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**Marsh et al.**

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(54) **SYSTEM AND METHOD FOR UPDATING FIRMWARE**

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(51) **Int. Cl.**
***G06F 9/44*** (2006.01)
***G06F 9/445*** (2006.01)

(52) **U.S. Cl.** ..... **717/172**; 713/2

(58) **Field of Classification Search** ..... 717/168–178; 713/187, 1–3, 201; 714/7
See application file for complete search history.

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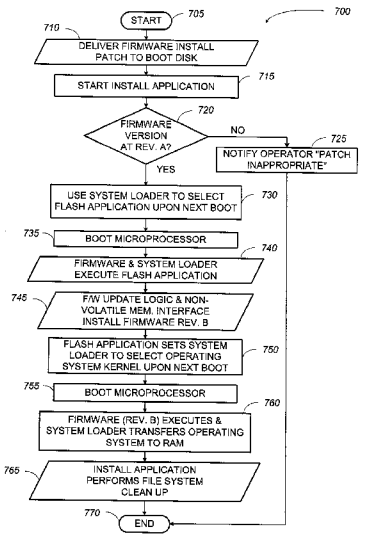
*Assistant Examiner*—Trenton J. Roche

(57) **ABSTRACT**

A system and a method that uses a software application operable under a current firmware/operating system configuration to install a new firmware version without "compromising" the operating system are presented. The software application may configure a computer system to install a plurality of software fixes configured to enhance functionality under a new firmware/operating system environment after the firmware has been successfully upgraded. Such functionality enhancements may be associated with external peripherals, as well as, input/output circuit cards, processors, and the like. In addition, the software application may configure the computing device to "boot" under the new firmware/operating system environment upon subsequent system initializations. Furthermore, the software application permits the distribution of firmware upgrades via a network. The capability to install firmware remotely permits a system administrator to "push" the new firmware to a plurality of network coupled computing devices, thus avoiding manual intervention at each device.

**22 Claims, 10 Drawing Sheets**



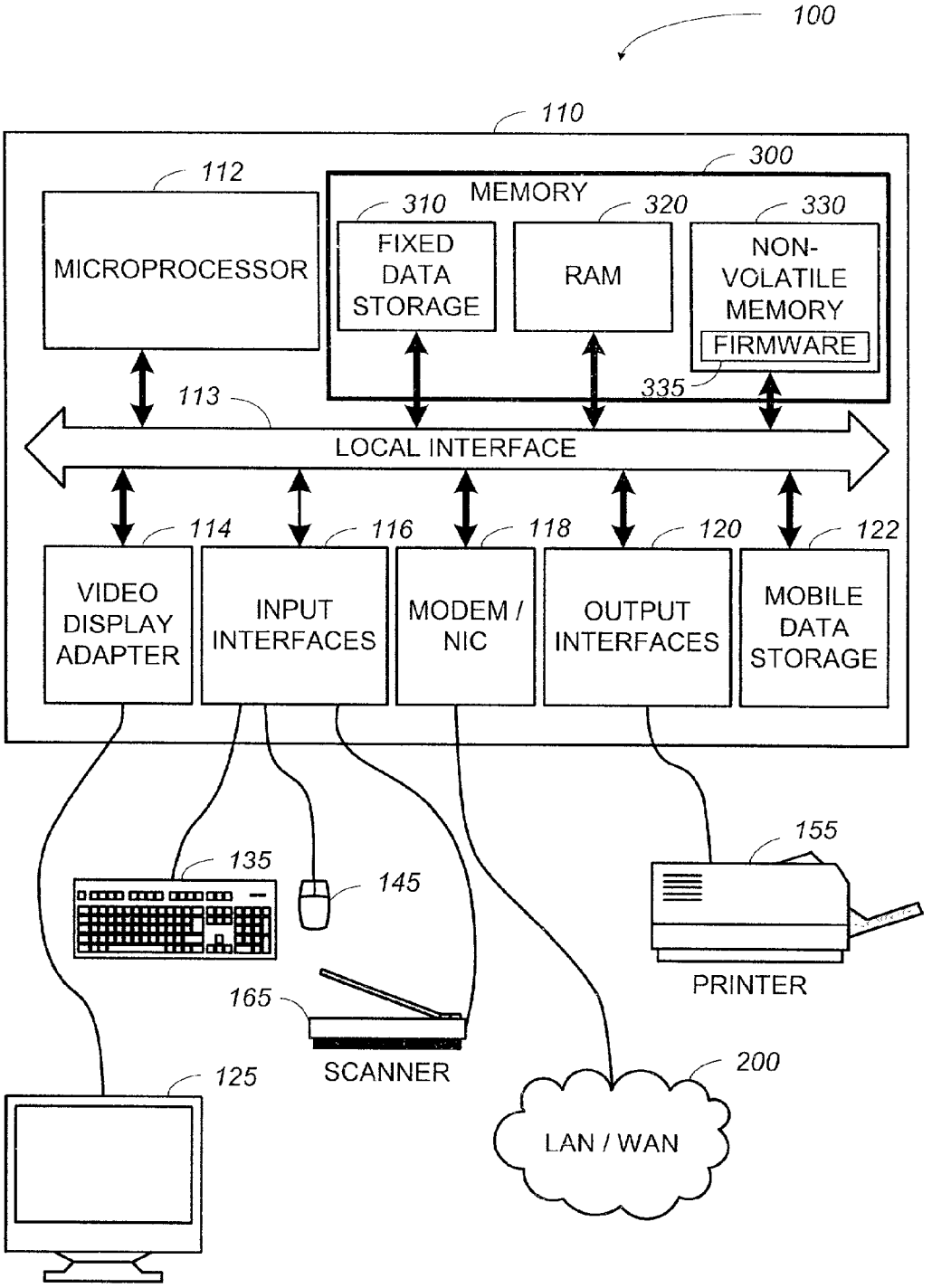

100
110
112
MICROPROCESSOR
300
MEMORY
310
FIXED DATA STORAGE
320
RAM
330
NON-VOLATILE MEMORY
FIRMWARE
335
113
LOCAL INTERFACE
114
VIDEO DISPLAY ADAPTER
116
INPUT INTERFACES
118
MODEM / NIC
120
OUTPUT INTERFACES
122
MOBILE DATA STORAGE
135
145
155
PRINTER
165
SCANNER
125
200
LAN / WAN

FIG. 1

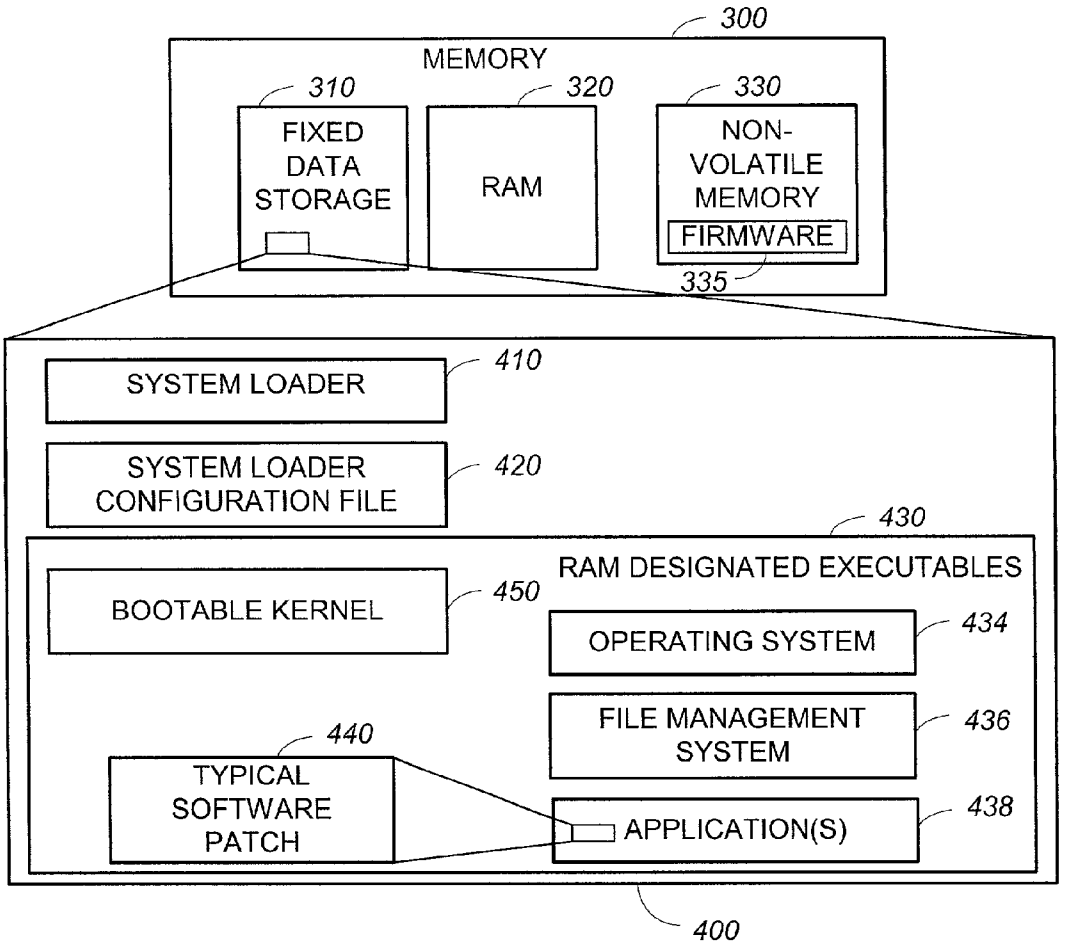

300
MEMORY
310
FIXED DATA STORAGE
320
RAM
330
NON-VOLATILE MEMORY
FIRMWARE
335
SYSTEM LOADER
410
SYSTEM LOADER CONFIGURATION FILE
420
430
RAM DESIGNATED EXECUTABLES
BOOTABLE KERNEL
450
OPERATING SYSTEM
434
FILE MANAGEMENT SYSTEM
436
440
TYPICAL SOFTWARE PATCH
APPLICATION(S)
438
400

