** is adapted to control the progress of MMU **281** in single step mode in order to analyze and determine the reason for the received interrupt.

The MOS communication module (MCM) **470** can be adapted to communicate with the MMU **281** (FIG. 2) in order to get status, interrupt, current virtual and/or physical address, etc. In the other direction MCM **470** may communicate the break-point locations to MMU **281**, the pages that are defined as read only pages etc.

In one exemplary embodiment of the present invention MCM **470** may be adapted to communicate with the SS **130** (FIG. 1) via network **120** (FIG. 1). In such embodiment, MCM **470** may further comprise a driver to a network interface board that is installed in the computer. On the other side, toward the GOS **215** (FIG. 2), the MCM **470** may comprise a simulator module. The simulator simulates the network interface board and communicates with the relevant port driver **240a-c** (FIG. 2) of GOS **215**. In such architecture MOS **400** and GOS **215** may have different private IP address to be used over network **120**. Using its private IP address, MOS **400** can communicate with the SS **130**.

ICM **450** is adapted to check the integrity of the data stored in the memory addressing space **530** (FIG. 5) of RAM **286**. An exemplary ICM **450** may use a cryptographic technique such as but not limited to MD5, SHA-1 for calculating a hash value of the data stored in the memory pages in space **530** that have been allocated to the SA **230** (FIG. 2) and compare the calculated value with a stored hash. The stored hash value can be stored in the boot-loader firmware **282**. Other exemplary embodiment of the present invention may use other methods for verifying the integrity of SA **230**. For example, a checksum

method can be used to check changes in the stored information. In such an example the result of the checksum value can be stored in advanced in boot-loader firmware.

Other exemplary embodiment of the present invention may use code signing or digital certification process. The security agent can be signed by its vendor using a private key. The public key of the certification can be stored in boot-loader firmware **282** (FIG. 2). The public key can be used by the ICM **450** in order to validate the security agent code.

Yet in an alternate embodiment of the present invention, signing the code of the security agent can be done by a certificate that is signed by a certificate authority. Exemplary certificate authorities can be such as but not limited to Versign INC. Thawte Inc., etc. In such an embodiment of the present invention the public key of the certificate authority is stored in the boot-loader firmware and be retrieved and used by ICM **450** in order to validate the security agent code.

The integrity of GOS **215** can be verified by checking the operating system configuration files whether the registered service and/or drivers are the correct ones. For example, if GOS **215** is Windows™ (Microsoft) operating system then the configuration file is the Registry. The Registry includes information on the appropriate drivers and filters that are currently in use. This information can be compared to the one that is written in the appropriate security policy in BOMSP **440**. More information on the operation of MOS **400** is depicted below in conjunction with FIG. 6 and FIG. 8.

FIG. 5 illustrates an exemplary system memory map **500** pointing the physical memory addresses of the program that is used by computer system **200** (FIG. 2). The map covers the memory addresses that are located in the boot-loader firmware **282** (FIG. 2) and in RAM **284**. In the example of FIG. 5 a low address space portion **510** is occupied by the contents of the boot-loader firmware **282** (FIG. 2). The remainder of the address space can be associated with RAM **284**. Addressing space **520** is allocated to MOS **260** (FIG. 2) and addressing space **530** is allocated to GOS **215** (FIG. 2). Addressing space **530** includes memory pages that are allocated to the SA **230**. In an alternate exemplary embodiment of the present invention memory space **520**, which is allocated to MOS **260**, may reside in boot-loader firmware **282** and not in RAM **284**.

Fig. 6 illustrates a flowchart depicting relevant steps of an exemplary method **600**. Method **600** may be initiated **602** by CPU **280** (FIG. 2) after power-on and/or reset when

the instruction pointer register of CPU **280** is reset and the CPU starts executing the code that is located in the lowest memory addressing space **510** (FIG. 5) for initiating the bootstrap process. Method **600** is implemented in addition to a common operation of a boot-loader program, which is adapted to be used in the computer system **200** (FIG. 2) having GOS **215** as the operating system of the computer **200**. The common operation of a boot-loader program may include processes like: loading the appropriate hard-disk driver, loading the keyboard driver, loading the mouse driver, loading the appropriate sectors from the hard-disk, etc.

In one exemplary embodiment of the present invention the process **600** can be embedded in the boot-loader firmware **282** (FIG. 2). In an alternate exemplary embodiment of the present invention the additional process **600** can be embedded in the MOS **260** (FIG. 2) and be stored in the hard disk **286** (FIG. 2) in appropriate sectors that are associated with the bootstrap process. Yet in another exemplary embodiment of the present invention the earlier portion of method **600**, which is implemented during loading of the MOS, can be stored in the boot-loader firmware **282**. The later stage of the process **600**, which is implemented during loading of the GOS **215** (FIG. 2), can be implemented by the MOS **260**. (FIG. 2). In the above exemplary embodiments of the present invention the common bootstrap process that is implemented by the GOS **215** may remain as is. Yet in an alternate exemplary embodiment of the present invention the boot-loader section of GOS **215** may be modified to include some of the functionalities of method **600**.

At step **604** an Operating System Counter (OS CNT) and a list of program are reset. The OS CNT indicated which operating system is currently loaded. The list of program codes will be used for determining whether program codes that are relevant to the security of the network **120** (FIG. 1) were loaded. Method **600** may gather parameters that are needed for the integrity check. Exemplary parameters can be the physical location of the different blocks of code of SA **230** and/or GOS **215** (FIG. 2) in RAM **284** (FIG. 2); verification parameters, etc. The verification parameters depend on the method that is used for verifying the integrity of the program code, as it is disclosed below. Those parameters may include one or more of the following parameters, public key, hash values, checksum values, names of block of codes, sizes, etc. At step **606** CPU **280** is instructed to fetch the next block of program code from the hard-disk **286** (FIG. 2). At this stage of

the bootstrap process, the next program code belongs to the MOS. Then an integrity checking process **608** can be initiated for verifying the validity of the fetched code.

