US008011010B2

(12) **United States Patent**
Michael et al.

(10) **Patent No.: US 8,011,010 B2**
(45) **Date of Patent: Aug. 30, 2011**

(54) **USING ANTIMALWARE TECHNOLOGIES TO PERFORM OFFLINE SCANNING OF VIRTUAL MACHINE IMAGES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 712 days.

(21) Appl. No.: **11/736,520**

(22) Filed: **Apr. 17, 2007**

(65) **Prior Publication Data**

US 2008/0263658 A1 Oct. 23, 2008

(51) **Int. Cl.**
G06F 12/14 (2006.01)
G08B 23/00 (2006.01)

(52) **U.S. Cl.** **726/24**; 726/22

(58) **Field of Classification Search** 726/22, 726/24

See application file for complete search history.

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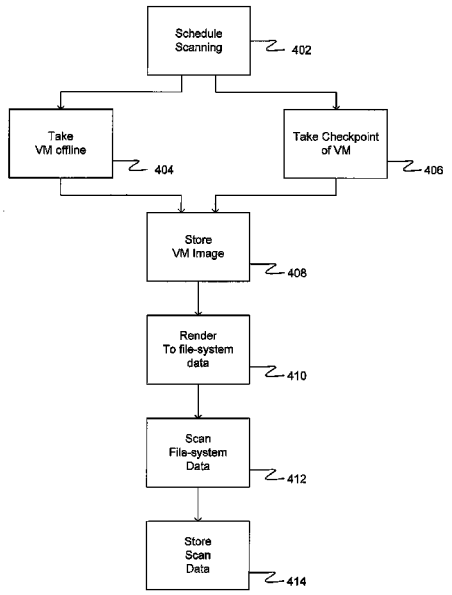
(57) **ABSTRACT**

Methods and systems for scanning a virtual machine image. The virtual machine image may be stored as a collection of one or more virtual hard disk files. The virtual machine image may be stored by taking the virtual machine off-line or may be stored by taking a checkpoint of the virtual machine while the virtual machine is on-line. The virtual machine image is rendered to file-system data. Rendering the virtual machine image to file-system data may comprise mounting the virtual machine image's virtual hard disk drives. An anti-malware engine is invoked to scan the exposed file-system data, and data indicative of the scanning may be stored.

19 Claims, 8 Drawing Sheets



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IPR2024-01109

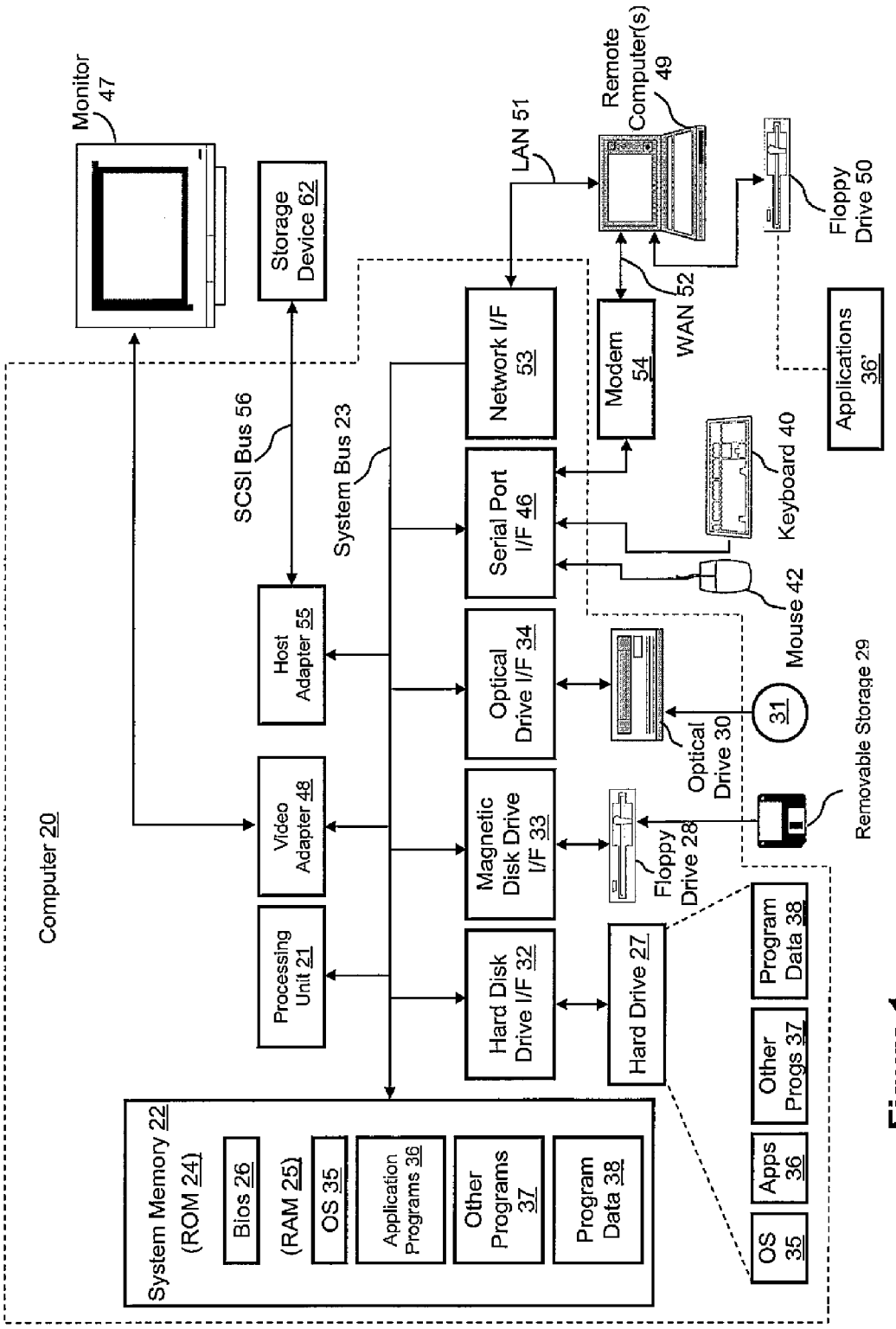
Monitor 47
Storage Device 62
LAN 51
Remote Computer(s) 49
Floppy Drive 50
Network I/F 53
Modem 54
WAN 52
Applications 36'
SCSI Bus 56
System Bus 23
Serial Port I/F 46
Keyboard 40
Mouse 42
Host Adapter 55
Optical Drive I/F 34
Optical Drive 30
31
Removable Storage 29
Video Adapter 48
Magnetic Disk Drive I/F 33
Floppy Drive 28
Computer 20
Processing Unit 21
Hard Disk Drive I/F 32
Hard Drive 27
Program Data 38
Other Progs 37
Apps 36
OS 35
System Memory 22 (ROM 24)
Bios 26
(RAM 25)
OS 35
Application Programs 36
Other Programs 37
Program Data 38