FIG. 2

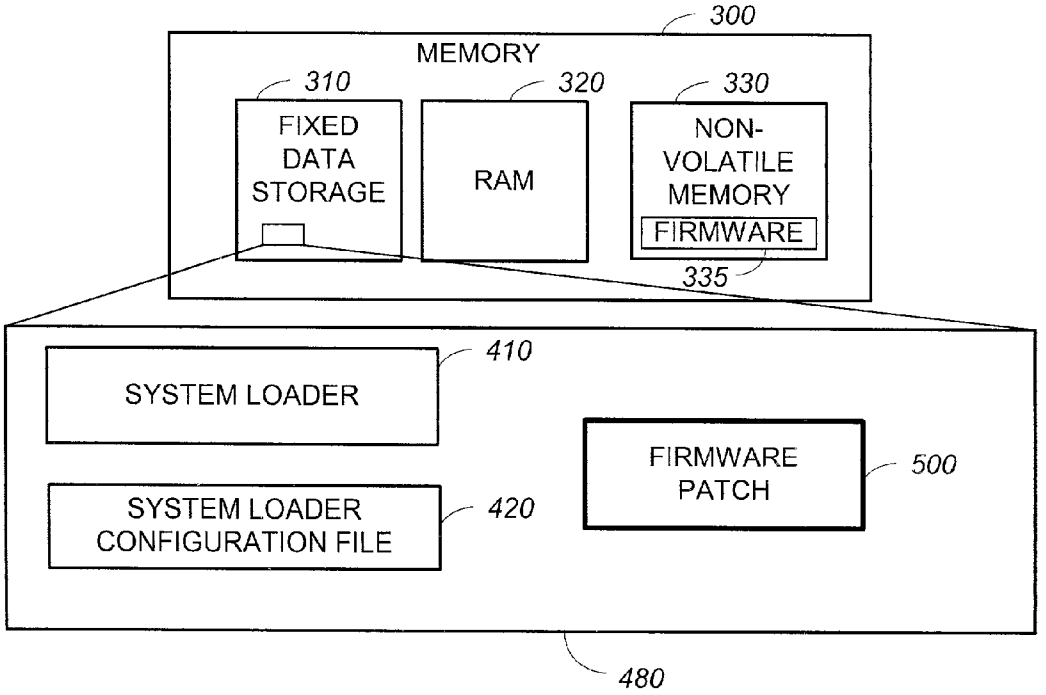

300
MEMORY
310
FIXED DATA STORAGE
320
RAM
330
NON-VOLATILE MEMORY
FIRMWARE
335
410
SYSTEM LOADER
SYSTEM LOADER CONFIGURATION FILE
420
FIRMWARE PATCH
500
480

FIG. 3

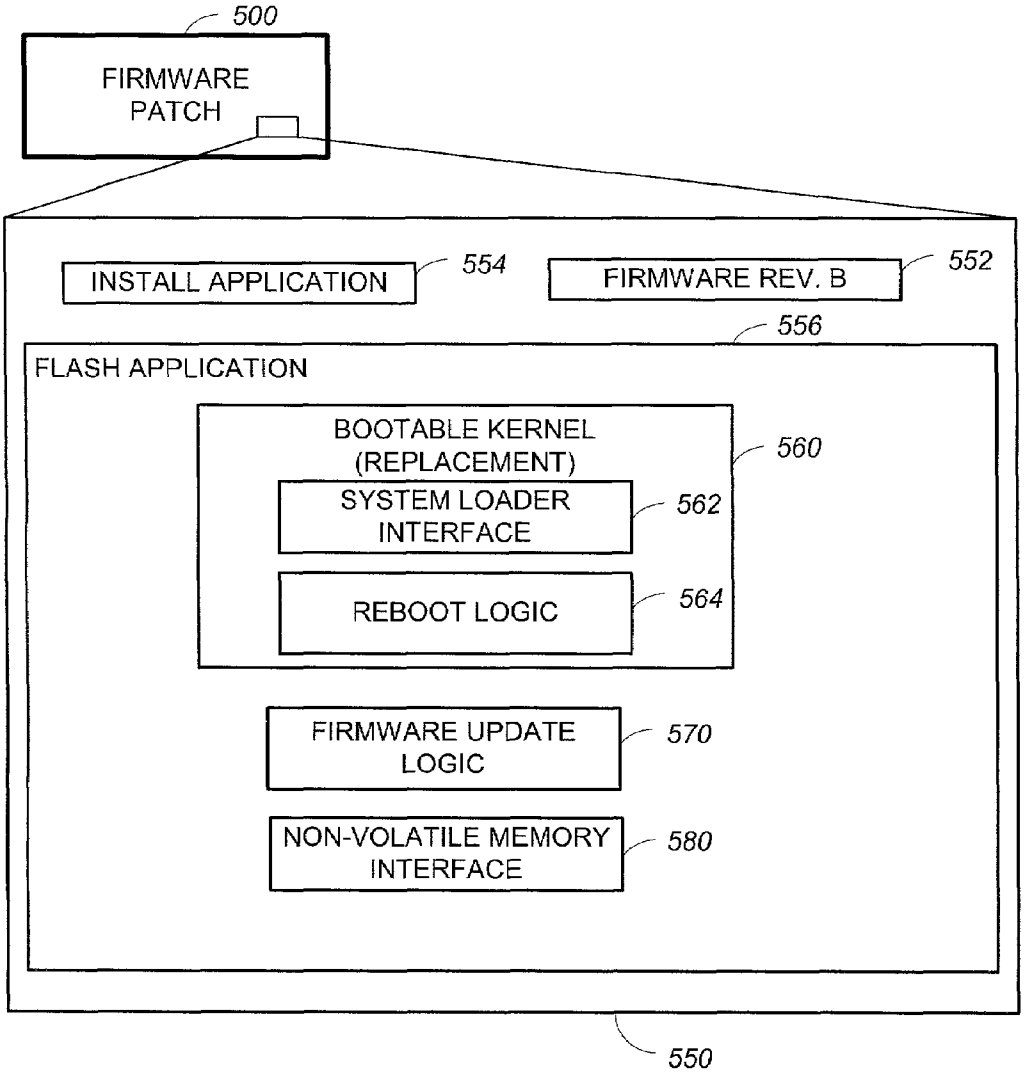

500
FIRMWARE PATCH
INSTALL APPLICATION
554
FIRMWARE REV. B
552
556
FLASH APPLICATION
BOOTABLE KERNEL (REPLACEMENT)
560
SYSTEM LOADER INTERFACE
562
REBOOT LOGIC
564
FIRMWARE UPDATE LOGIC
570
NON-VOLATILE MEMORY INTERFACE
580
550

FIG. 4

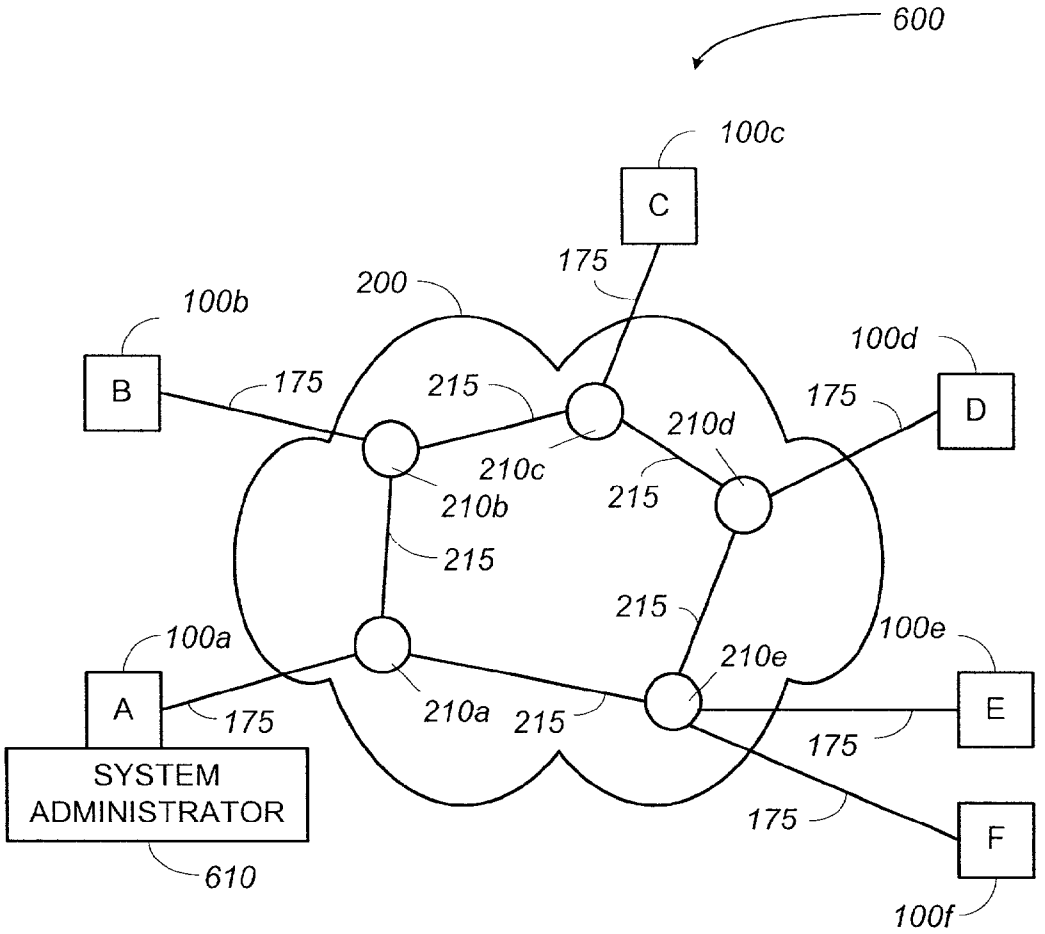

600
100c
C
175
200
100b
B
175
215
100d
D
175
210d
210c
210b
215
215
215
100a
A
175
210a
215
210e
100e
E
175
175
F
100f
SYSTEM
ADMINISTRATOR
610