5 The verification process **608** can be implemented by using a cryptographic technique such as but not limited to MD5, SHA-1, for example, for calculating a hash value for the fetched block codes and compares the calculated hash to a stored predefined one. The predefined hash can be calculated by the SS **130** (FIG. 1) or by the software vendor and be stored at the boot-loader firmware **282** (FIG. 2). In one exemplary embodiment of the present invention a signing method can be used. The signing method can use a public key cryptographic algorithm. Signing a block of program code can be done by the vendor of  
10 the code by using the private key and the authentication is done by using a public key. The public key can be stored in firmware **282** (FIG. 2) by the administrator of network **120**.

Yet another exemplary verification method can be used by other exemplary embodiment of the present invention, for example checking the size of each block of code and compare it to a stored size, etc. The stored size can be calculated by SS **130** (FIG. 1)  
15 during loading the MOS **260**, SA **230** and GOS **215** to the hard-disk **286** of computer system **200** (FIG. 2). The size, a list of names, and sizes can be stored by SS **130** in the boot-loader firmware **282** (FIG. 2) as verification parameters.

In another exemplary embodiment of the present invention step **608** and step **610** can be  
20 adapted to check the integrity of a block of program code that belongs to MOS **260** only. In such embodiment the validity of SA **230** and the integrity of the GOS can be checked by MOS **260** during on going operation of the system.

At the end of the authentication process a decision is made **610** whether the block of data is valid. If **610** not, an error message can be displayed **636** on a display that is associated  
25 to computer system **200** (FIG. 2) and method **600** stops the boot-loader process and may ask the user to reboot the computer. Alternatively or in addition a request for the password of the network administrator may be displayed. If **610** the block of code is valid, then method **600** proceed to step **612**.

At step **612** the block of program code is stored in RAM **284** (FIG. 2). It can be stored in  
30 addressing space: **520** (FIG 5) for a block that belongs to MOS **260** or in addressing space **530** (FIG. 5) for a block of code that belongs to SA **230** or GOS **215**. Then a page table

can be updated accordingly. Information on this block of program code is stored **614** in a list of program codes. The list of program codes can include information on the type of the block of code (a MOS, SA, driver, etc...), size, hash number (if exist), checksum value (if exist), virtual pages, physical pages, in which the block is stored in RAM **284** (FIG. 2),  
5 etc. The existence of the hash number and/or the checksum value depends on the method that is used for authenticating the integrity of the SA **230** and/or the GOS **215**. The list can be stored in address space **520** that is associated by MOS **260**. This information can be used by MOS **260** for checking the integrity of the SA **230** and/or the GOS **215** during the operation of computer system.

10 At step **620** a decision is made whether additional blocks of program code exist in the hard-disk. If **620** yes, method **600** return to step **604** for fetching the next block from the hard-disk **286** (FIG. 2). If **620** there are no additional blocks of program code to be fetched from the hard-disk **286**, then the list of program codes can be compared to a list of required blocks of code. The list of required blocks of code can be stored in boot-loader  
15 firmware **282** by the administrator of network **120** (FIG. 1). The list can define mandatory blocks of code, which belong to MOS **260**, SA **230** or GOS **215** (FIG. 2) and are mandatory from the security of network **120** (FIG. 1). Any missing block can affect the safety of the organization.

If **630** the list of program codes is not completed and does not include all the program  
20 blocks that are mentioned in the list of required blocks of code. Then an error message can be displayed **636** on a display that is associated to computer system **200** (FIG. 2) and method **600** can stop the boot-loader process.

If **630** the list of program codes is completed, then the value of the OS CNT is checked  
25 **640**. If the value of the OS CNT is zero, indicating that the bootstrap process loads the MOS **260** (FIG. 2). Then, the MOS process can be initiated **642**, OS CNT is set to one and the MOS return to step **606** to continue the bootstrap process for loading blocks of program codes that belong to the GOS **215** (FIG. 2) from the hard-disk **286**. Those codes are stored in memory section **530** (FIG. 5) of RAM **281** (FIG. 2). Initiating the MOS can be done by setting the instruction pointer register of the CPU **280** (FIG. 2) to the first  
30 address of memory section **520** (FIG. 5).

If **640** the value of the OS CNT is other than zero, which indicates that the bootstrap process loads the GOS and the GOS can be initiated, then **644** a timer that is associated with MOS **260** (FIG. 2) is initiated. The timer period can be in the range of few seconds to few minutes. Then, GOS **215** (FIG. 2) is initiated, the instruction pointer register of CPU **280** (FIG. 2) is loaded with the address of first page in addressing space **530** (FIG. 5). The MOS boot-loader task is terminating **650** and the interrupt system of CPU **280** is allowed. The GOS **215** and MOS **260** (FIG. 2) start their ongoing operation. In one exemplary embodiment of the present invention process **644** may further include updating the MMU **281** (FIG. 2) with the relevant protected pages (zones) in RAM **284** that are associated with the MOS, SA and GOS. Some of those pages can be defined as read only pages; break-points can be associated with other protected pages such as pages that are relevant to the security agent **230** or certain device driver **220a-c** (FIG. 2) or port driver **240a-c**. In another exemplary embodiment of the present invention the boot-loader program, during process **632** (FIG. 6) may update the MMU **281** with the protected zones.

Fig. 7 illustrates a flowchart depicting relevant steps of an exemplary method **700**. Method **700** may be used by SA **230** (FIG. 2) in order to associated the content of the hard-disk **286** (FIG. 2) with the operation of the SA **230**. Process **700** may use encryption/decryption method for associating the SA **230** and the content of the hard-disk **286**. Method **700** can be initiated in each read/write cycle to the hard-disk **286**, after the SA determined that the request is allowed according to a current used security policy. The encryption/decryption method that is used by process 700 can be one of common encryption/decryption methods that are known to those skilled in the art. Exemplary encryption/decryption methods may include private key methods or symmetrical key methods. Exemplary encryption/decryption algorithm may include: RSA, AES, DES, 3DES, and RC4.