Figure 1

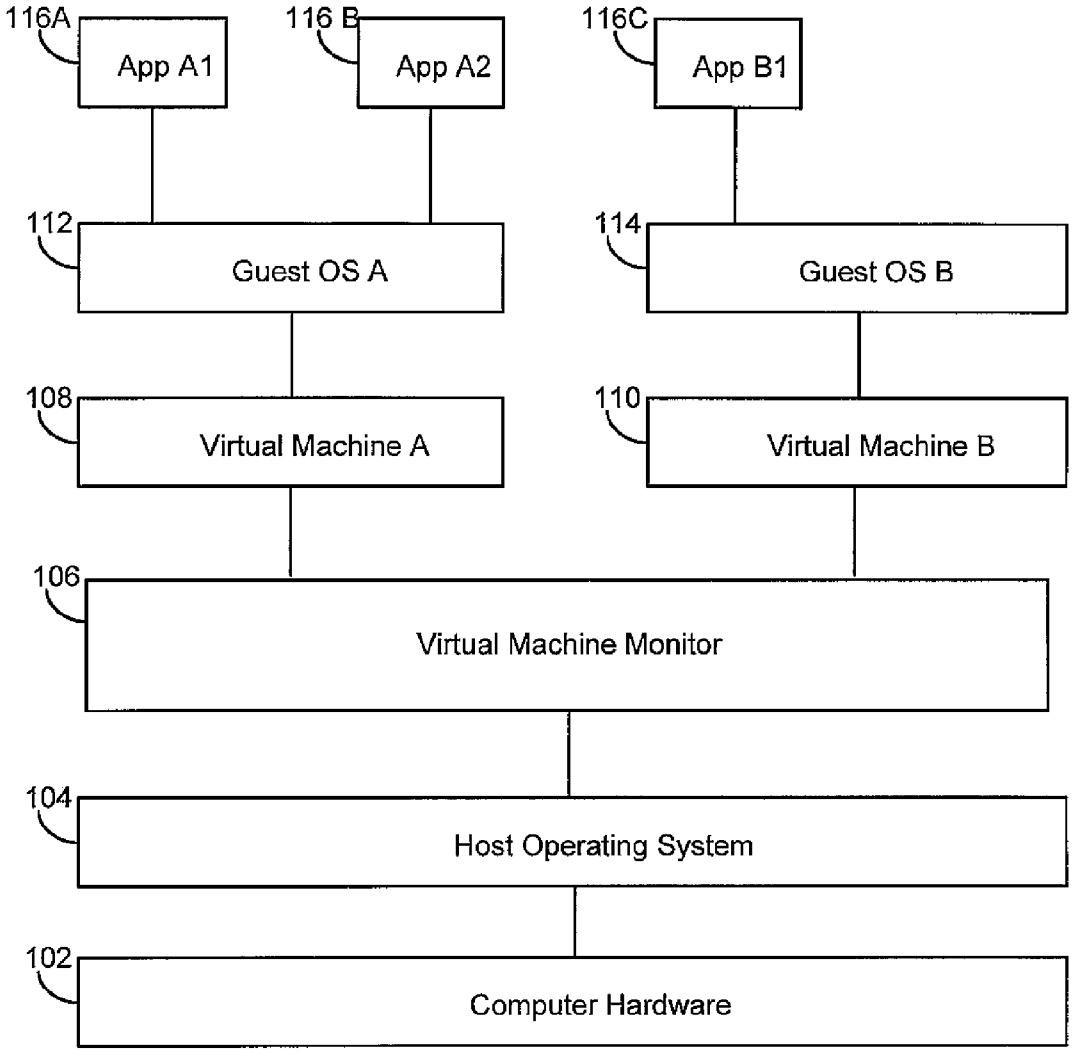
116A
App A1
116 B
App A2
116C
App B1
112
Guest OS A
114
Guest OS B
108
Virtual Machine A
110
Virtual Machine B
106
Virtual Machine Monitor
104
Host Operating System
102
Computer Hardware

Figure 2A

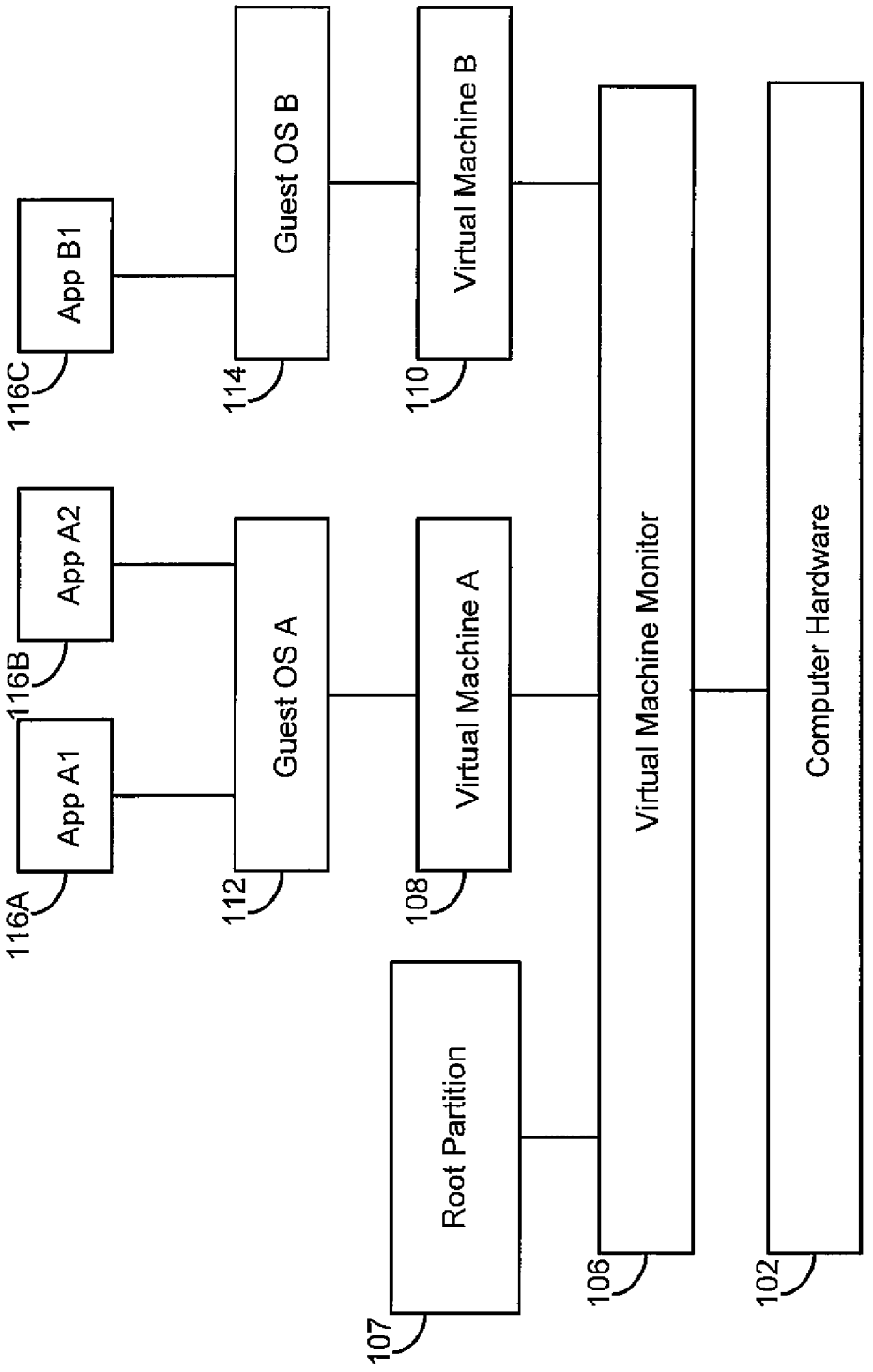
App B1
116C
Guest OS B
114
Virtual Machine B
110
App A2
116B
Guest OS A
112
Virtual Machine A
108
App A1
116A
Root Partition
107
Virtual Machine Monitor
106
Computer Hardware
102

Figure 2B

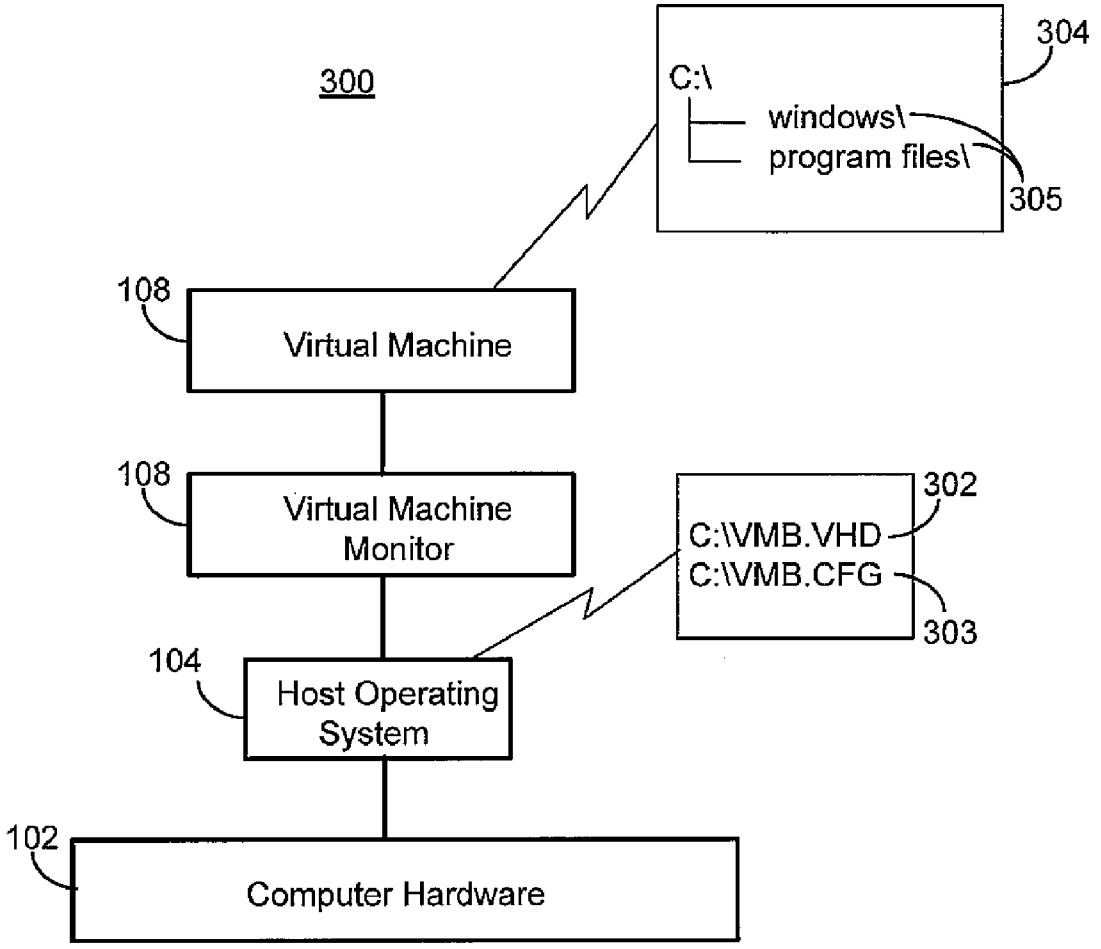
300
304
C:\
windows\
program files\
305
108
Virtual Machine
108
Virtual Machine Monitor
302
C:\VMB.VHD
C:\VMB.CFG
303
104
Host Operating System
102
Computer Hardware