FIG. 5

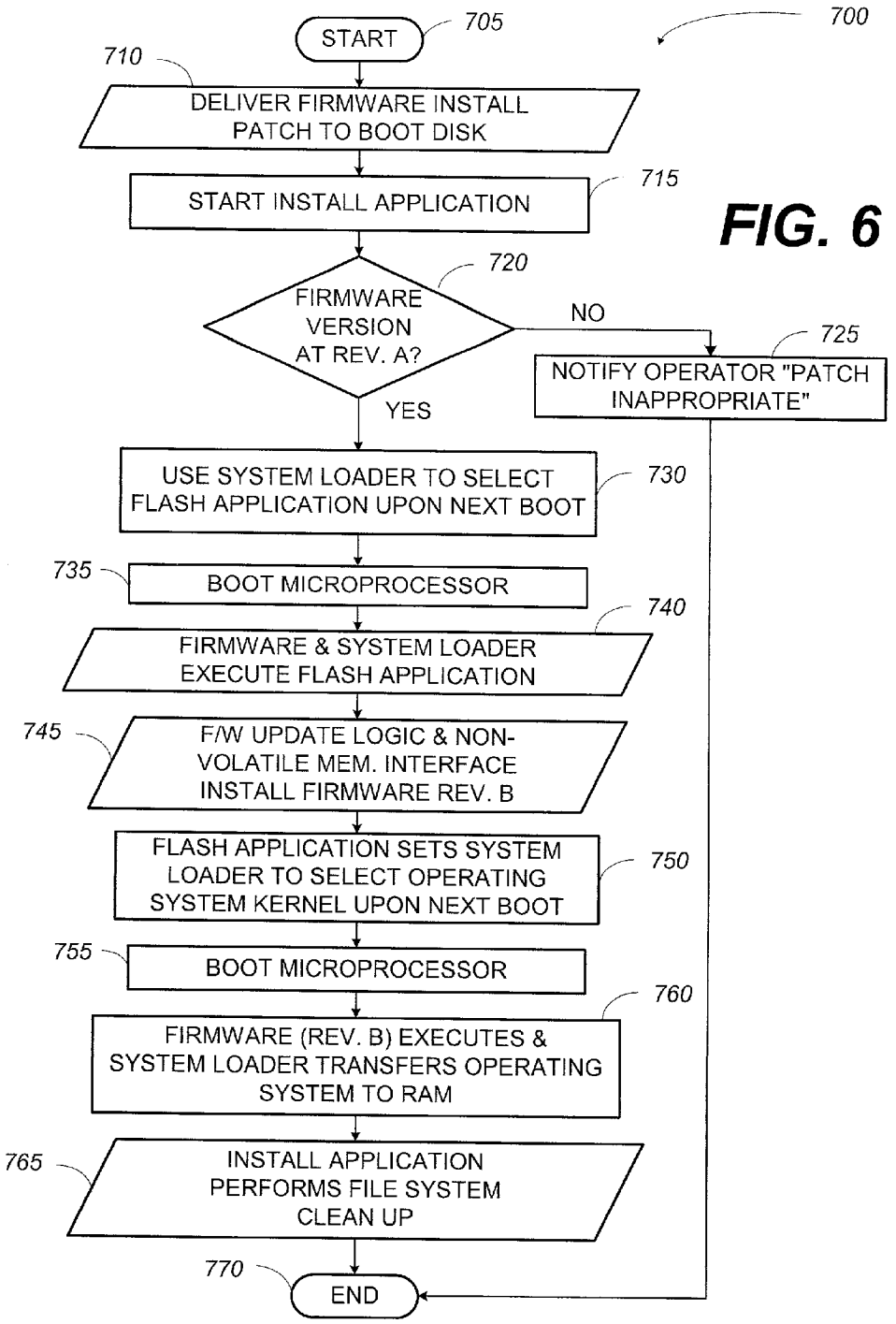

700
START
705
710
DELIVER FIRMWARE INSTALL PATCH TO BOOT DISK
START INSTALL APPLICATION
715
720
FIRMWARE VERSION AT REV. A?
NO
725
NOTIFY OPERATOR "PATCH INAPPROPRIATE"
YES
USE SYSTEM LOADER TO SELECT FLASH APPLICATION UPON NEXT BOOT
730
735
BOOT MICROPROCESSOR
740
FIRMWARE & SYSTEM LOADER EXECUTE FLASH APPLICATION
745
F/W UPDATE LOGIC & NON-VOLATILE MEM. INTERFACE INSTALL FIRMWARE REV. B
FLASH APPLICATION SETS SYSTEM LOADER TO SELECT OPERATING SYSTEM KERNEL UPON NEXT BOOT
750
755
BOOT MICROPROCESSOR
760
FIRMWARE (REV. B) EXECUTES & SYSTEM LOADER TRANSFERS OPERATING SYSTEM TO RAM
765
INSTALL APPLICATION PERFORMS FILE SYSTEM CLEAN UP
770
END

FIG. 6

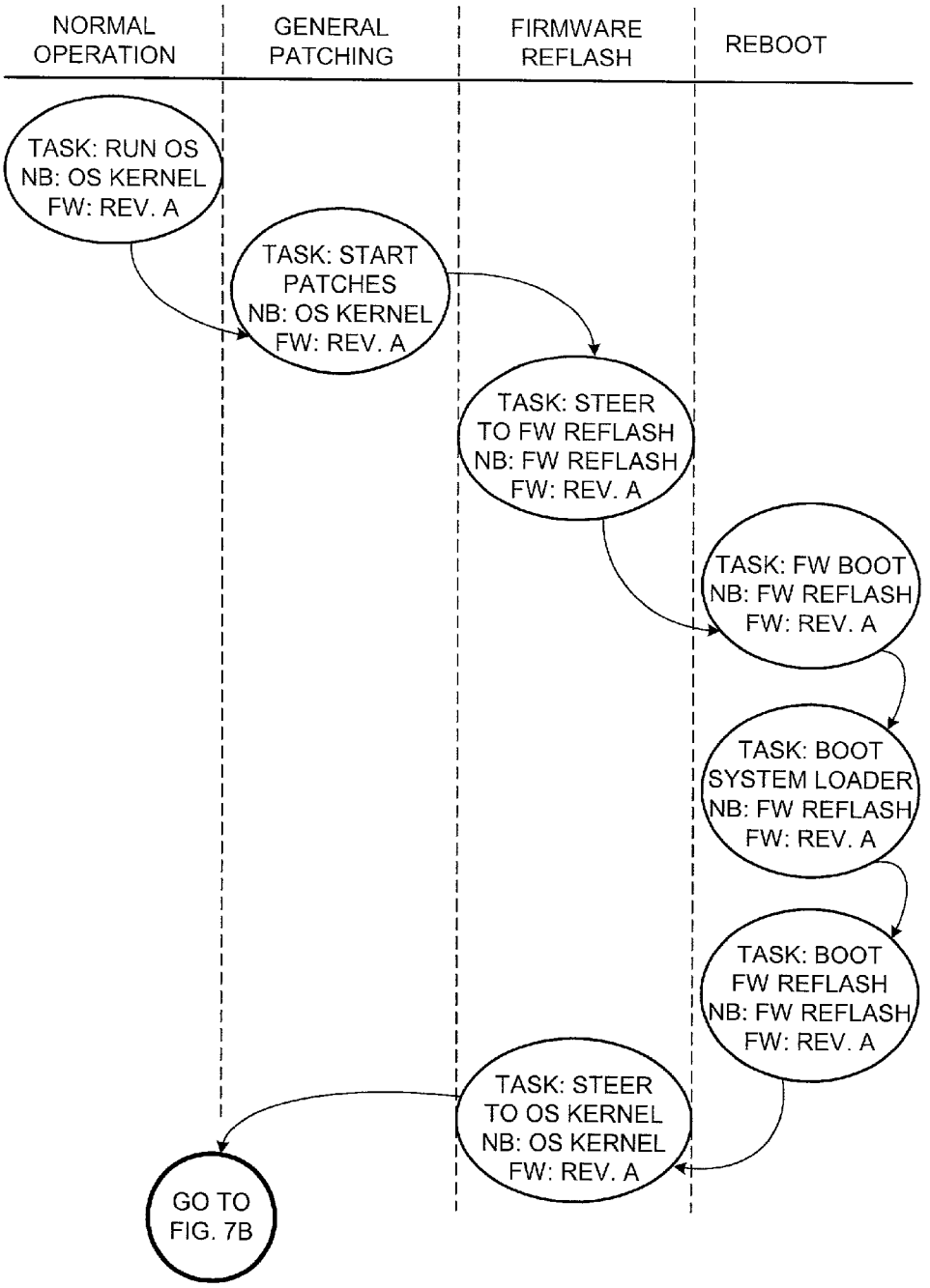

NORMAL OPERATION
GENERAL PATCHING
FIRMWARE REFLASH
REBOOT
TASK: RUN OS
NB: OS KERNEL
FW: REV. A
TASK: START PATCHES
NB: OS KERNEL
FW: REV. A
TASK: STEER TO FW REFLASH
NB: FW REFLASH
FW: REV. A
TASK: FW BOOT
NB: FW REFLASH
FW: REV. A
TASK: BOOT SYSTEM LOADER
NB: FW REFLASH
FW: REV. A
TASK: BOOT FW REFLASH
NB: FW REFLASH
FW: REV. A
TASK: STEER TO OS KERNEL
NB: OS KERNEL
FW: REV. A
GO TO FIG. 7B