At step **710** a decision is made whether the cycle is a read cycle. If yes, then the private key is retrieved **712** from its location in memory addressing space **530** (FIG. 5) that is associated to the SA **230**. The private key was stored during the boot-loader program. In case of using symmetrical key encryption algorithm then the private key is replaced by the symmetrical key.



At step 714 the retrieved block of data from the hard-disk 286 is decrypted using the retrieved key and according to the encryption/decryption algorithm that is used in process 700. The decrypted block of data is transferred 716 via the hard-disk device driver 220 (FIG. 2) toward an application program 210a-c (FIG. 2) that initiated the read command.  
5 Then process 700 is terminating 730.

Returning now to step 710 in which a decision is made whether the cycle is a read cycle. If no, which means that it is a write cycle to the hard-disk 286 (FIG. 2), then the public key is retrieved 722 from its location in memory addressing space 530 (FIG. 5) that is associated to the SA 230. The public key was stored during the boot-loader program. In  
10 case of using symmetrical key encryption algorithm then the public key is replaced by the symmetrical key.

At step 724 the block of data that has to be stored in the hard-disk 286 is encrypted using the retrieved key and according to the encryption/decryption algorithm that is used in process 700. The encrypted block of data is transferred 726 via the appropriate port driver  
15 220 (FIG. 2) toward the hard-disk 286 (FIG. 2) and process 700 is terminating 730. The appropriate port driver 240 depends on the physical port to which the hard-disk is connected. Exemplary port drivers can be USB, SCSI port driver, for example.

Other exemplary embodiment of the present invention may use other methods for associating the content of the hard-disk 286 (FIG. 2) to the operation of the SA 230 (FIG.  
20 2). One exemplary method may encrypt/decrypt the directory of the hard-disk 284 and not the entire content. In such embodiment of the present invention method 700 can be adapted to encrypt/decrypt just the read/write cycles to the directory of the hard-disk 286.

An alternate exemplary embodiment of the present invention may associate the content of the hard-disk with a virtual user and any allow read/write access to the hard-disk only to  
25 the virtual user. In such a case every access to hard-disk 286 (FIG. 2) may be followed by a request for the virtual user name and password. The SA 230 can be adapted to emulate the virtual user and to respond to the requests by delivering a name and a password that were stored in the boot-loader firmware 282 during stamping the firmware by the SS 130 (FIG. 1). Those values can be stored during the boot-loader program in the memory  
30 addressing space that is associated with the SA.

In such an embodiment of the present invention method **700** can be modified. Step **724** can be modified to calculate a hash value to be associated with the current block of data and to be stored with it in the hard-disk. Step **714** can be modified to authenticate the virtual user (SA **230**) name and password by calculating a hash value for each block of data that is currently read and comparing it to the stored associated hash number that was  
5 calculated during the writing cycle of the same block of data.

Fig. 8 illustrates a flowchart depicting relevant steps of an exemplary method **800**. Method **800** can be used by an exemplary embodiment of MOS **260** (FIG. 2) for checking the integrity of the SA **230** program code with or without the integrity of the GOS **215** (FIG. 2) during the ongoing operation of the computer system **200** (FIG. 2). Method **800**  
10 can be initiated **802** at the end of method **6000** when the interrupt system of the CPU **280** (FIG.2) is allowed.

After initiation, method **800** may wait **804** for an interrupt. During the boot-loader program the CPU **280** (FIG. 2) can be set to response to an interrupt by setting the instruction pointer register of the CPU to the appropriate physical address of the program code of method **800** in memory addressing space **520** (FIG. 5). When an interrupt is received, a decision is made **810** whether the interrupt was sent by a timer that was set in  
15 step **644** (FIG. 6). If yes, then the integrity of the SA and the GOS is checked, steps **812**, **814**, **816** and **818**. Checking the integrity of the SA and the GOS code (step **812** and **816** respectively) that is stored in RAM **284** (FIG. 2) memory section **530** (FIG. 5) can be  
20 done by using similar methods to the ones that is depicted above in conjunction with FIG. 6 steps **608**.

If both modules, the SA **230** and the GOS **215** are valid (step **814** and **818** respectively), then the timer is reset **819** and method **800** returns to step **802** waiting for the next interrupt. If one of those modules is not valid (step **812** and **816**), then an error message  
25 can be displayed **832** on the display that is associated to computer system **200** (FIG. 2) and method **800** may reset or stop the computer **200** (FIG. 2).

If **810** the interrupt was not sent from the timer, then a decision is made **820** whether the interrupt was initiated as an indication to an access to one of the protected zones in  
30 memory addressing space **520** and/or **530** (FIG. 5). The protect zones may include pages that are associated with the SA **230**, MOS **260**, and GOS **215** (FIG. 2) etc. If **820**, the

interrupt is not a result of accessing to one of the protected zones, then the interrupt is transferred to GOS to be processed **822** and method **800** returns to step **804** waiting for the next interrupt.

5 If **820** the interrupt was initiated due to a trial to access one of the protected pages, then an authorization process **824** can be initiated. During the authorization process **824** a single step mode can be used via MMU **281** and controlled by method **800** in order to determine whether the access is legal. The decision can be based on the current policy, from the BOMSP **440** (FIG. 4) that is used by MMDM **430** (FIG. 4). Following are few examples of the authorization process. Example 1: the interrupt was initiated during a trial  
10 to access a page that is associated with MOS **260** (a page in addressing space **520** FIG. 5). Then, the access will be authorized only if the current user is the administrator of the network **120** (FIG. 1). Example 2: the interrupt was initiated during a trial to write a new device driver into a page that is associated with the configuration file of GOS **215** (a page that is associated the registry of GOS in addressing space **530** FIG. 5, for example). The  
15 access will be authorized only if device driver can be authenticated and is allowed by the current policy. Example 3: the interrupt was initiated during a trial to write into a page that is associated with the protected file of GOS **215**. However the access was done by the security agent code therefore the access will be authorized, etc.