Figure 3

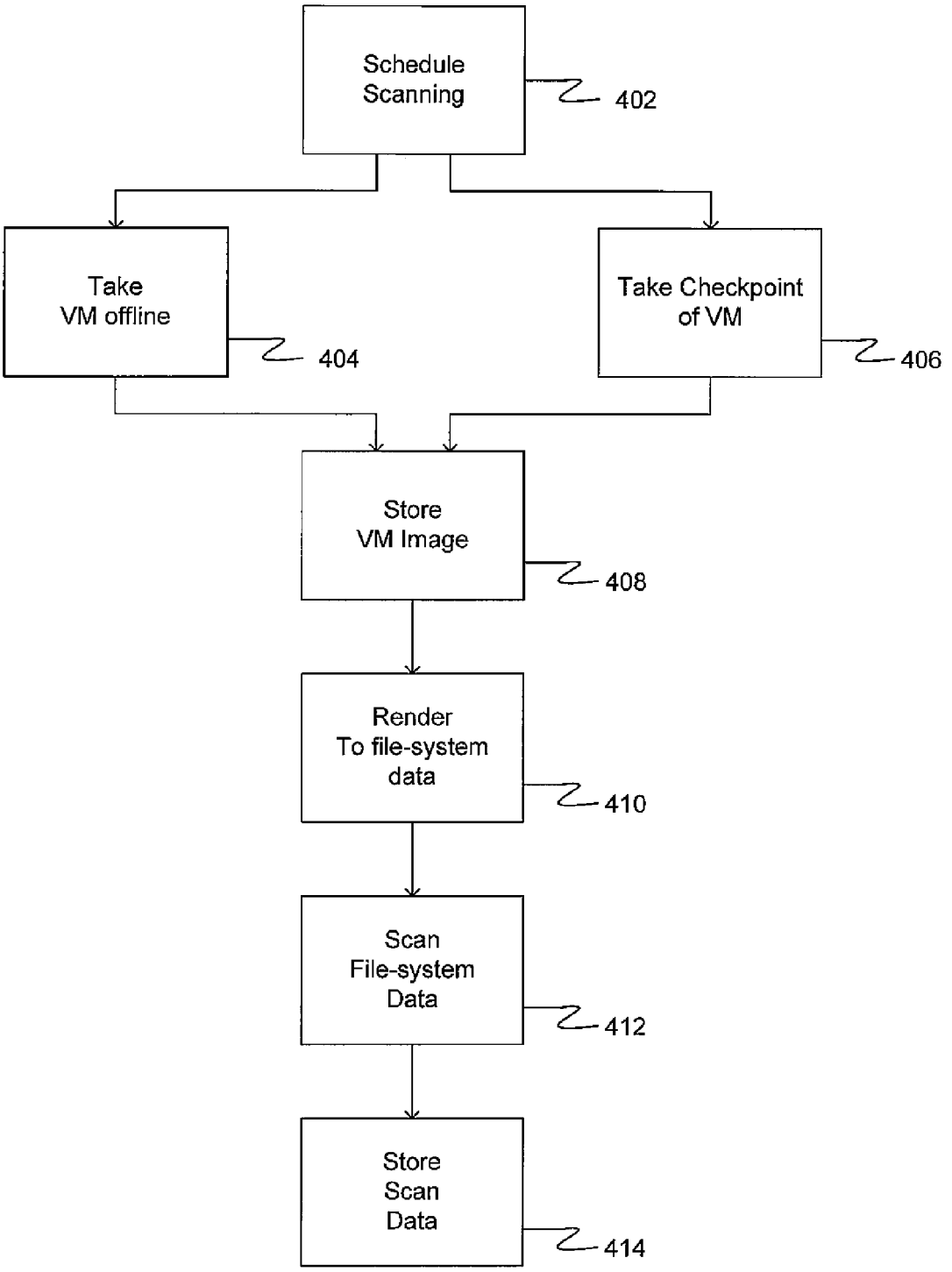
Schedule Scanning
402
Take VM offline
404
Take Checkpoint of VM
406
Store VM Image
408
Render To file-system data
410
Scan File-system Data
412
Store Scan Data
414

Figure 4

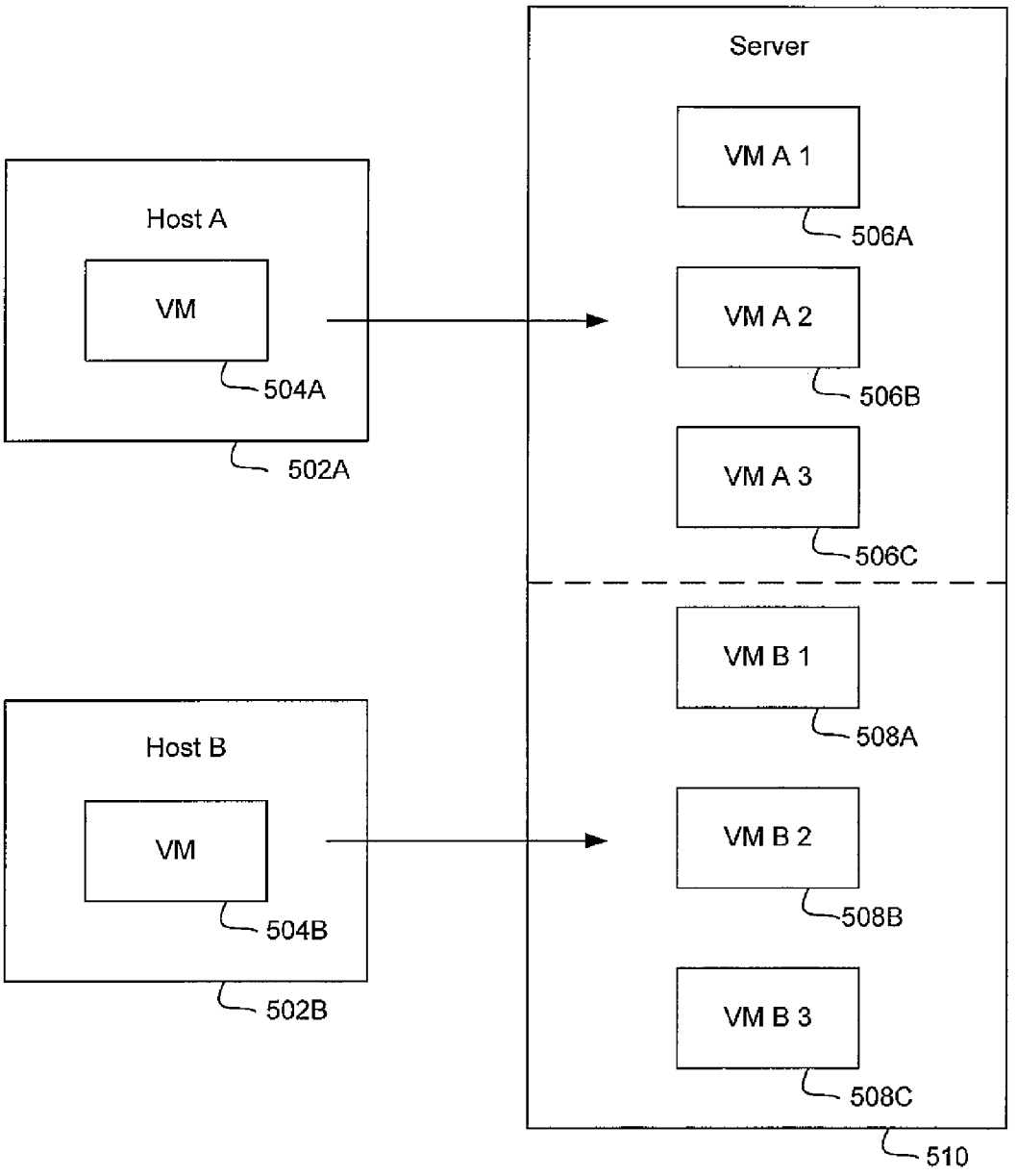
Server
VM A 1
506A
VM A 2
506B
VM A 3
506C
Host A
VM
504A
502A
VM B 1
508A
VM B 2
508B
VM B 3
508C
Host B
VM
504B
502B
510