FIG. 7A

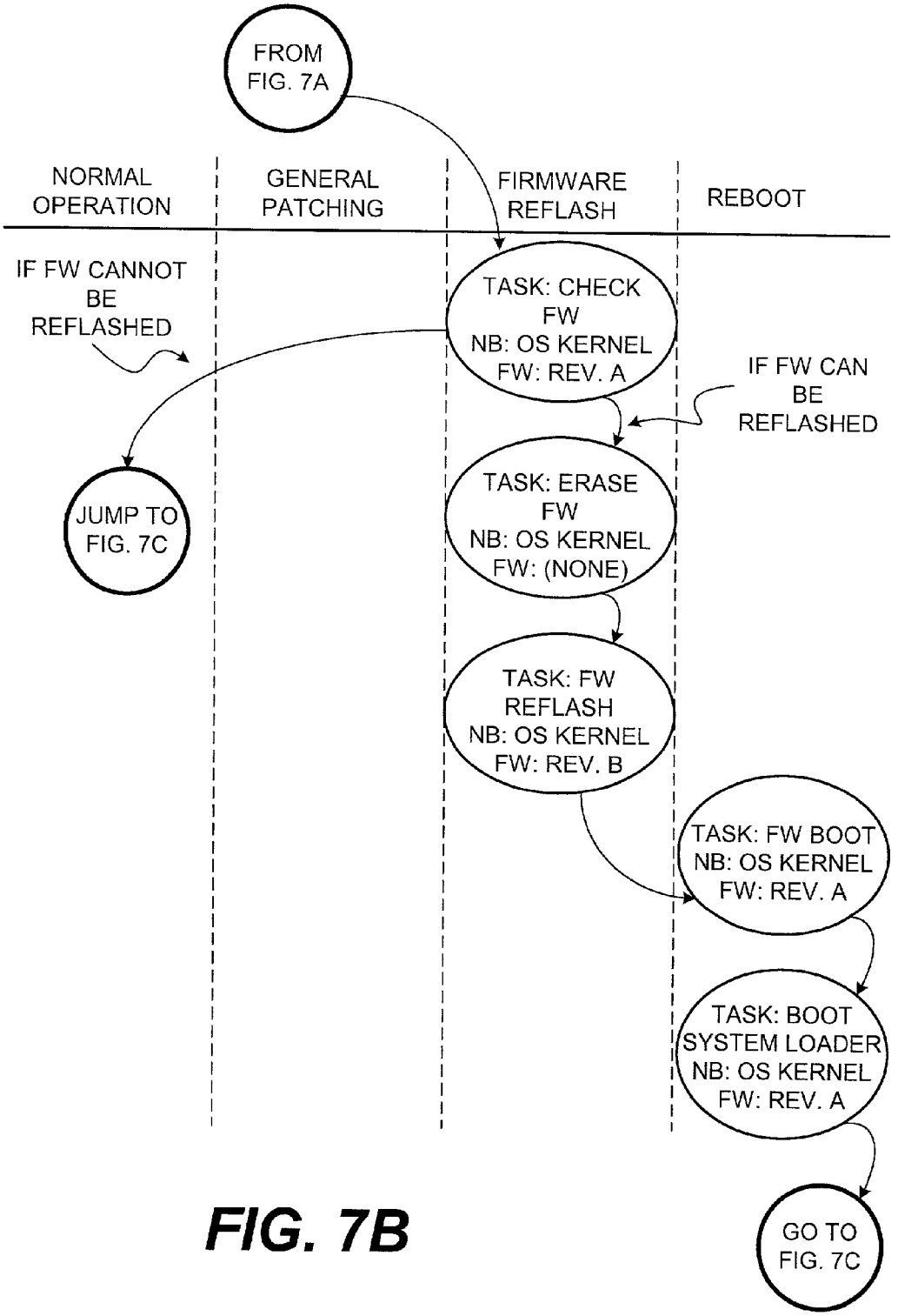

FROM FIG. 7A
NORMAL OPERATION
GENERAL PATCHING
FIRMWARE REFLASH
REBOOT
IF FW CANNOT BE REFLASHED
TASK: CHECK FW NB: OS KERNEL FW: REV. A
IF FW CAN BE REFLASHED
JUMP TO FIG. 7C
TASK: ERASE FW NB: OS KERNEL FW: (NONE)
TASK: FW REFLASH NB: OS KERNEL FW: REV. B
TASK: FW BOOT NB: OS KERNEL FW: REV. A
TASK: BOOT SYSTEM LOADER NB: OS KERNEL FW: REV. A
GO TO FIG. 7C

FIG. 7B

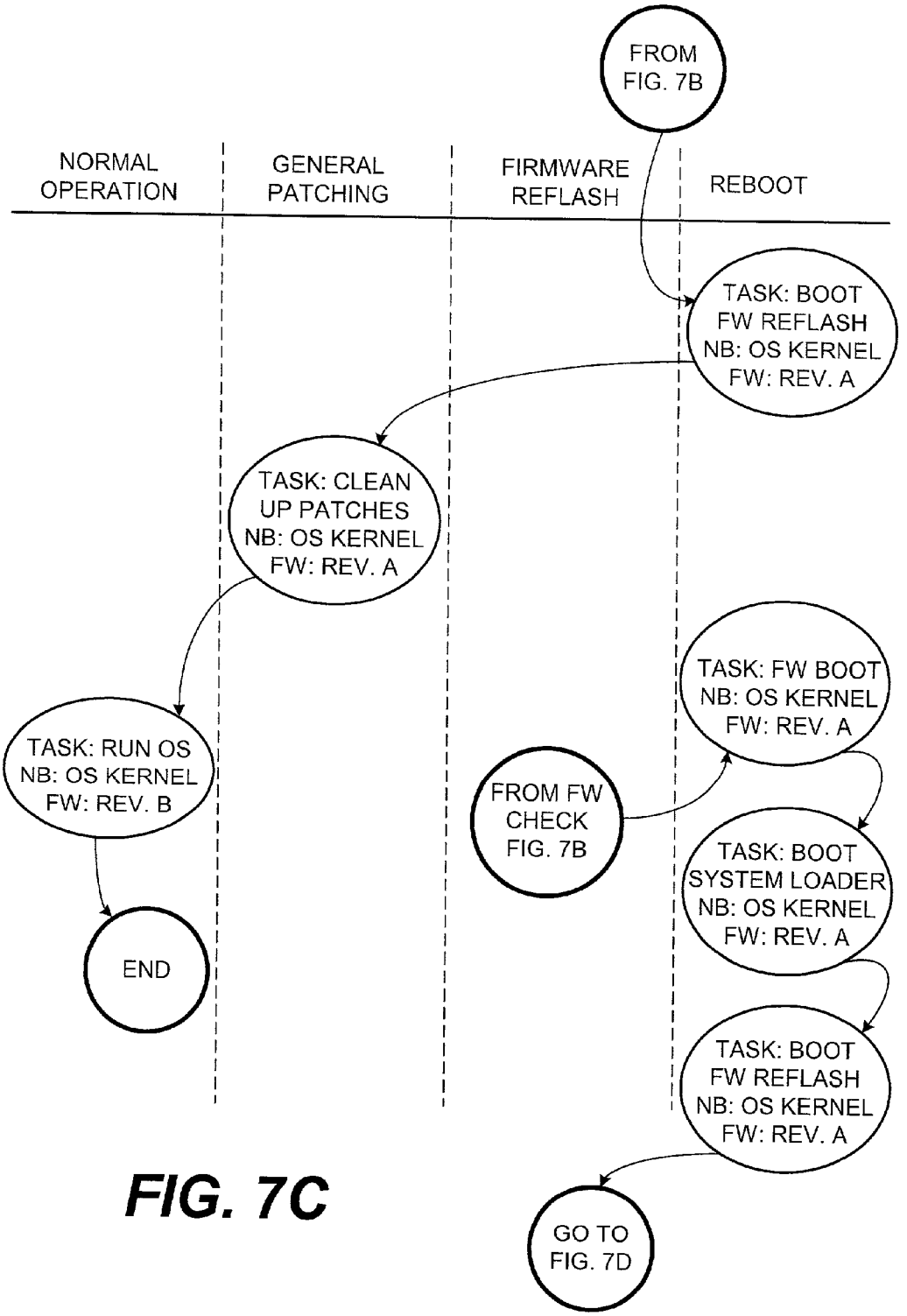

FROM FIG. 7B
NORMAL OPERATION
GENERAL PATCHING
FIRMWARE REFLASH
REBOOT
TASK: BOOT FW REFLASH NB: OS KERNEL FW: REV. A
TASK: CLEAN UP PATCHES NB: OS KERNEL FW: REV. A
TASK: FW BOOT NB: OS KERNEL FW: REV. A
TASK: RUN OS NB: OS KERNEL FW: REV. B
FROM FW CHECK FIG. 7B
TASK: BOOT SYSTEM LOADER NB: OS KERNEL FW: REV. A
END
TASK: BOOT FW REFLASH NB: OS KERNEL FW: REV. A
GO TO FIG. 7D