At the end of the authorization process a decision is made **830** whether to authorize the  
20 request to access the protected zone, if not an error message can be displayed **832** on the display that is associated to computer system **200** (FIG. 2) and method **800** may reset or stop the computer. If **830** yes, then the interrupt is transferred to GOS to be processed **834** and method **800** returns to step **804** waiting for the next interrupt.

In this application, the words “unit”, “task”, and “module” may be used interchangeably.  
25 Anything designated as a unit or module may be a stand-alone unit or a specialized or integrated module. A unit or a module may be modular or have modular aspects allowing it to be easily removed and replaced with another similar unit or module. Each unit or module may be any one of, or any combination of, software, hardware, and/or firmware.

In the description and claims of the present disclosure, each of the verbs, “comprise”,  
30 “include”, “have”, and conjugates thereof, are used to indicate that the object or objects of

the verb are not necessarily a complete listing of members, components, elements or parts of the subject or subjects of the verb.

It will be appreciated that the above described methods may be varied in many ways, including, changing the order of steps, and the exact implementation used. It should also  
5 be appreciated that the above described description of methods and apparatus are to be interpreted as including apparatus for carrying out the methods and methods of using the apparatus.

The described embodiments comprise different features, not all of which are required in all embodiments of the invention. Some embodiments of the present invention utilize  
10 only some of the features or possible combinations of the features. Different combinations of features noted in the described embodiments will occur to persons skilled in the art. The scope of the invention is limited only by the following claims.

## CLAIMS

What is claimed is:

1. A method for enforcing the operation of a security program in a computer device, the method comprising:
  - associating a boot-loader firmware with the security program; and
  - associating the security program with data stored in a hard-disk, said security program associated with the computer device.
2. The method of claim 1, wherein associating the security program with data stored in the hard-disk comprising:
  - encrypting data prior to storage on the hard-disk; and
  - decrypting data after retrieval from the hard disk, wherein encrypting and decrypting are performed by the security program.
3. The method of claim 2, wherein associating the boot-loader firmware with the security program comprises:
  - storing in the boot-loader firmware at least one parameter required for associating the security program with data stored in the hard-disk; and
  - loading the at least one parameter to the security program during execution of the boot-loader program.
4. The method of claim 3, wherein the at least one parameter comprises a key used in encryption and/or decryption of the data.
5. The method of claim 1, further comprising:
  - loading a mini operating system (MOS) during a boot-loader process; and
  - initiating the MOS.
6. The method of claim 5, further comprising verifying integrity of the MOS.
7. The method of claim 1 or claim 5, further comprising loading a guest operating system (GOS).
8. The method of claim 7, further comprising verifying integrity of the GOS.
9. The method of claim 1 or claim 5, further comprising loading the security program.

10. The method of claim 9, further comprising verifying integrity of the security program.
11. The method of claim 9, further comprising adapting the MOS to verify the integrity of the security program.
12. The method of claim 5, wherein said the MOS is adapted to communicate with a security server.
13. The method of claim 5, wherein the MOS is adapted to protect integrity of the security program while the computer device is operating.
14. A system for enforcing the operation of a security program in a computer device, the system comprises:
  - a server comprising a security module;
  - a plurality of computer devices coupled to the server through a network, wherein each computer device comprises a boot-loader firmware and a hard disk, wherein the security module is operable to:
    - associate a security program to each one of the computer devices, wherein the security program comprises a module which is adapted to manipulate data transferred to and from the hard disk of the computer device; and
    - store in the boot-loader firmware of each of the computer devices at least one parameter required for the data manipulation.
15. The system of claim 8, wherein manipulating the data transferred to and from the hard disk of each of the computer devices comprises encrypting the data transferred to the hard disk and decrypting the data transferred from the hard disk.
16. The system of claim 9, wherein said at least one parameter needed for the data manipulation is a encryption key and/or a decryption key.
17. The system of claim 8, wherein the security module is operable to:
  - store a mini operating system (MOS) in the hard disk of each of the computer devices, wherein the MOS comprises a module adapted to protect operation of the security program during ongoing operation of the computer device.
18. A computer device, comprising:

- a central processing unit (CPU);
- a hard disk coupled to the CPU;
- a system memory, coupled to the CPU, the system memory comprising non-volatile program memory and random access memory, the non-volatile program memory storing program instructions corresponding to a boot-loader sequence;
- a security program code loaded from the hard disk to the random access memory during execution of the boot-loader sequence, wherein the security program is adapted to manipulate data transportation to and from the hard disk using a parameter stored in the non-volatile program memory.