Figure 5

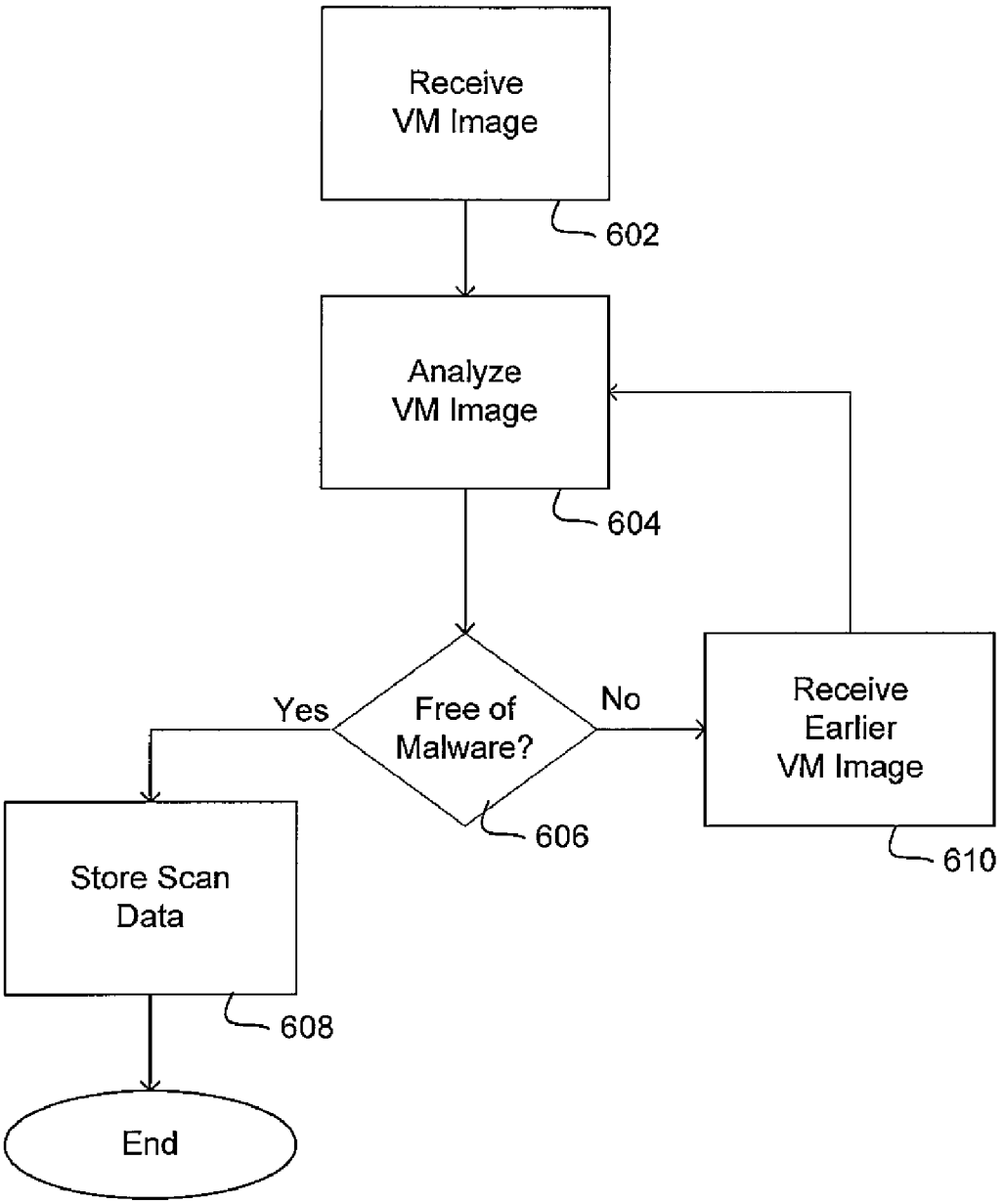
Receive VM Image
602
Analyze VM Image
604
Free of Malware?
606
Yes
No
Receive Earlier VM Image
610
Store Scan Data
608
End

Figure 6

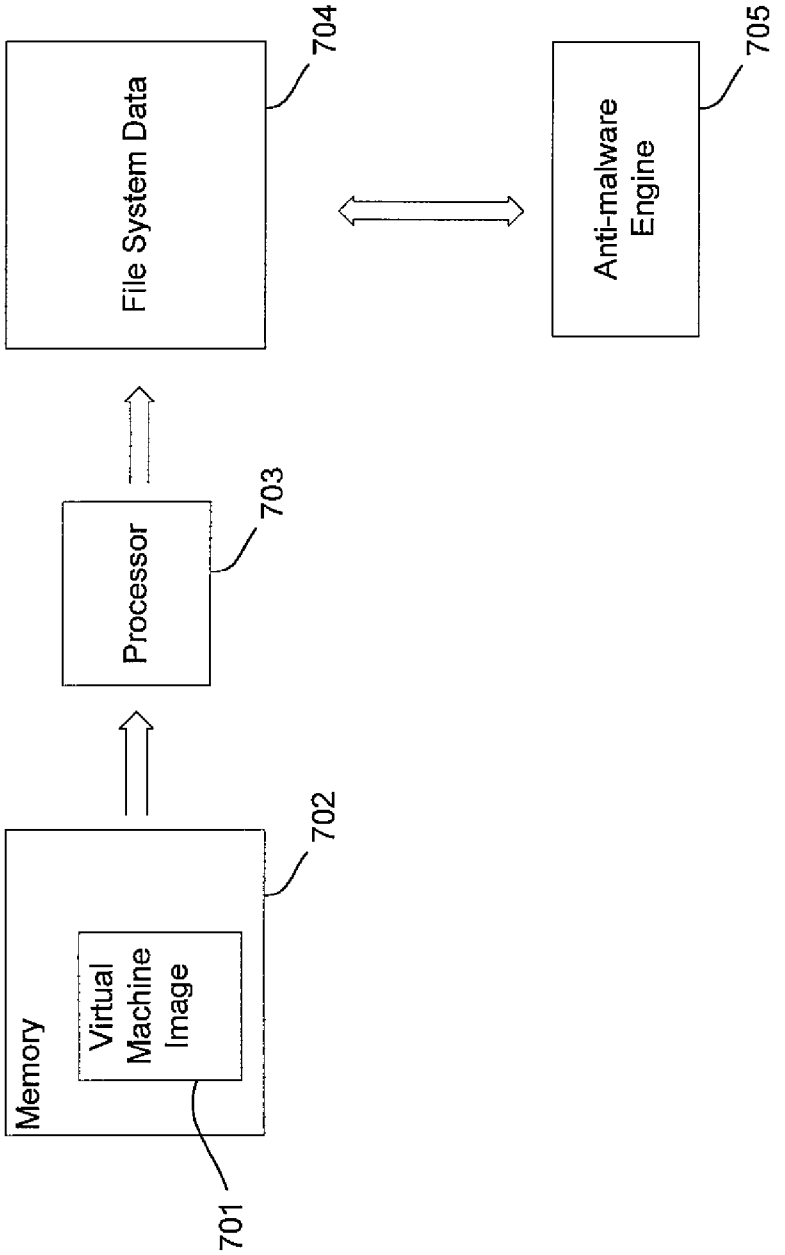
Memory
Virtual Machine Image
701
702
Processor
703
File System Data
704
Anti-malware Engine
705

Figure 7

USING ANTIMALWARE TECHNOLOGIES TO PERFORM OFFLINE SCANNING OF VIRTUAL MACHINE IMAGES

BACKGROUND

With virtual machines, a host computer may support a number of virtual machines, each representing its own execution environment. Each virtual machine may run an operating system and distinct applications. Because multiple operating environments may run on a single host, a virtual machine architecture provides a great deal of flexibility and scalability to a system administrator or computer system architect and may enhance security and reliability by effectively isolating the virtual machines from one another.