FIG. 7C

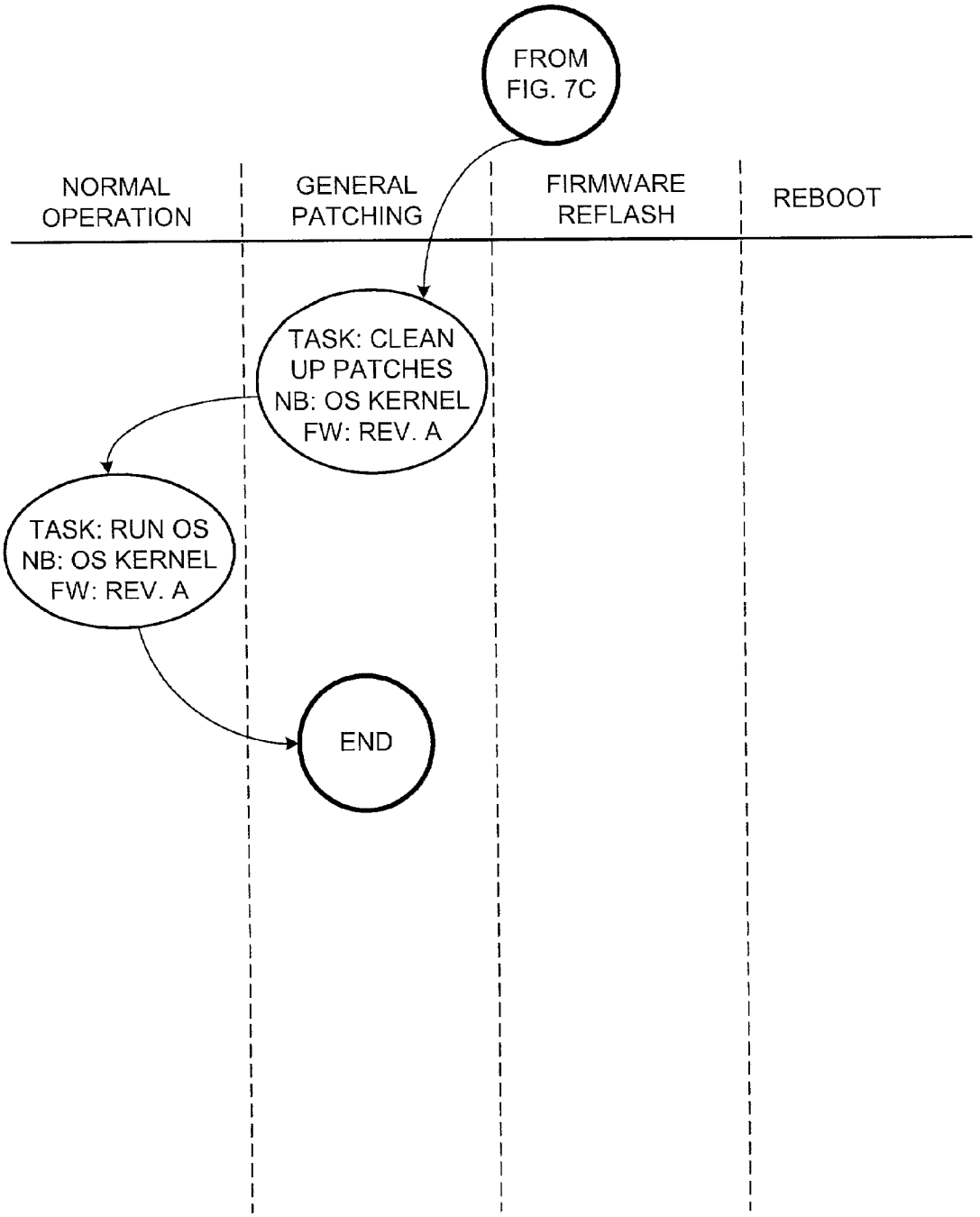

FROM
FIG. 7C
NORMAL
OPERATION
GENERAL
PATCHING
FIRMWARE
REFLASH
REBOOT
TASK: CLEAN
UP PATCHES
NB: OS KERNEL
FW: REV. A
TASK: RUN OS
NB: OS KERNEL
FW: REV. A
END

FIG. 7D

# SYSTEM AND METHOD FOR UPDATING FIRMWARE

## FIELD OF THE INVENTION

The present invention generally relates to microprocessor based computing devices, which operate pursuant to program instructions or firmware stored in nonvolatile memory. More specifically, the invention relates to a system and method for enabling a system administrator to remotely deliver firmware updates to a plurality of network coupled computing devices.

## BACKGROUND OF THE INVENTION

Microprocessors and memory devices are key elements in computing devices. When power is initially applied to a computing device, a microprocessor attempts to read a particular memory address in a non-volatile memory device to receive preliminary instructions. After reading the preliminary instructions, the microprocessor executes the instructions thereby permitting the computing device to become operational. This process is commonly known as "booting." As a result of a "boot" process, the microprocessor transitions from a non-functional mode to an operational mode upon power initialization by reading and executing essential instructions commonly known as firmware.

The firmware or Basic Input/Output System (BIOS) in a Personal Computer (PC) dictates what the PC can accomplish without accessing programs from a disk storage device. The firmware or BIOS contains all the programming code required to control the keyboard, display monitor, mouse, disk drives, serial communication ports, and a number of miscellaneous functions. The BIOS is typically placed in a read only memory (ROM) integrated circuit device that is included within the PC. This mode of delivering the firmware or BIOS ensures that the BIOS will always be available and will not be damaged by disk failures. It also enables a PC to "boot" itself. After the PC has successfully loaded and executed the BIOS, the PC may then be configured to load an operating system into random access memory (RAM).

An operating system is one of the most important programs on a PC. Most general-purpose computers utilize an operating system for running other programs. Operating systems perform basic tasks, such as recognizing input from the keyboard, sending output to the display monitor, managing directories and files on fixed disks, and controlling peripheral devices such as disk drives and printers. Operating systems provide a software platform on top of which other programs, called applications, may run. Applications are typically written to run on top of a particular operating system. For PCs, disk operating system (DOS), operating system 2 (OS/2), Windows, and Linux are some of the most popular operating systems.

A kernel is the central module of an operating system. It is the part of the operating system that loads first, and it remains in RAM. Because the kernel resides in RAM, it is desirable for the kernel to be as small as possible while still providing all the essential services required by other parts of the operating system and applications. Typically, the kernel is responsible for memory management, process and task management, and disk management.

For large computing systems, the operating system has even greater responsibilities and powers. In this regard, the operating system ensures that different programs and users running at the same time do not interfere with each other.



The operating system is also responsible for managing security issues, including authorization for access to the system.

An electrically erasable programmable read only memory (EEPROM) device is a non-volatile memory commonly used for storing firmware used by computing devices in their respective "boot" processes. A flash EEPROM permits its entire memory to be erased in a single step. In recent years, flash EEPROMS having selective erasable/writable memory block addressing capabilities have been used extensively for storing firmware. The flash EEPROM is particularly useful as it allows firmware to be erased and upgraded by an operator without the need to physically remove and replace a ROM integrated circuit chip.

The capability to upgrade the firmware by loading programming code to a flash EEPROM both simplifies the upgrade process and reduces the costs associated with firmware upgrades. The extensive use of flash EEPROMs has also increased the reliability of the computing device, which embodies the EEPROM, because printed circuit board sockets are no longer required to support integrated circuit replacement.

However, the use of flash EEPROMS does not resolve a number of problems inherent in the process of distributing firmware updates. Because of the natural progression of the command hierarchy from firmware to operating system to applications, the firmware cannot be removed or manipulated without compromising the operating system. As a result, manual intervention is still required to install new firmware. Typically, this is accomplished by interrupting the "boot" process via keyboard input prior to the transfer of the operating system into RAM and entering a set of appropriate commands to load a boot image and the new firmware from a storage media compatible with a mobile data storage device (e.g., a CD-ROM, a magnetic tape drive, a floppy disk drive, and the like).

Manual firmware upgrades for networked computing devices are problematic for at least the reason that they may require manual repetitive operation of critical steps at what may amount to a non-trivial number of computing devices. Indeed, the services of a skilled technician is often required to perform firmware updates at each computing device even in the case where the computing devices designated for firmware updates are coupled to the same network.

## SUMMARY OF THE INVENTION

In light of the foregoing, the invention relates to a system and a method for utilizing a software application that is operable under the current firmware/operating system configuration for installing new firmware without "compromising" the operating system. A software application in accordance with the present invention may configure a computing device to install a plurality of software fixes for enhancing computing device functionality under a new firmware/operating system environment. In addition, a software application in accordance with the present invention may configure the computing device to "boot" under the new firmware/operating system environment upon subsequent system initializations.

A software application in accordance with the present invention may allow for the distribution of firmware upgrades via a network. The capability to install firmware remotely may permit a system administrator to "push" the new firmware to a plurality of network coupled computing devices, thus avoiding manual intervention at each device.

A computer system in accordance with the present invention may comprise a programmable non-volatile memory, a microprocessor, and a fixed storage device. The microprocessor may be configured to execute instructions from the programmable non-volatile memory in response to a boot request and to controllably write to the programmable non-volatile memory. The fixed storage device contains a boot image and is configured with appropriate instruction code for transitioning at least one microprocessor to an operational mode, wherein the storage device receives a modified set of boot instructions containing all execution code and data necessary to perform a firmware upgrade. After the fixed storage device stores the modified boot image, which may be delivered along with its own set of boot instructions, the fixed storage device or "boot" disk may be configured to apply the modified boot image and boot instructions upon the next microprocessor boot request. The boot image may comprise a complete copy of the present firmware installed on the computer system, as well as, a copy of the new firmware, an install application, and a flash application.

In response to the microprocessor boot request, the install application may direct the microprocessor to apply the copy of the present firmware along with the operating system and the file management system when booting the microprocessor. Next, the install application may instruct the microprocessor to replace the firmware in the non-volatile memory with the new firmware. Having completed the firmware upgrade, the install application may contain the necessary instructions to redirect the microprocessor to use the new firmware in response to subsequent microprocessor boot requests. The install application may also install an operating system along with any software patches that require the new firmware/operating system environment. In addition, the install application may perform a file system clean-up operation on the fixed storage device.

The present invention can also be viewed as providing a method for performing a firmware upgrade via a network. In its broadest terms, the method can be described by the following steps: delivering a firmware install patch containing a modified boot image to a boot disk within a plurality of computer systems on a network; initiating an install application; modifying a system loader to direct a microprocessor to execute instructions from the modified boot image upon a microprocessor boot request; initiating a microprocessor boot that loads instructions in the modified boot image; erasing the firmware stored in the computer system; and writing the new firmware.