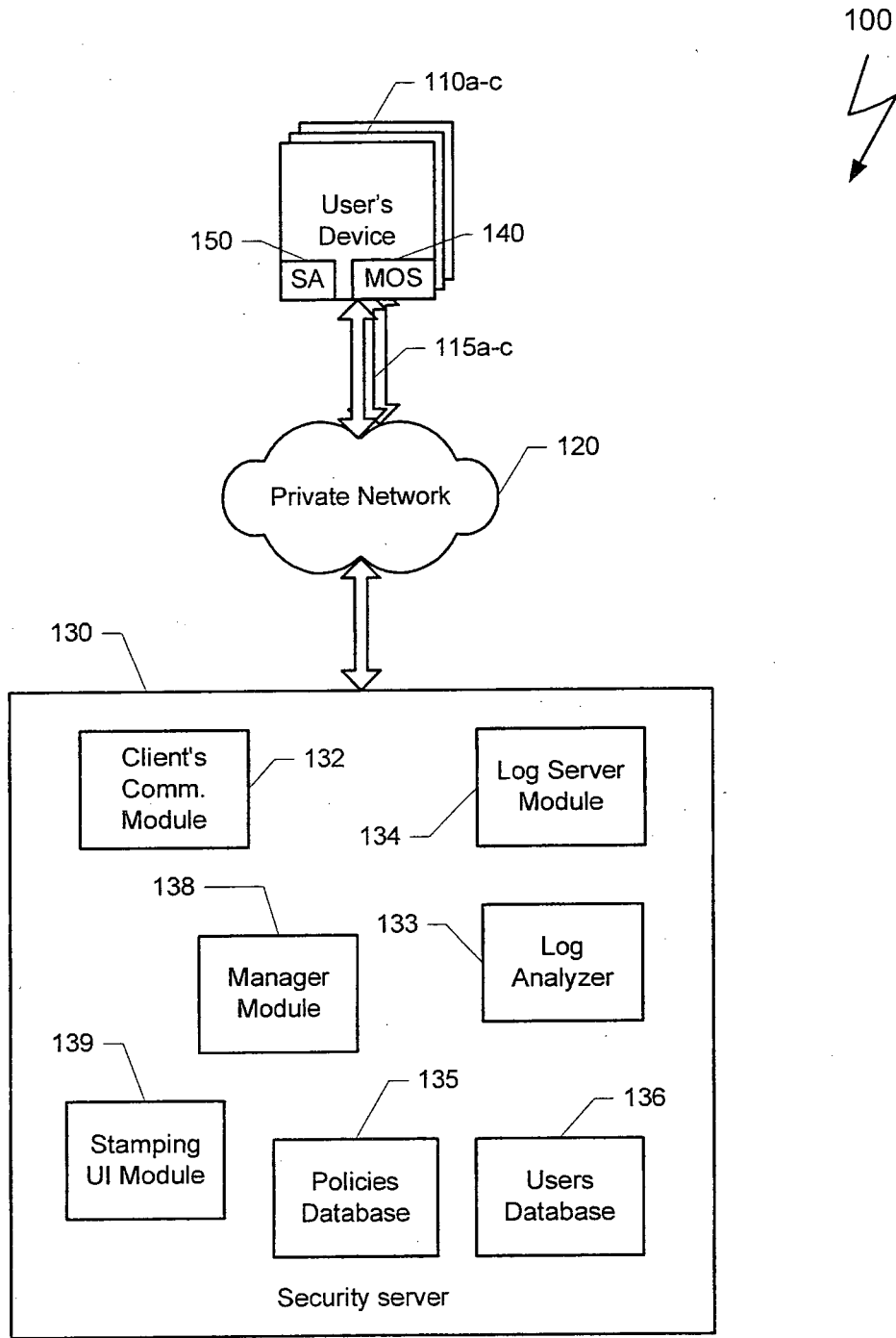


Fig. 1



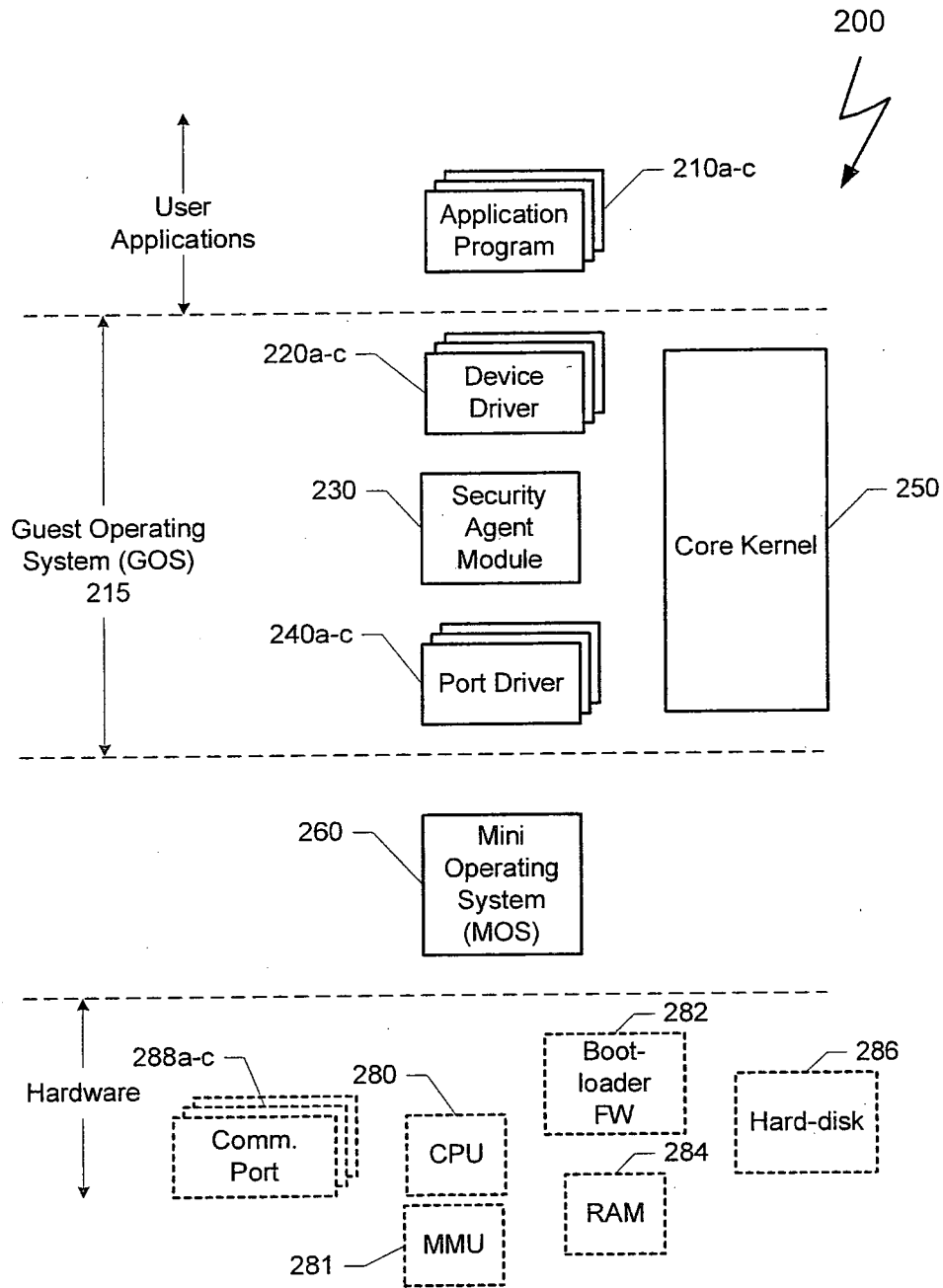


Fig. 2

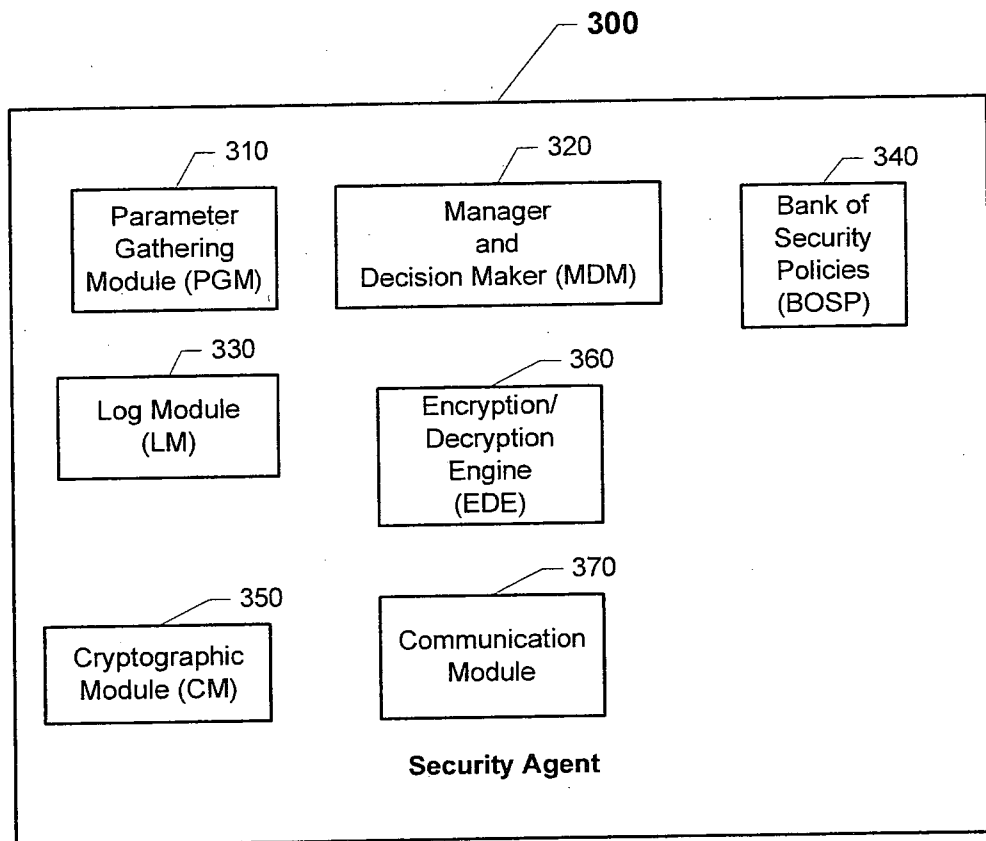