System administrators may bring virtual machines on-line and off-line faster than deploying physical computing devices. Also, virtual machines allow administrators to create, copy, modify, backup and rollback the execution state of the virtual machines faster than with physical computing devices. For example, in a server farm of web servers and e-commerce servers, the server farm may only have a fixed number of physical computing devices deployed. With virtual machines, the administrator may quickly change the ratio of web server to e-commerce servers to match demand by quickly deploying additional virtual machines within the server farm.

Virtual machine technology makes the operation of migrating from one server to another similar to that of copying and moving files. For example, suppose the virtual machine image of the web server faces increased utilization of processing and/or memory resources. If the virtual machine's host is unable to provide more resources, the virtual machine can be easily and quickly migrated to another host that can provide the additional resources needed. Such a process is often referred to as resource balancing or load balancing of virtual machines across hosts. Because this dynamic flexibility provides significant value for the user and administrator, virtual machines have seen a rapid adoption in many computing environments.

In addition, virtual machines allow for users to deploy and rapidly scale large numbers of servers. For example, depending on the hardware resources and the nature of the application, a single physical server may support tens of virtual machines, each supporting different applications. Virtual machines that don't need to be always running can be rapidly deployed or taken off-line to save resources. Along with the benefits of scalability come the challenges of management and security. With a vast number of virtual machines in a network, it becomes difficult to provide adequate protection against malicious software, also known as malware, such as computer viruses, spyware, worms, root kits and the like.

Further compounding the problem, because of the ease with which virtual machines may be brought on-line and off-line, an infestation of malware may become difficult to cure. For example, when a computer worm attacks a conventional network of computers, the worm typically infects multiple computers relatively quickly. Once the administrator identifies which machines are infected and provides the appropriate remedies, such as cleanup patches and procedures, the computers may be safe from being later infected.

However, in a virtual machine environment, virtual machines may be brought into service and brought out of service regularly. This transient topology of virtual machines makes it difficult for administrators to quickly identify and remove infected machines. Accordingly, virtual machines that are infected may be taken out of service, or off-line, before being cleaned or patched. Later, when the virtual machine is brought back into service, an infestation may be reintroduced to the network. As a result, worm and virus infections of networks of virtual machines tend to persist at a low-level indefinitely.

Traditional malware scanning technology provides the ability to scan computers for resident malware. Such software scanners are typically licensed and deployed on a per-computer-basis. Thus, an administrator may be forced to manage at least one malware application per operating environment.

With legacy scanning technology, in a virtual machine environment, the administrator may have to manage at least one malware application per virtual machine. The difficulty of such management may be exacerbated by the large number and transient nature of the virtual machines in the network. Operating an individual malware application per virtual machine may increasingly tax processing and memory resources, especially when more than one virtual machine may be deployed per physical computing device, and may incur costs for additional licensing for each antimalware agent deployed. Additionally, some malware is adept at hiding itself from antimalware programs that are running while the operating system is running.

SUMMARY

A virtual machine image may be stored as a collection of one or more virtual hard disk files (VHDs). The virtual machine image may be stored by taking the virtual machine off-line. Also, a copy of the virtual machine image may be stored by taking a snapshot or a checkpoint of the virtual machine while the virtual machine is on-line. Virtual machine images may be used to create other virtual machines as in, for example, cloning a virtual machine. The virtual machine may be rendered to file-system data comprising the virtual machine's files and system data. Rendering the virtual machine to file-system data may comprise mounting the virtual machine VHDs and exposing them as physical hard disks on the host computer. An anti-malware engine may be engaged to scan the exposed physical hard disks and their file-system data. Scanning the exposed physical hard disks is similar to, and more effective than, scanning the file-system data from within the virtual machine if an anti-malware agent were to be deployed inside the operating system. Data indicative of the scanning may be stored. For example, the data may comprise a scanning timestamp, a scanning result, and a list of infected components.

With more than one set of virtual machine VHDs, each associated with the same virtual machine, such as with a set of checkpoints associated with a virtual machine, one virtual machine image may be associated with a time more recent than others. Upon discovery of malware within a virtual machine image, successively older checkpoints can be scanned iteratively back in time, enabling the discovery of when the virtual machine became infected and allowing appropriate action to be taken with the checkpoint images. Such a process of walking backward through time in a chain of checkpoints or snapshots would identify the last virtual machine image that is safe for operation.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing summary, as well as the following detailed description of preferred embodiments, is better understood when read in conjunction with the appended drawings. For the purpose of illustrating the invention, example embodi-

ments are shown in the drawings; however, the invention is not limited to the specific methods and instrumentalities disclosed.

FIG. **1** is a block diagram representing an example operating environment;

FIGS. **2**A and **2**B depict example virtualized computing systems;

FIG. **3** depicts data in an example virtualized computing system;

FIG. **4** depicts an illustrative process for scanning a virtual machine image;

FIG. **5** depicts an example host/server architecture for virtual machine images;

FIG. **6** depicts an illustrative process for scanning a plurality of virtual machine images; and

FIG. **7** is a block diagram of an example system embodying an illustrative process.

DETAILED DESCRIPTION

The inventive subject matter is described with specificity to meet statutory requirements. However, the description itself is not intended to limit the scope of this patent. Rather, the inventor has contemplated that the claimed subject matter might also be embodied in other ways, to comprise different steps or combinations of steps similar to the ones described in this document, in conjunction with other present or future technologies. Moreover, although the term "step" may be used herein to connote different elements of methods employed, the term should not be interpreted as implying any particular order among or between various steps herein disclosed unless and except when the order of individual steps is explicitly described.

Numerous embodiments of the present invention may execute on a computer. FIG. **1** and the following discussion are intended to provide a brief general description of a suitable computing environment in which the invention may be implemented. Although not required, the invention will be described in the general context of computer executable instructions, such as program modules, being executed by a computer, such as a client workstation or a server. Generally, program modules comprise routines, programs, objects, components, data structures and the like that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the invention may be practiced with other computer system configurations, including hand held devices, multi processor systems, microprocessor based or programmable consumer electronics, network PCs, minicomputers, mainframe computers and the like. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

As shown in FIG. **1**, an example general purpose computing system comprises a conventional personal computer **20** or the like, including a processing unit **21**, a system memory **22**, and a system bus **23** that couples various system components including the system memory to the processing unit **21**. The system bus **23** may be any of several types of bus structures including a memory bus or memory controller, a peripheral bus, and a local bus using any of a variety of bus architectures. The system memory comprises read only memory (ROM) **24** and random access memory (RAM) **25**. A basic input/output system **26** (BIOS), containing the basic routines that help to transfer information between elements within the personal computer **20**, such as during start up, is stored in ROM **24**. The personal computer **20** may further comprise a hard disk drive **27** for reading from and writing to a hard disk, not shown, a magnetic disk drive **28** for reading from or writing to a removable magnetic disk **29**, and an optical disk drive **30** for reading from or writing to a removable optical disk **31** such as a CD ROM or other optical media. The hard disk drive **27**, magnetic disk drive **28**, and optical disk drive **30** are connected to the system bus **23** by a hard disk drive interface **32**, a magnetic disk drive interface **33**, and an optical drive interface **34**, respectively. The drives and their associated computer readable media provide non volatile storage of computer readable instructions, data structures, program modules and other data for the personal computer **20**. Although the example environment described herein employs a hard disk, a removable magnetic disk **29** and a removable optical disk **31**, it should be appreciated by those skilled in the art that other types of computer readable media which can store data that is accessible by a computer, such as magnetic cassettes, flash memory cards, digital video disks, Bernoulli cartridges, random access memories (RAMs), read only memories (ROMs) and the like may also be used in the example operating environment.

A number of program modules may be stored on the hard disk, magnetic disk **29**, optical disk **31**, ROM **24** or RAM **25**, including an operating system **35**, one or more application programs **36**, other program modules **37** and program data **38**. A user may enter commands and information into the personal computer **20** through input devices such as a keyboard **40** and pointing device **42**. Other input devices (not shown) may comprise a microphone, joystick, game pad, satellite disk, scanner or the like. These and other input devices are often connected to the processing unit **21** through a serial port interface **46** that is coupled to the system bus, but may be connected by other interfaces, such as a parallel port, game port or universal serial bus (USB). A monitor **47** or other type of display device is also connected to the system bus **23** via an interface, such as a video adapter **48**. In addition to the monitor **47**, personal computers typically comprise other peripheral output devices (not shown), such as speakers and printers. The example system of FIG. **1** also comprises a host adapter **55**, Small Computer System Interface (SCSI) bus **56**, and an external storage device **62** connected to the SCSI bus **56**.