Other features and advantages of the present invention will become apparent to one skilled in the art upon examination of the following drawings and detailed description. It is intended that all such additional features and advantages be included herein within the scope of the present invention, as defined by the claims.

## BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood from the detailed description given below and from the accompanying drawings of the preferred embodiment of the invention. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views. While the invention is described in connection with these drawings, there is no intent to limit it to the embodiment or embodiments disclosed therein. On the contrary, the intent is to cover all alternatives, modifications, and equivalents included within the spirit and scope of the invention as defined by the appended claims.

FIG. **1** is a functional block diagram of a computer system with peripheral devices that may be configured to receive, store, distribute, and execute a firmware patch in accordance with the present invention.

FIG. **2** is a schematic diagram illustrating various items that may be stored within a boot image on the fixed data storage device within the computer system of FIG. **1**.

FIG. **3** is a schematic diagram illustrating a modified boot image in accordance with the present invention.

FIG. **4** is a schematic diagram illustrating a firmware patch that may be received, stored, and executed by the computer system of FIG. **1**.

FIG. **5** is a schematic diagram illustrating an exemplary network configuration that may be used to distribute and execute the firmware patch of FIG. **4**.

FIG. **6** is a flowchart illustrating a method for delivering and installing firmware upgrades that may be practiced via a computer system coupled to the network of FIG. **5**.

FIGS. **7**A–**7**D present a schematic diagram illustrating an exemplary state table that further details a firmware upgrade in accordance with the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention generally relates to a system and network for upgrading firmware in a computing device. It is significant to note that the system and method of the present invention are presented in association with a particular exemplary implementation using a computer system communicatively coupled to a network. In the particular example presented, which represents a preferred embodiment, a system administration node within the network is used to distribute a firmware patch to machines having a firmware version that is designated for a firmware upgrade. The firmware patch may also be configured to verify that each particular computer system is at an appropriate firmware level to successfully execute the desired firmware upgrade. It will be appreciated that the firmware patch may be configured to successfully upgrade a computer system having a plurality of compatible preceding firmware versions to the new firmware version.

Furthermore, the firmware patch may be self-initiating. In alternative embodiments, the firmware patch may be remotely initiated by a system administrator or other operator. It will be appreciated by those skilled in the art that both the system and the method for upgrading firmware in a computing device in accordance with the present invention may be selectively applied to any number of suitably configured computing devices coupled to the network.

Reference is now directed to FIG. **1**, which illustrates a computer system with peripheral devices that may be configured to receive, store, distribute, and execute a firmware patch in accordance with the present invention. As shown in FIG. **1**, a computer system **100** may comprise a computer **110**, a display monitor **125**, a keyboard **135**, and a mouse **145**. As further illustrated in FIG. **1**, various peripheral devices may be integrated with the computer **110** to permit other methodologies for transferring information both to and from the computer **110**. For example, a printer **155** and a scanner **165** may also be communicatively coupled to the computer **110**. In addition, the computer **110** may be coupled to an external network **200** thus allowing the computer **110**

to send and receive data via the external network **200** to remote computing devices. As shown, the external network **200** may be a local area network (LAN), a wide area network (WAN), or other similar network.

The computer **110** may comprise a microprocessor **112** and a memory **300** in communication with each other via a local interface **113**. The memory **300** may comprise, for example, a fixed data storage device **310**, a random access memory (RAM) **320**, and a non-volatile memory (ROM) **330**. Together the microprocessor **112** and the various memory devices comprising the computer memory **300** (i.e., the fixed data storage **310**, RAM **320**, and non-volatile memory **330**) operate to load firmware **335** to "boot" the computer **110**, load an operating system, manage files, and execute programs. As previously described, the firmware **335** controls what the microprocessor **112** can accomplish without accessing programs from a disk storage device (i.e., the fixed data storage device **310** or mobile data storage device **122**).

The firmware **335** may contain all the programming code required to control the keyboard **135**, display monitor **125**, mouse **145**, mobile data storage **122**, other input/output devices, and a number of miscellaneous functions. In order to ensure that the firmware **335** is always available for the microprocessor **112**, the firmware **335** may be stored in the non-volatile memory **330**. It is significant to note that the term "volatile" refers to memory devices that generally lose data stored therein upon the loss of power. Thus, a non-volatile memory device refers to a memory device that does not lose stored data upon the loss of power.

After loading the firmware **335**, the microprocessor **112** and memory **300** may work together to transfer the operating system from the fixed data storage device **310** to the RAM **320**. Once the operating system has been successfully loaded into the RAM **320**, the computer **110** may execute application software suited to coordinate data transfers between the RAM **320** and various input/output peripheral interfaces. For example, the computer **110** may further comprise a video display adapter **114**, a plurality of input interfaces **116**, a modem/network interface card (NIC) **118**, a plurality of output interfaces **120**, and a mobile data storage device **122**, all of which may also be coupled to the local interface **113**.

Having generally introduced and described the computer system **100** with regard to FIG. **1**, reference is now directed to FIG. **2**, which presents a schematic illustrating various items that may be stored on the fixed data storage device **310** within the computer system **100** of FIG. **1**. As illustrated in FIG. **2**, the memory **300** may comprise a boot image **400** that may be stored on the fixed data storage device **310**. The boot image **400** may comprise a system loader **410**, a system loader configuration file **420**, and a plurality of RAM designated executables **430**. As further illustrated in FIG. **2**, the RAM designated executables **430** may comprise a bootable kernel **450**, an operating system **434**, a file management system **436**, and applications **438**. Each of the aforementioned items comprising the boot image **400** may contain instructions or executable programming code compatible with microprocessor **112** (FIG. **1**). As such, the system loader **410**, the system loader configuration file **420**, the bootable kernel **450**, the operating system **434**, the file management system **436**, and the applications **438**, as well as, any other code stored on the fixed data storage device **310** may be identified by a start memory address and an indicator indicative of respective size.

When power is initially applied to the computer **110** (FIG. **1**), the microprocessor **112** (FIG. **1**) may be supplied power, and in response, may be configured to read particular memory addresses in the non-volatile memory device **330** (e.g., firmware **335**) to receive preliminary instructions. Next, the microprocessor **112** (FIG. **1**) may execute the firmware instructions thereby permitting the computer **110** (FIG. **1**) to become operational. The firmware **335** may contain all the programming code required to control the keyboard **135**, display monitor **125**, mouse **145**, fixed data storage devices **310**, input interface **116**, and output interface **120**, and a number of miscellaneous functions (FIG. **1**). Once the firmware **335** is successfully processed by the microprocessor **112** (FIG. **1**), the microprocessor **112** may retrieve the boot image **400** from the fixed data storage device **310**.

As illustrated in FIG. **2**, the boot image **400** for a boot process that does not require a firmware upgrade may proceed as follows. First, the boot image **400** directs the microprocessor **112** (FIG. **1**) to the system loader **410**. The system loader **410** may be configured to add to the command infrastructure provided by the firmware **335**. The system loader **410** may build upon the firmware **335** by supplying instruction code that allows higher-level functionality than that required to interrupt the boot process. In addition, the system loader **410** may be configured to direct the microprocessor **112** (FIG. **1**) using data supplied by the system loader configuration file **420**. As illustrated in FIG. **2**, the system loader configuration file **420** may contain data suited to direct the microprocessor **112** to a plurality of RAM designated executables **430**. For example, the system loader configuration file **420** may be configured to direct the microprocessor **112** to load the bootable kernel **450**, the operating system **434**, the file management system **436**, and other applications **438** into RAM **320**. By moving a copy of the RAM designated executables **430** into RAM **320**, the computer **110** (FIG. **1**) optimizes computer system performance by taking advantage of the faster data transfer rates possible with RAM **320** than data transfer rates possible between the microprocessor **112** and the fixed data storage **310**.

As further illustrated in FIG. **2**, a boot image **400** may contain applications **438** that include a software patch **440**. A software patch is an actual piece of object code that is inserted into (or "patched" into) an executable program, such as applications **438**. The typical software patch **440** thus becomes a part of the improved application **438** to which it was applied. As a result, the typical software patch **440** together with the improved application **438** rely on the operating system **434**, the file management system **436**, the bootable kernel **450**, the system loader configuration file **420**, the system loader **410**, and the firmware **335** to supply an appropriate command structure for manipulating data within the computer **110** (FIG. **1**).

Often, a software patch **440** will be accompanied by an associated install script, which may contain specific instructions tailored to the particular requirements of the installation. In this context, a script is a file containing a sequence of operating system commands that may also contain means for controlling the sequence of such execution. It is significant to note that an executable program or any other method of directing the computer **110** to perform the necessary tasks may be utilized.

Improved Method for Implementing Firmware Upgrades

Having described a typical boot process with regard to the manipulation and processing of the various items comprising an exemplary boot image **400** with regard to FIG. **2**, reference is now directed to FIG. **3**, which presents a

modified boot image in accordance with the present invention. As illustrated in FIG. **3**, the memory **300** may comprise a modified boot image **480** that may be stored on the fixed data storage device **310**. The modified boot image **480** may comprise a system loader **410**, a system loader configuration file **420**, and a firmware patch **500** in accordance with the present invention.

In a preferred embodiment, the system loader configuration file **420** of the modified boot image **480** may be configured to direct the system loader **410** to execute the firmware patch **500** upon the next boot request. The firmware patch **500** differs from prior art software patches, such as the exemplary typical software patch **440** (FIG. **2**) for at least the reason that prior art software patches are reliant upon the current command infrastructure as defined by the present firmware version and operating system. The firmware patch **500** is unique in that it contains the execution code necessary to perform a firmware upgrade. Specifically, the firmware patch **500** contains a bootable kernel, firmware update logic, and a non-volatile memory interface. The bootable kernel may further comprise a system loader interface and reboot logic.