Fig. 3

400

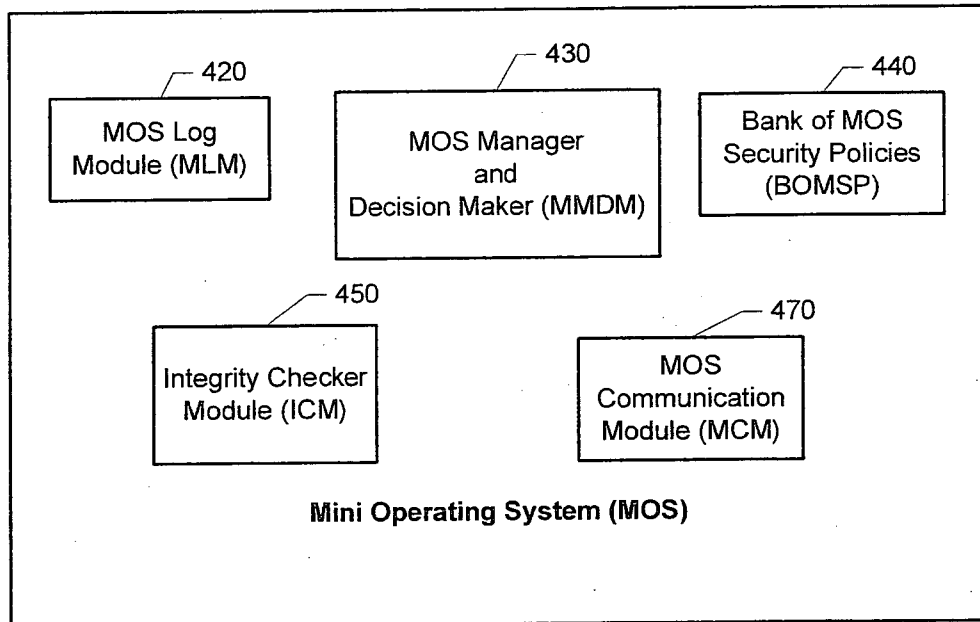


Fig. 4

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