The personal computer **20** may operate in a networked environment using logical connections to one or more remote computers, such as a remote computer **49**. The remote computer **49** may be another personal computer, a server, a router, a network PC, a peer device or other common network node, and typically comprises many or all of the elements described above relative to the personal computer **20**, although only a memory storage device **50** has been illustrated in FIG. **1**. The logical connections depicted in FIG. **1** comprise a local area network (LAN) **51** and a wide area network (WAN) **52**. Such networking environments are commonplace in offices, enterprise wide computer networks, intranets and the Internet.

When used in a LAN networking environment, the personal computer **20** is connected to the LAN **51** through a network interface or adapter **53**. When used in a WAN networking environment, the personal computer **20** typically comprises a modem **54** or other means for establishing communications over the wide area network **52**, such as the Internet. The modem **54**, which may be internal or external, is connected to the system bus **23** via the serial port interface **46**. In a networked environment, program modules depicted relative to the personal computer **20**, or portions thereof, may be stored in the remote memory storage device. It will be appre-

ciated that the network connections shown are example and other means of establishing a communications link between the computers may be used. Moreover, while it is envisioned that numerous embodiments of the present invention are particularly well-suited for computerized systems, nothing in this document is intended to limit the invention to such embodiments.

From a conceptual perspective, computer systems generally comprise one or more layers of software running on a foundational layer of hardware. This layering may be done for reasons of abstraction. By defining the interface for a given layer of software, that layer may be implemented differently by other layers above it. In a well-designed computer system, each layer may rely on the layers adjacent. This allows a layer or a stack of multiple adjoining layers to be replaced without negatively impacting other layers above.

For example, software applications **36** typically rely on lower levels of the operating system **35** to write files to some form of permanent storage, and these applications **36** may not need to understand the difference between writing data to a floppy disk **50**, a hard drive **27**, or a network folder (not shown). If this lower layer is replaced with new operating system components for writing files, the operation of the upper layer software applications may remain unaffected.

FIGS. **2**A and **2**B depict example virtualized computing systems. Referring to FIG. **2**A, the flexibility of layered software allows a virtual machine **108**, **110** to present a virtual hardware layer that may be in fact another software layer. In this way, a virtual machine **108**, **110** may create the illusion for the software layers above it that said software layers are running on their own isolated private computer system and physical hardware, and thus virtual machines may allow multiple guest systems **112**, **114** and associated applications **116**A, B, C to run concurrently on a single host system **104**.

A virtualized computing system may comprise a host operating system software layer **104** running directly above physical computer hardware **102**. A virtual machine monitor (VMM) **106** may virtualize all the resources of the machine by exposing interfaces that are the same as those of the hardware on which the host operating system **104** is running, enabling the host operating system **104** to go unnoticed by guest operating systems **112**, **114** running in the virtual machines **108**, **110**.

Referring to FIG. **2**B, in another embodiment, a virtual machine monitor **106** (VMM) software layer acting as a hypervisor may be running directly on computer hardware **102**. A root partition **107** running in a layer on top of the VMM **106** may provide host operating system services to the VMM **106**. Virtual machine A **108** and virtual machine B **110** may be virtualized computer hardware representations. Virtual machine A **108** and virtual machine B **110** may present a virtualized environment to Guest OS A **112** and Guest OS B **114** respectively. The virtual machine monitor **106** may perform all of the software steps necessary for Guest OS A **112** and Guest OS B **114** to indirectly interact with the real physical computer hardware **102** while leveraging the host OS facilities from the root partition **107**. Guest OS A **112** may provide an operating environment for applications **116**A, B. Likewise, Guest OS B **114** may provide an operating environment for applications **116**C.

In one embodiment, the virtual machine monitor **106** may comprise part of the host operating system **104**. In other embodiments, the virtual machine monitor **106** may be an application running above the host operating system **104** and interacting with the computer hardware **102** through said host operating system **104**, for example. In yet other embodiments, the virtual machine monitor **106** may comprise a partially independent software system that may interact indirectly with the computer hardware **102** via the host operating system **104** but may also virtual machine monitor **106** interacts with the computer hardware **102**. In another embodiment, the virtual machine monitor **106** may comprise an independent software system that may interact with the computer hardware **102** without utilizing the host operating system **104**.

The variations for implementing virtual machines and virtual machine monitors or hypervisors described above are just exemplary implementations, and nothing herein should be interpreted as limiting the disclosure to any particular virtualization aspect.

FIG. **3** depicts data in an example virtualized computing system. A host computer **300** may comprise computer hardware **102** and a host operating system **104**. A virtual machine monitor **106** may virtualize machine resources and facilitate the operation of one or more virtual machines **108**. A virtual machine **108** may comprise a virtual machine image **304**. The virtual machine image **304** may comprise the data required to operate the virtual machine **108**. The virtual machine image **304** may comprise the system files, data files, and related file-system information relating to the virtual machine **108** and the operating system within it. Each virtual machine **108** may be identified by one or more associated virtual machine files.

In one embodiment, the virtual machine image **304** may be represented to the host operating system by one or more virtual hard disk files **302** and a configuration file **303**. The virtual hard disk files **302** may in part encapsulate a physical disk device **304**. Each virtual hard disk file **302** represents a physical disk of a virtual machine **108** and may contain the system files, data files, and file-system information relating to the virtual machine **108**. For example, the virtual hard disk file **302** represents a physical hard disk inside the guest operating system, which might in turn contain one or more volumes, file systems, or the like. For example, the hard disk file **302** may comprise data indicative of the application that is running inside the guest operating system and data indicative of the operating system **104** within which the hard disk file **302** was created, the original and current VHD file size, and data indicative of the disk geometry and type.

To the virtual machine **108**, the virtual hard disk file **302** may be represented as a physical disk device **304** that contains a file-system for example. The virtual machine **108** may access individual system files, data files, and other data represented as being stored on this file-system. For example, the virtual machine **108** may access files and directories **305** associated with this disk device **304**.

The virtualization provides a level of abstraction such that what appears as a disk and a file-system to the virtual machine **108** appears as a collection of files to the host operating system **104**. In one embodiment, the virtual hard disk file **302** may have a .VHD file extension.

The virtual hard disk file **302** may be accompanied by metadata. The metadata may be stored in a metadata file **303**. For example, the metadata file **303** may have a .CFG or a .VMC extension. The metadata may comprise information relating to the nature of the virtual hard disk file **302**, for example, whether the virtual hard disk file **302** represents a system or boot drive. Metadata related to the virtual machine configuration may also be stored in a file, such as with a .VMC extension.

When the virtual machine **108** is on-line, the virtual machine image **304** may be inaccessible to other processes of the host computer **300**. For example, in one embodiment,

when the virtual machine **108** is on-line, the associated virtual hard disk files **302** may be locked.

Off-line virtual machines and virtual machine images may be stored in a library file server for extended periods of time and used as templates for new virtual machine deployments, cloning, or for simply storing the virtual machines until they are needed again. For example, virtual machines could be stored to conserve resources on the virtual machine hosts. Viruses and malware are problems that are haunting IT administrators today, and the VHD files in a library are not immune to such problems. Moreover, since the virtual machines represent separate computing entities, there could be malware and viruses embedded inside the operating system of the virtual machines as well. The threat here is double. In addition, because templates of virtual machines can be used to create new virtual machines, it is imperative that those templates are kept clean from viruses and malware. In some embodiments, stored or off-line virtual machines may be loaded into an operating system entity through VHD mounting and scanned for malware in configured intervals so that the library of offline virtual machines and VHDs is always kept clean.

FIG. **4** depicts an illustrative process for scanning a virtual machine image **304**. At **402**, a scan of a virtual machine image **304** may be scheduled. The scheduling may occur via a management application. In one embodiment, the management application may run locally on the host computer **300** on which the virtual machine **108** being scanned resides. In another embodiment, the management application may run remotely on a server operatively connected to the host computer **300**.

The management application may be used to schedule an immediate scan, such as a scan on demand for example, or a scan at a future time. The management application may be used to select the time and date of the scan. In addition, the management application may schedule a periodic scanning, such as once a week for example. The management application may record historical data, data for generating reports, data relating to the scan, such as the host name and IP address of the host computer **300** on which the virtual machine **108** is located, the host name or other identifier of the virtual machine **108** to be scanned, and the nature of the scan. The nature of the scan may comprise information about the types, names, locations or other information relating to the files or data to be scanned. The scheduling of scanning may occur through a web based interface or other management interface.