The firmware patch **500** permits a system administrator to distribute a firmware upgrade to a class of machines via a network. In addition, the firmware patch **500** permits a system administrator to "push" the firmware update to a plurality of network connected computer systems simultaneously. Furthermore, the firmware patch **500** can be bundled along with other software patches that may rely on the firmware update. Once the firmware patch **500** has upgraded the firmware **335** within each respective computer system **100** (FIG. **1**), the associated executable application may be configured to modify the boot image **480** such that the computer system **100** is programmed to boot in the new firmware/operating system environment rather than repeatedly applying the firmware patch **500** upon each power-up or computer system boot.

Reference is now directed to FIG. **4**, which presents a schematic diagram illustrating the various elements comprising the firmware patch **500** of FIG. **3**. In this regard, the firmware patch **500** may comprise a patch memory map **550** that may contain all the necessary function code and data to perform the designated firmware upgrade. As illustrated in FIG. **4**, the patch memory map **550** may comprise a firmware revision **552**, an install application **554**, and a flash application **556**. As also illustrated in FIG. **4**, the flash application **556** may comprise a bootable kernel **560**, which may further comprise a system loader interface **562** and a reboot logic **564**. The bootable kernel **560**, the system loader interface **562**, and the reboot logic **564** may be compatible with the underlying firmware presently stored within the nonvolatile memory **330** (FIG. **3**) on the computer system **100** (FIG. **1**).

In a preferred embodiment, the install application **554** may be configured to load the bootable kernel **560**, the system loader interface **562**, and the reboot logic **564** from the flash application **556** on the fixed data storage device **310** or "boot" disk. As previously described, the modified boot image **480** (FIG. **3**) may comprise the firmware patch **500**, which may comprise the modified memory map **550**. The install application **554** may also be configured to direct the system loader **410** to load the firmware patch **500** and guide the computer **110** (FIG. **1**) through the firmware upgrade boot process. Once the computer **110** is operative in a mode that is compatible with the presently installed firmware **335**, the flash application **556** may verify that the presently installed firmware **335** is indeed a version that is designated for the firmware upgrade. If it is determined that the present firmware version is suited for the upgrade, the flash application **556** may be configured to replace the contents of the non-volatile memory device **330** with the firmware revision **552**. Next, the install application **554** may include code necessary to apply an upgraded operating system, software patches, and other application programs compatible with the new firmware (i.e., the firmware revision **552**). Last, the install application **554** may include code to load a suitable boot image for the new command environment. This may include the necessary instruction for directing subsequent boot processes to the boot image for the new command environment and for removing the firmware revision **552** and the flash application **556** from the boot disk.

Reference is now directed to FIG. **5**, which presents a schematic diagram illustrating an exemplary network configuration that may be used to distribute and execute the firmware patch **500** of FIG. **4**. In this regard, FIG. **5** illustrates a network environment **600** that uses a plurality of nodes to transfer data to and from a plurality of computing devices. More specifically, the network environment **600** comprises a plurality of workstations **100***a*–**100***f*, herein labeled, "A," "B," "C**1**" "D," "E," and "F" in communication with each other via communication links **175** and a network **200**. Each of the workstations **100***a*–**100***f* may be configured identical to the workstation **100** illustrated in FIG. **1**. As illustrated in FIG. **5**, the network **200** comprises a plurality of nodes **210***a*–**210***e* in communication with each other via a plurality of network communication links **215**. It will be appreciated that the network communication links **215** may comprise a plurality of singular or grouped Ethernet, T**1**, T**3**, E**1**, E**3**, synchronous optical network (SONET) or other data network communication links. As illustrated, the network **200** may comprise a plurality of nodes **210***a*–**210***e*.

As also illustrated in FIG. **5**, the network **200** may be configured in a ring configuration such that either of two different physical pathways formed by the various network communication links **215** may be traversed by data transfers between any of the various workstations **100**. For example, data originating from workstation **100***a*, herein labeled "A," may be communicated along a first communication link **175** to a first node **210***a*. As shown, node **210***a* may be in communication with two other nodes **210***b* and **210***e*. As a result of the network structure illustrated in FIG. **5**, each of the workstations **100***b*, **100***c*, **100***d*, **100***e* and **100***f* may receive data originating from workstation **100***a* via the network **200** and the various communication links **175** that interconnect each of the workstations **100** to a network node **210**.

In a well-known manner, data originating at computer system **100***b* and suitably configured to designate computer system **100***d* as its destination may be transmitted along communication link **175** to network node **210***b* of the network **200**. Network node **210***b* may then use information contained within the data to identify the network node associated with a designated destination computer system. In the case of computer system **100***d*, the appropriate destination node is network node **210***d*. Those skilled in the art will appreciate that the data may traverse the network **200** via the path identified by network nodes **210***b*, **210***c*, and **210***d*. Alternatively, the data may traverse network nodes **210***b*, **210***a*, **210***e*, and **210***d*.

Having been properly transferred from a first or source network node **210***b* to a second or destination network node **210***d* within the network **200**, the data may then be transmitted from the second network node **210***d* via the communication link **175** to the designated destination computer

system **100***d*. It will be appreciated that the network environment **600** may be used to transmit video, voice, and text data between each of the interconnected computer systems **100***a*–**100***f*. It will be further appreciated that the network environment **600** may comprise bi-directional communication links **175** and bi-directional network nodes **210***a*–**210***e* to permit simultaneous video, voice, and text data transfers to and from each of the computer systems **100***a*–**100***f* coupled to the network **200**. As a result, it is possible to configure the firmware patch **500** of the present invention to provide suitable feedback to a system administrator **610** that "pushes" the firmware upgrade to a plurality of networked computer systems **100***b*–**100***f* to indicate the status of the firmware upgrade. For example, if the flash application **556** determines that the presently installed firmware on computer system **100***e* is not suited for the current firmware patch **500**, the flash application **556** may be configured to report accordingly to a suitably configured firmware upgrade database status application (not shown) executing at computer system **100***a* on the network **200**. Similarly, if the firmware upgrade has been successfully installed, each of the upgraded computer systems **100***b*–**100***f* may be configured to report the same to the firmware upgrade status application.

It is significant to note that the network **200** is presented for simplicity of illustration and description, with a limited number of network nodes **210***a*–**210***e* and network communication links **215**. Those skilled in the art will appreciate that, in more practical configurations, a network **200** may comprise any number of network nodes **210***a*–**210***e* and network communication links **215** necessary to communicatively couple remotely located computer systems **100***a*–**100***f*.

Having briefly described a network environment **6**OO (FIG. **5**), which may support remote application of the firmware patch **500**, reference is now directed to FIG. **6**, which illustrates a method for delivering and installing firmware upgrades that may be practiced via a workstation coupled to the network of FIG. **5**. As illustrated in FIG. **6**, a method for performing firmware upgrades **700** may begin with step **705**, herein labeled, "Start." Next, as indicated in step **710**, the method for performing firmware upgrades **700** may deliver a firmware install patch to a boot disk on each workstation **100** (FIG. **1**) that is designated to receive the firmware upgrade. Once the firmware install patch has been stored on the boot disk within a workstation **100** (FIG. **1**), the install application **554** (FIG. **4**) may be initiated as shown in step **715**. The method for performing firmware upgrades **700** may continue by performing a verification of the firmware version presently operative on the respective workstation **100**, as indicated in the query of step **720**. If the determination in step **720** is negative, the method for performing firmware upgrades **700** may be configured to notify an operator that the presently installed firmware is incompatible with the intended firmware upgrade as shown in step **725**. Having notified the operator, the method may proceed to terminate, as indicated by the flowchart of FIG. **6**.

Otherwise, if the determination in step **720** is affirmative, the method for performing firmware upgrades may continue by performing step **730** where the system loader **410** (FIG. **3**) may be configured to select the flash application **556** (FIG. **4**) upon the next boot of the computer system **100** (FIG. **1**). Next, the install application **554** (FIG. **4**) may trigger a boot of the microprocessor **112** (FIG. **1**) as indicated in step **735**. With the flash application **556** (FIG. **4**) designated in the modified boot image **550** (FIG. **4**), the method for performing a firmware upgrade **700** may proceed by executing the flash application **556** (FIG. **4**) as shown in step **740**. With the computer system appropriately configured to allow the microprocessor **112** (FIG. **1**) to install the firmware upgrade into the non-volatile memory device **330** without compromising the operating system, the method may now use the firmware update logic **570** and the non-volatile memory interface **580** from the flash application **556** (FIG. **4**) to load the new firmware as shown in step **745**. As illustrated in step **750**, the method for performing firmware upgrades may use the flash application **556** (FIG. **4**) to select the operating system **434** (FIG. **2**) upon the next boot of the computer system **100** (FIG. **1**).

Having installed the firmware revision **552** (FIG. **4**) in the non-volatile memory device **330** of the computer system **100** (FIG. **1**) in step **745**, and reset the system loader configuration file **420** (FIG. **2**) to select the operating system kernel for transfer into RAM **320** (FIGS. **1**–**3**), the install application **554** (FIG. **4**) may be configured to boot the microprocessor as indicated in step **755**. As further illustrated in step **760** of the flowchart of FIG. **6**, the method for performing firmware upgrades **700** may be configured to pause while the newly installed firmware revision **552** (FIG. **4**) executes and the reconfigured system loader **410** transfers the operating system kernel into RAM **320** (FIGS. **1**–**3**). Once the boot process has completed, the method for performing firmware upgrades **700** may be configured to clean up the file system by removing the flash application **556** and the firmware revision **552** from the on the fixed storage data device **310** (FIG. **1**), as illustrated in step **765**. The method for performing firmware upgrades **700** may then terminate as indicated in step **770** herein labeled, "End."

Any process descriptions or blocks in the flowchart of FIG. **6** should be understood to represent modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process for performing firmware upgrades **700**. Alternate implementations are included within the scope of the preferred embodiment of the present invention in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present invention.