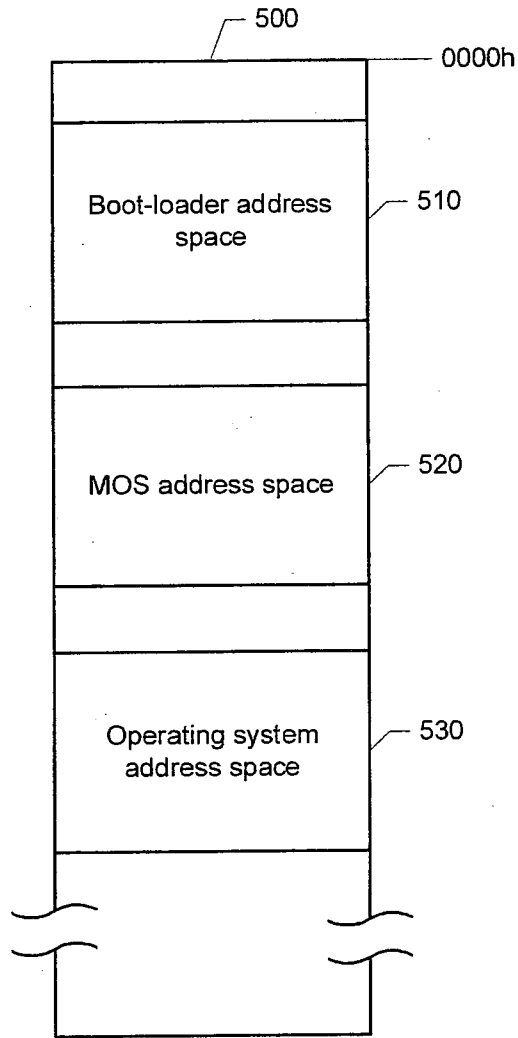


Fig. 5

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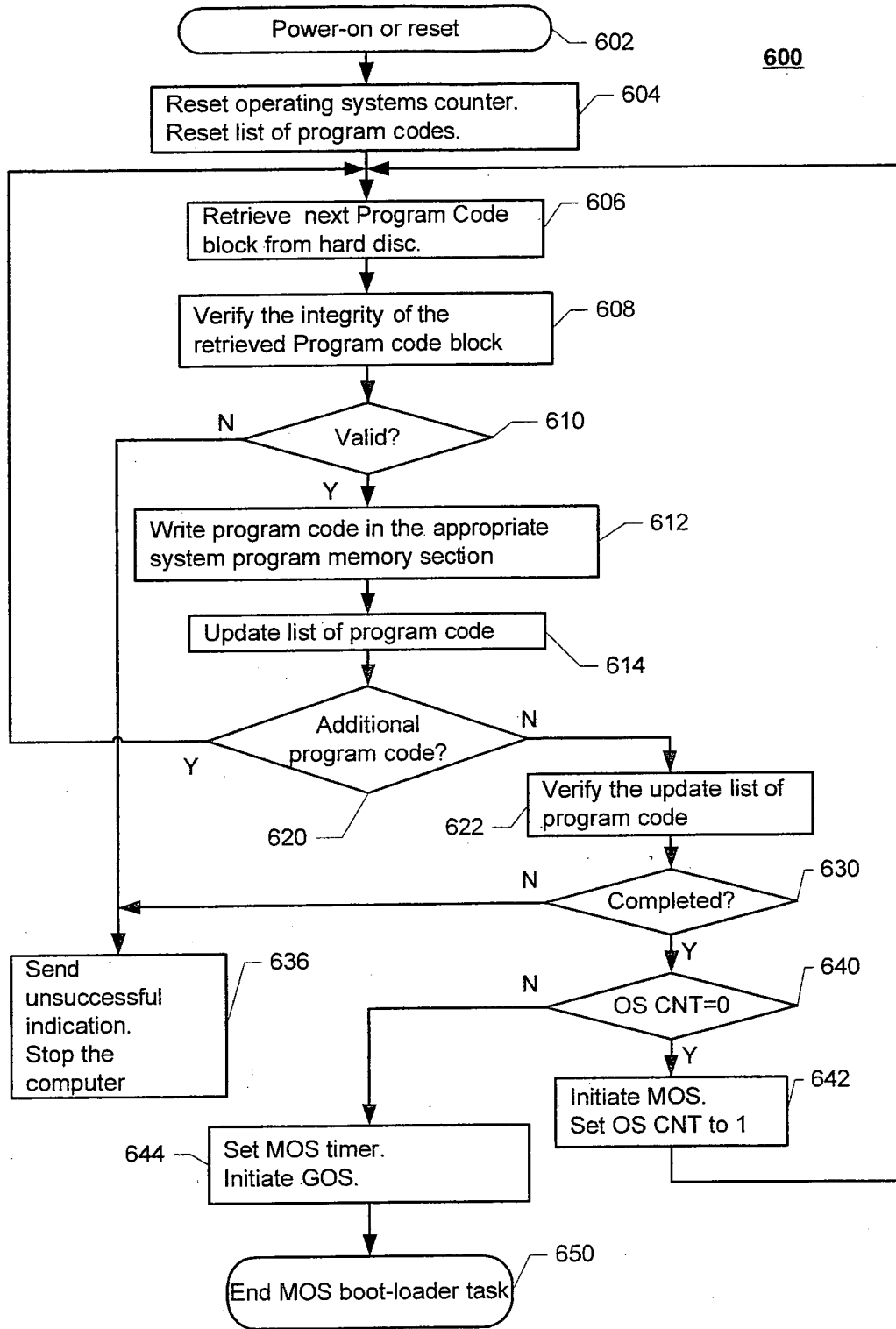