At **404**, a virtual machine **108** to be scanned may be taken off-line. A copy of the virtual machine image **304** may be made. In another embodiment, at **406** a checkpoint (or point-in-time copy) of the virtual machine **108** may be made while the virtual machine **108** is online. For example, the virtual machine monitor **106** may export a copy of the virtual machine image **304**. The checkpoint may result in a virtual machine image **304** that may be stored. In one embodiment, the virtual machine image **304** may be stored as one or more virtual hard disk files **302**. In another embodiment, the virtual hard disk files **302** may be accompanied by metadata **303**. By periodically creating a checkpoint of a running virtual machine and scanning the checkpoint image, a virtual machine may be verified to be free of malware even without having an anti-malware agent running inside the virtual machine.

At **408** the virtual image may be stored. For example, the virtual machine image **304** may be stored on the host computer **300**, on a remote server (see FIG. **5**), a network data store, a storage area network, a database, and the like. Storing the virtual machine image **304** may comprise storing both the virtual hard disk file **302** and the metadata file **303**. In one embodiment storing the virtual machine image **304** may comprise copying the virtual machine image **304** into a database, as well as, collecting other information about the virtual machine image **304** and storing it in the database as well. For example the other information may comprise a timestamp, date stamp, and/or the hostname from which the virtual machine image **304** was taken, the IP address or other identifier of the host computer **300** from which the virtual machine image **304** was taken, the virtual machine's function, and the like.

At **410**, the virtual machine image **304** may be rendered to file-system data. Because the virtual machine image **304** may appear as a virtual hard disk file **302** outside of the context of the virtual machine **108** itself, the virtual machine image **304** may be rendered to information suitable for scanning. When the virtual machine image **304** is stored as a virtual hard disk file **302**, the files may not be available for scanning, for example because of their binary compressed format. For example, the virtual machine image **304** may encapsulate the virtual machine's system files and registry hive. Rendering the stored virtual machine image **304** may comprise translating the virtual machine image **304** into a format such that the files and directories **305** readable inside the virtual machine **108** are now readable by a host operating system **104** or another computer's operating system, for example. The process of rendering may comprise mounting the VHD files **302** on the host operating system via a kernel mode driver (file system driver and the like). The mounter will expose the VHD file as it is exposed inside the VM, as a physical disk device. Then, letters may be assigned to the volumes of the disk and data exposed as if it were inside the guest operating system of the virtual machine image **304**. Since no operating system is running on the exposed data, everything is seen as data and as being offline. Once rendered, objects such as the virtual machines system files, registry hive, and other aspects of the virtual machine image **304** may be available for scanning.

In one embodiment, rendering the virtual machine image **304** to file-system data comprises translating the virtual machine image **304** to data understandable by the host operating system's file system. For example, the file-system data may comprise a listing or representation of all the files contained within the virtual machine image **304**. Rendering a virtual machine image **304** may comprise translating metadata information, from a metadata file **303** for example, and relating the metadata information to the contents of the virtual machine image **304**. For example, the metadata information may describe and identify the VHDs and volumes comprising the virtual machine image **304** as system volumes or data volumes. This information may be desirable when scanning for boot sector viruses, scanning registry hives, and the like.

In one embodiment, rendering the virtual machine image **304** to file-system data may comprise mounting the virtual hard drive image as a physical disk device. When the virtual machine image **304** is mounted, on a host computer **300** or server computer (see FIG. **5**), the virtual machine image **304** may appear under a drive letter as an available volume and file-system. The files within the virtual machine image **304** may be available for scanning under the now mounted VHD file as they are now part of the host operating system list of volumes. Mounting may be accomplished with a tool such as the VHD mounter, for example.

In another embodiment, rendering the virtual machine image **304** may comprise a kernel mode driver filter connected to an anti-malware engine. Such a filter may be used to render the virtual machine image **304** to file-system data available to the anti-malware engine without mounting the

virtual hard drive image. With such a filter, the virtual machine image **304** may be rendered and scanned concurrently. With such a filter embedded in the VMM, a virtual machine can even be scanned while running without needing to render the virtual machine image.

At **412**, collection of volumes that comprise the virtual machine image may be scanned for malware by an anti-malware engine. For example, anti-virus software and anti-spyware software may scan for malware on a computer generally. For example, scanning for malware may comprise searching the system files, boot and driver records, and registry hive for corresponding malware signatures. Scanning for malware may comprise heuristics scanning, for example. Scanning the registry hive might, for example, comprise loading the registry hive into memory and scanning the loaded data.

The anti-malware engine may be an anti-virus engine, an anti-spyware engine, an anti-spam engine, and the like. Scanning the file-system data may comprise a full scan in which every aspect or file of the file-system data is checked for malware. The scanning may comprise a partial scan in which only targeted files and aspects of the file-system data, such as system files, the registry hive and aspects of the file-system data related to booting, are scanned for malware. A huge advantage of scanning the file system and the registry hive and the OS of the virtual machine in an off-line way is that the malware does not have an opportunity to mask itself since it is not running. In a traditional scan for malware, the OS is booted up and the malware could be running, preventing the anti-malware engine from effectively scanning it because the malware has commandeered certain OS functions.

Responsive to the scan, malware may be detected and based on user recommendations the virtual machine image might be cleaned of malware or the virtual machine image **304** may be free of malware. At **414**, data relating to the scanning may be stored. For example, an indication of the result of the scan may be stored. The anti-malware engine may give an indication to the user of the results of the scanning. For example, it may e-mail, text-message, provide visual or audio indication, and the like that malware has been detected or that malware has not been detected.

The anti-malware engine may store other data relating to the scan. For example, the anti-malware engine may store a log file describing each file scanned and the result of that scan. Data indicative of the time and date at which the virtual machine image **304** was scanned may be stored as well.

The anti-malware engine may record the identity of the virtual machine **108**. For example, when the virtual machine image **304** is represented by a virtual hard disk file **302**, the anti-malware engine may store the file name and location of the virtual hard disk file **302**. Also for example, data that indicates to which virtual machine **108** the virtual machine image **304** corresponds and from which host the virtual machine image **304** was taken may be stored.

In one embodiment, the related data may be stored in a database, table, or the like. The data may be collected across many scans. For example, scans of multiple virtual machine images **304** may be stored. The anti-malware engine may run on the local host computer **300** or a remote server for example.

FIG. **7** depicts a simplified block diagram of a system that may embody the process described above. A virtual machine image **701** is stored in a memory unit **702**. For example, the virtual machine image **701** may comprise one or more virtual hard disk files and associated metadata files and the memory unit **702** may be any sort of memory unit suitable for file storage. A processor **703** is configured to render the virtual machine image **701** to file-system data **704**. In some embodiments the processor **703** may be a VHD mounter. The rendered file-system data **704** is in a format such that files and system information represented by the virtual machine image are accessible to, for example, a host operating system, another computer's operating system, or an anti-malware engine **705**. An anti-malware engine **705** is configured to scan the file-system data **704** as described above in relation to FIG. **4**.

FIG. **5** depicts an example host/server architecture for virtual machines. One or more hosts **502**A, B may be associated with a server **510**. Each host **502**A, B may support one or more virtual machines **504**A, B. A host **502**A, B may be any computing device capable of supporting a virtual machine **504**A, B. For example, the host **502**A, B may be a personal computer, a handheld device, laptop computer, cell phone, and the like. Each host **502**A, B may be identified by hostname for example.

The server may also be any computing device capable of processing and storing multiple virtual machine images **506**A-C, **508**A-C. The server may be in operative communication with each host **502**A, B. The host **502**A, B and server **510** may be programmed such that virtual machine images **506**A-C, **508**A-C may be stored in the server **510**. The virtual machine images **506**A-C, **508**A-C may be stored from the hosts **502**A, B, deployed to the hosts **502**A, B, modified, copied, and the like.

In one embodiment, virtual machines images **506**A-C, **508**A-C of each host **502**A, B may be stored periodically as a checkpoint. Such checkpoints may represent a snapshot of the state and data of the virtual machine **504**A, B at the time of the checkpoint, for example a point-in-time copy of the virtual machine image. The virtual machine images **506**A-C, **508**A-C from each host **502**A, B may be transferred to the server **510**. The server **510** may be a library server, database, data store, storage area network, and the like. For example, the server **510** may store the virtual machine images **506**A, B, **508**A, B as well as data indicative of the source of the virtual machine image **506**A-C, **508**A-C and the time and date at which the virtual machine image **506**A-C, **508**A-C was taken.