It will be appreciated that the methods for performing firmware upgrades **700** in accordance with the present invention may comprise an ordered listing of executable instructions for implementing logical functions and can be embodied in any computer-readable medium for use by or in connection with an instruction execution system, apparatus, or device, such as a computer-based system, processor-containing system, or other system that can fetch the instructions from the instruction execution system, apparatus, or device and execute the instructions. In the context of this document, a "computer-readable medium" can be any means that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The computer readable medium can be, for example but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, device, or propagation medium. More specific examples (a non-exhaustive list) of the computer-readable media would include the following: an electrical connection (electronic) having one or more wires, a portable computer diskette (magnetic), a random access memory (RAM) (electronic), a read-only memory (ROM) (electronic), an erasable programmable read-only memory (EPROM or Flash memory) (electronic), an optical fiber (optical), and a portable compact disc

read-only memory (CDROM) (optical). Note that the computer-readable medium could even be paper or another suitable medium upon which the program is printed, as the program can be electronically captured, via for instance optical scanning of the paper or other medium, then compiled, interpreted or otherwise processed in a suitable manner if necessary, and then stored in a computer memory.

Reference is now directed to FIGS. **7**A–**7**D, which present a schematic diagram illustrating an exemplary state table that further details a firmware upgrade in accordance with the present invention. In this regard, the state table may be characterized by a plurality of state types as labeled generally across the top of each of the FIGS. **7**A–**7**D. As shown in FIGS. **7**A–**7**D, the state types may comprise normal operation (i.e., normal operation of a computer **110**), general patching (i.e., operations using a high level patch application that typically include an install script), firmware reflash, and reboot operations.

Normal operation may comprise running various applications that have been loaded into RAM **320** (FIGS. **1**–**3**) from the fixed storage device **310** (FIGS. **1**–**3**). General patching operations may comprise network and file system manipulations to modify RAM designated executables **430** (FIG. **2**). Firmware reflash operations, on the other hand, may comprise non-volatile memory **330** manipulations (e.g., erasing and writing). Finally, reboot operations may comprise tasks associated with identifying a source for data instructions to be used when initializing the computer **110** (FIG. **1**). For example, the firmware **335** (FIGS. **1**–**3**), the modified boot image **480** (FIG. **3**), or the fixed data storage device **310** (FIGS. **1**–**3**).

As illustrated in FIGS. **7**A–**7**D, each of the states in the state table may be identified by a task (TASK), a variable indicating the next boot source (NB), and a variable indicating the firmware version (FW) present in the non-volatile memory device **330** (FIGS. **1**–**3**). It will be appreciated by those skilled in the art that the progression through the various states illustrated in FIGS. **7**A–**7**D is by way of example only. In fact, multiple variations are possible (i.e., a number of states may be encountered out of the exemplary order presented) all such variations are deemed within the scope of the preferred embodiment of the present invention.

It should be emphasized that the above-described embodiments of the present invention, particularly, any "preferred" embodiments, are merely possible examples of implementations, merely set forth for a clear understanding of the principles of the invention. Many variations and modifications may be made to the above-described embodiment(s) of the invention without departing substantially from the spirit and principles of the invention. For example, it will be appreciated by those skilled in the art that portions of code which include one or more executable instructions for implementing specific logic functions or steps in the process for performing firmware upgrades **700** may be implemented in hardware. If implemented in hardware, as in an alternative embodiment, the method for performing firmware upgrades **700** may be implemented with any, or a combination, of the following technologies, which are all well known in the art: a discrete logic circuit(s) having logic gates for implementing logic functions upon data signals, an application specific integrated circuit (ASIC) having appropriate combinational logic gates, a programmable gate array(s) (PGA), a field programmable gate array (FPGA), etc. All such modifications and variations are intended to be included herein within the scope of the present invention and protected by the following claims.

Therefore, having thus described the invention, at least the following is claimed:

**1**. A computer system communicatively coupled to a network, comprising:

an operating system;

a programmable non-volatile memory;

at least one microprocessor operatively coupled to execute at least one instruction from the programmable non-volatile memory in response to a boot request, the microprocessor configured to controllably write to the programmable non-volatile memory; and

at least one fixed storage device operatively coupled to the at least one microprocessor, wherein the at least one fixed storage device receives from the network at least a portion of a boot image comprising:

a system loader;

a firmware patch;

a configuration file modifiable to direct the system loader to execute the firmware patch instead of the operating system in response to a subsequent boot request; and

the firmware patch configured to write a firmware upgrade to the programmable non-volatile memory, the firmware patch comprising:

an install application;

a firmware revision containing at least one instruction different from firmware within the programmable non-volatile memory; and

a flash application having a bootable kernel, firmware update logic, and a non-volatile memory interface, wherein the firmware update logic is executable on the microprocessor to write the firmware revision to the programmable non-volatile memory.

**2**. The computer system of claim **1**, wherein the at least one fixed storage device receives and stores new firmware.

**3**. The computer system of claim **1**, wherein the at least one fixed storage device receives and stores an application.

**4**. The computer system of claim **1**, wherein the bootable kernel comprises a system loader interface and reboot logic.

**5**. The computer system of claim **4**, wherein the bootable kernel comprises an operating system.

**6**. The computer system of claim **4**, wherein the bootable kernel comprises a file management system.

**7**. A computer network, comprising:

a plurality of computer systems communicatively coupled to a network infrastructure, each of the plurality of computer systems configured with a non-volatile memory containing a common firmware version designated for replacement and a fixed storage device containing a boot image having appropriate instruction code suited to transition the respective computer system to an operational mode;

a user input device communicatively coupled to at least one computer system communicatively coupled to the network infrastructure, the at least one computer system configured with write access permission for the respective fixed storage device associated with each of the plurality of computer systems, wherein an input from the user input device initiates a transfer of a modified boot image to the plurality of computer systems, the modified boot image comprising a revised firmware, a configuration file, an install application, and a firmware patch having a bootable kernel different from an operating system operable on the respective computer system, the configuration file modifiable to select the firmware patch instead of the operating

system for execution on a next boot, the install application executable in the respective computer system to verify whether the revised firmware is able to successfully upgrade the common firmware version.

**8**. A method for performing a firmware upgrade, comprising:

delivering, over a network, a firmware install patch containing new firmware, an install application, a configuration file, and a flash application to boot disks within respective plurality of networked computer systems, each of said computer systems having a version of a firmware designated for the firmware upgrade, wherein the flash application comprises a bootable kernel, firmware update logic, and a non-volatile memory interface;

initiating the install application contained within the firmware install patch;

modifying the configuration file in the firmware install patch to direct a system loader to execute the firmware install patch instead of an operating system in each computer system in response to a subsequent microprocessor reset;

initiating a microprocessor reset;

executing the flash application in response to the initiated microprocessor reset;

erasing, by the firmware update logic, the firmware within each of the plurality of networked computer systems in response to execution of the flash application; and

writing, by the firmware update logic, the new firmware to each of the plurality of networked computer systems in response to execution of the flash application in each of the plurality of networked computer systems.

**9**. The method of claim **8**, wherein the delivered firmware install patch comprises at least one executable configured to verify the version of the firmware stored in the computer system prior to writing the new firmware.

**10**. The method of claim **8**, further comprising:

installing an operating system that requires the new firmware;

installing a software patch that requires the new firmware;

resetting the configuration file to redirect the system loader to select the appropriate memory address upon a subsequent microprocessor reset to apply the upgraded firmware, operating system, and software patch; and

removing the firmware install patch from the computer system.

**11**. A computer system communicatively coupled to a network, comprising:

a programmable non-volatile memory having a first firmware;

at least one microprocessor operatively coupled to controllably write to the programmable non-volatile memory and execute at least one instruction from the programmable non-volatile memory in response to a boot request; and

at least one fixed storage device operatively coupled to the at least one microprocessor, the storage device containing a firmware patch and a configuration file configurable to select the firmware patch for execution on a next boot, the firmware patch comprising:

an install application;

a second firmware different from the first firmware; and

a flash application comprising:

a bootable kernel including a system loader interface and reboot logic;

a firmware update logic; and

a non-volatile memory interface to enable the firmware update logic to upgrade the first firmware in the programmable non-volatile memory with the second firmware,

the install application executable on the microprocessor to verify whether the second firmware is able to successfully upgrade the first firmware.

**12**. The computer system of claim **11**, further comprising a system loader to execute the flash application upon the next boot based on the configuration file.

**13**. The computer system of claim **11**, wherein the firmware update logic and the non-volatile memory interface store the second firmware on the non-volatile memory.

**14**. The computer system of claim **11**, wherein upon the occurrence of a next boot after updating the first firmware with the second firmware, the second firmware and a system loader transfer an operating system to a random access memory communicatively coupled to the at least one microprocessor.

**15**. The computer system of claim **11**, wherein the install application executes a file system operation.

**16**. The computer system of claim **15**, wherein the file system operation results in the removal of the firmware patch from the at least one fixed storage device.

**17**. The computer system of claim **1**, wherein the install application resets the configuration file in the boot image to select the operating system to execute on a subsequent boot after writing of the firmware revision.

**18**. The computer system of claim **1**, wherein the firmware patch is executable on the microprocessor to verify whether the firmware revision can successfully upgrade the firmware within the programmable non-volatile memory.

**19**. The computer system of claim **18**, wherein the firmware patch is executable on the microprocessor to report to a remote system whether the firmware revision can successfully upgrade the firmware within the programmable non-volatile memory.

**20**. The method of claim **8**, further comprising resetting the configuration file to direct the system loader to execute the operating system in each computer system upon a next microprocessor reset after writing the new firmware.

**21**. The computer system of claim **11**, wherein the configuration file is resettable to enable execution of the operating system in response to a next boot after updating the first firmware with the second firmware.

**22**. The computer system of claim **11**, wherein the fixed storage device further stores a boot image, the boot image containing the firmware patch and configuration file.

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