Fig. 6

700

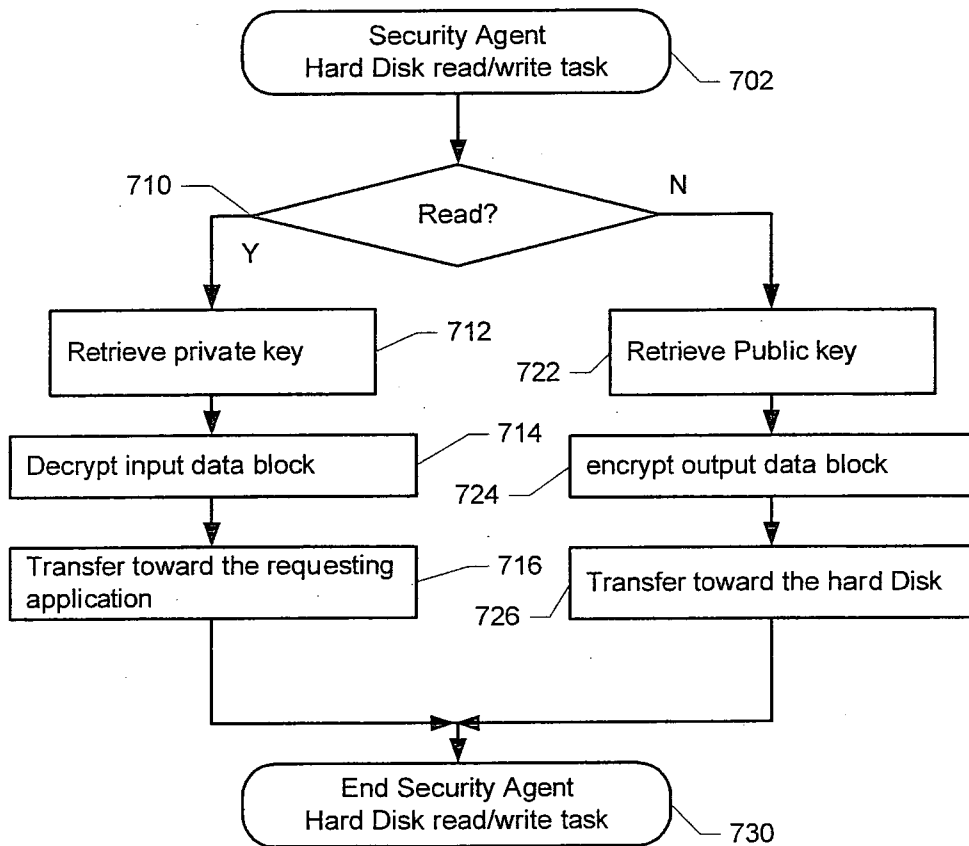


Fig. 7

800

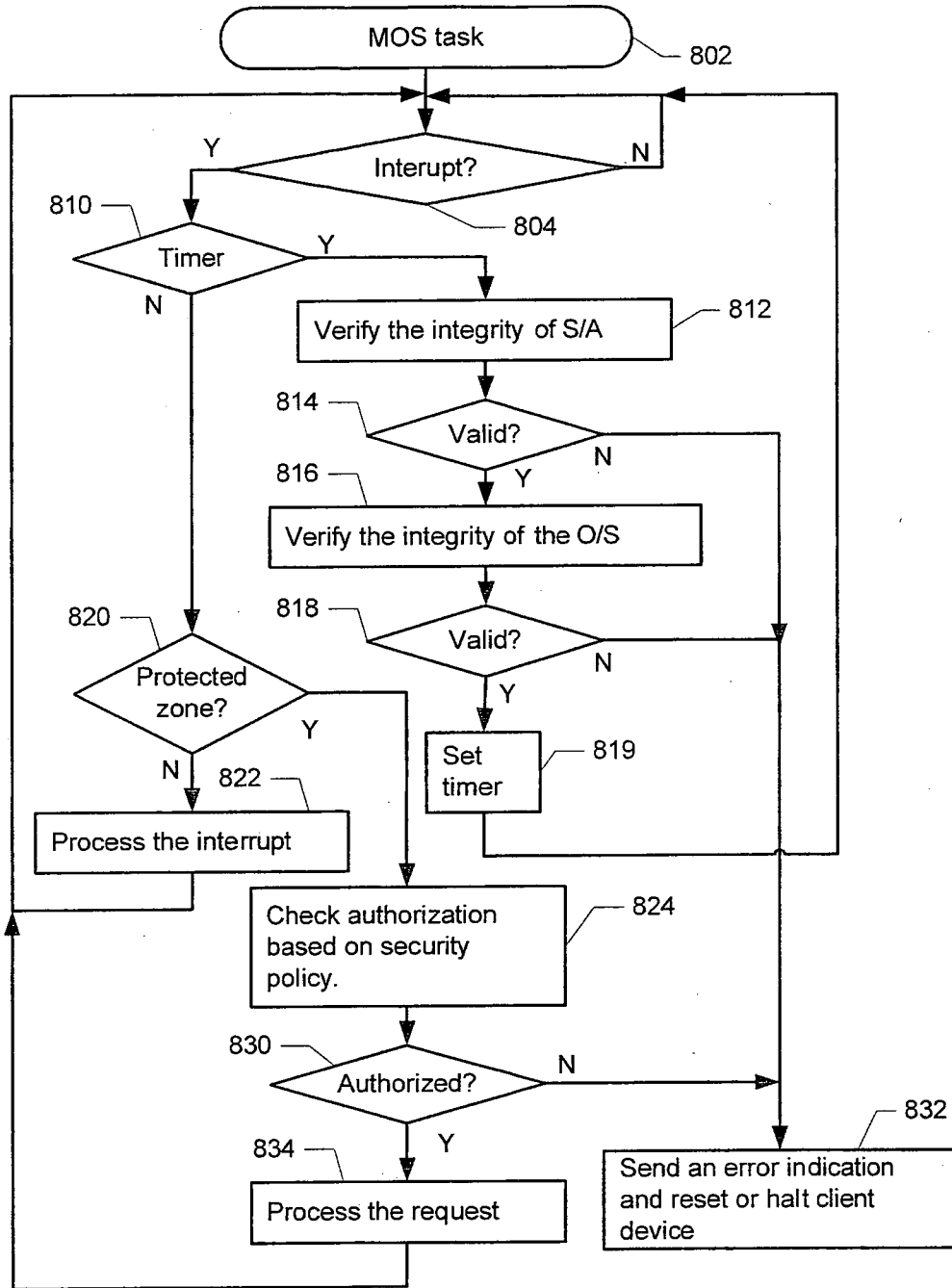


Fig. 8