As a result, the server **510** may contain a comprehensive view across all hosts **502**A, B in network of virtual machines and their respective status at different points in time. Such a collection of data presents a particular advantage. The administrator may essentially go back in time to restore the network of hosts **502**A, B and virtual machines **504**A, B to a state at a previous point in time. By taking earlier virtual machine images **506**A-C, **508**A-C from the server **510** and reinstating them on the hosts **502**A, B, the administrator may be able to restore a network of hosts **502**A, B and virtual machines **504**A, B following an infestation of malware.

Such an infestation may be computer virus, worm, hacker attack, and the like. In addition, the administrator may be able to determine forensic data about the infestation, such as the time of infestation and the source of the infestation for example. For example, if malware is detected in an existing VM, an anti-malware engine could be applied to checkpoints going back in time to identify when and where the malware was introduced, and to locate the most recent malware-free virtual machine image for restoration.

An administrator could have a numerous checkpoints for each VM. Some of these checkpoints may go more than a few weeks back in time. Those checkpoints may not have updated virus definitions or have not been scanned for malware for a quite some time. If an administrator chooses to revert to such a checkpoint, the checkpoint image can be scanned offline

prior to the reversion, ensuring that no older copy of a VM that has not been scanned is allowed to be run.

FIG. **6** depicts an illustrative process for scanning a plurality of virtual machine images **506**A-C, **508**A-C. At **602**, the server **510** may receive a virtual machine image **506**A-C, **508**A-C. The server **510** may collect a plurality of virtual machine checkpoint images **506**A-C, **508**A-C, each associated with the same virtual machine **504**A, B and each taken at different points in time. The server **510** may store a set of virtual images **506**A-C, **508**A-C and the point in time each one represents.

At **604**, a first virtual machine image **304** may be analyzed. In one embodiment, the most recently captured virtual machine image **506**A-C, **508**A-C of the set of virtual machine images may be analyzed. Analyzing the virtual machine image **304** may comprise both rendering the virtual machine image **506**A-C, **508**A-C to file-system data and scanning the file-system data with the anti-malware engine.

Upon analyzing the virtual machine image **506**A-C, **508**A-C, at **606**, the anti-malware engine may indicate that the virtual machine image **506**A-C, **508**A-C is infested with malware or that the virtual machine image **506**A-C, **508**A-C is not infested with malware. If the virtual machine image **506**A-C, **508**A-C is not infested, the server **510** may store scan data, at **608**. On the other hand, if the virtual machine image **506**A-C, **508**A-C is infested, the server **510** may receive a second virtual machine image **506**A-C, **508**A-C, at **610**. The second virtual machine image **506**A-C, **508**A-C may be the next most recently captured virtual machine image **506**A-C, **508**A-C. The second virtual machine image **506**A-C, **508**A-C may be analyzed similar to first virtual machine image **304**.

The server **510** may be able to iteratively scan time-stamped virtual machine checkpoint images **506**A-C, **508**A-C, stepping back in time until a virtual machine image **506**A-C, **508**A-C without malware is found. Once the virtual machine image **506**A-C, **508**A-C is found without a malware infestation, the virtual machine image **506**A-C, **508**A-C may be used to restore an infested virtual machine **504**A, B.

While the present disclosure has been described in connection with various embodiments, illustrated in the various figures, it is understood that similar aspects may be used or modifications and additions may be made to the described aspects of the disclosed embodiments for performing the same function of the present disclosure without deviating therefrom. Therefore, the present disclosure should not be limited to any single aspect, but rather construed in breadth and scope in accordance with the appended claims.

What is claimed:

1. A method for scanning a virtual machine image associated with a most recent non-infected checkpoint of a virtual machine, the method comprising:

scanning a set of checkpoints of the virtual machine to identify the most recent non-infected checkpoint, the scanning of the set beginning with a most recently captured checkpoint and then repeatedly progressing to a next most recently captured checkpoint until the most recent non-infected checkpoint is identified;

rendering the virtual machine image associated with the most recent non-infected checkpoint to file-system data by translating the virtual machine image into a format understandable to a file system, the translating comprising translating a .cfg or .vmc metadata file into a format understandable to the file system and relating metadata information in the metadata file to contents of the virtual machine image, the metadata information identifying the contents of the virtual machine image as system volumes or data volumes; and

scanning the file-system data with an anti-malware engine based on the metadata information.

2. A method as recited in claim **1**, wherein the file-system data corresponds to a file system of the virtual machine.

3. A method as recited in claim **1**, further comprising:

taking the virtual machine off-line; and

storing an image of the virtual machine.

4. A method as recited in claim **1**, further comprising:

taking a checkpoint of the virtual machine while the virtual machine is on-line.

5. A method as recited in claim **1**, wherein the rendering the virtual machine image to file-system data comprises rendering the virtual machine image to file-system data for use by the anti-malware engine.

6. A method as recited in claim **1**, wherein the data indicative of the scanning comprises at least one of a scanning timestamp, a scanning result, and a list of infected components within the file-system data.

7. A method as recited in claim **1**, further comprising scheduling a time and date for the rendering and scanning of the file system data.

8. A method as recited in claim **1**, wherein the virtual machine image comprises a virtual hard disk file.

9. A method as recited in claim **8**, wherein the rendering the virtual machine image to file-system data comprises mounting the virtual hard disk file as a physical hard drive.

10. A computer readable storage medium excluding transmission media and carrier waves comprising computer executable instructions, the instructions comprising instructions for:

scanning a set of checkpoints of a virtual machine to identify a most recent non-infected checkpoint, the scanning of the set beginning with a most recently captured checkpoint and then repeatedly progressing to a next most recently captured checkpoint until the most recent non-infected checkpoint is identified;

rendering the virtual machine image associated with the most recent non-infected checkpoint to file-system data by translating the virtual machine image into a format understandable to a file system, the translating comprising translating a .cfg or .vmc metadata file into a format understandable to the file system and relating metadata information in the metadata file to contents of the virtual machine image, the metadata information characterizing the contents of the virtual machine image as system volumes or data volumes; and

invoking an anti-malware engine to scan the file-system data based on the metadata information.

11. A computer readable storage medium as recited in claim **10**, wherein the instructions further comprise instructions for:

receiving a first virtual machine image associated with the virtual machine at a first time;

receiving a second virtual machine image associated with the virtual machine at a second time, wherein the first time is earlier than the second time;

analyzing the second virtual machine image, wherein the analyzing comprises rendering the second virtual machine image to file-system data and invoking an anti-malware engine to scan the file-system data; and

responsive to analyzing the second virtual machine image, analyzing the first virtual machine image.

12. A computer readable storage medium as recited in claim **11**, wherein the instructions for receiving a first virtual

machine image comprise instructions for receiving at a server a checkpoint image from an on-line virtual machine on a host computer.

13. A computer readable storage medium as recited in claim **11**, wherein the instructions for receiving a first virtual machine image comprise instructions for retrieving the first virtual image from a library of virtual machine images.

14. A computer readable storage medium as recited in claim **11**, further comprising instructions for:

receiving scheduling data at a server,

initiating the rendering according to the received scheduling data; and

invoking the anti-malware agent to scan the file-system data according to the received scheduling data.

15. A computer readable storage medium as recited in claim **10**, wherein the instructions further comprise instructions for:

generating a signal indicative of the identified most recent non-infected checkpoint.

16. A system for scanning a virtual machine image associated with a most recent non-infected checkpoint of a virtual machine, the method comprising:

a processor;

memory having stored therein instructions comprising instructions for:

scanning a set of checkpoints of the virtual machine to identify the most recent non-infected checkpoint, the scanning of the set beginning with a most recently captured checkpoint and then repeatedly progressing to a next most recently captured checkpoint until the most recent non-infected checkpoint is identified;

rendering the virtual machine image associated with the most recent non-infected checkpoint to file-system data by translating the virtual machine image into a format understandable to a file system, the translating comprising translating a .cfg or .vmc metadata file into a format understandable to the file system and relating metadata information in the metadata file to contents of the virtual machine image, the metadata information describing the contents of the virtual machine image as system volumes or data volumes; and

scanning the file-system data with an anti-malware engine based on the metadata information.

17. A system as recited in claim **16**, wherein the virtual machine image is a result of taking a checkpoint of an on-line virtual machine.

18. A system as recited in claim **16**, wherein the virtual machine image comprises a virtual hard disk file.

19. A system as recited in claim **18**, further comprising a mounter configured to mount the virtual hard disk file as a physical hard drive.

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