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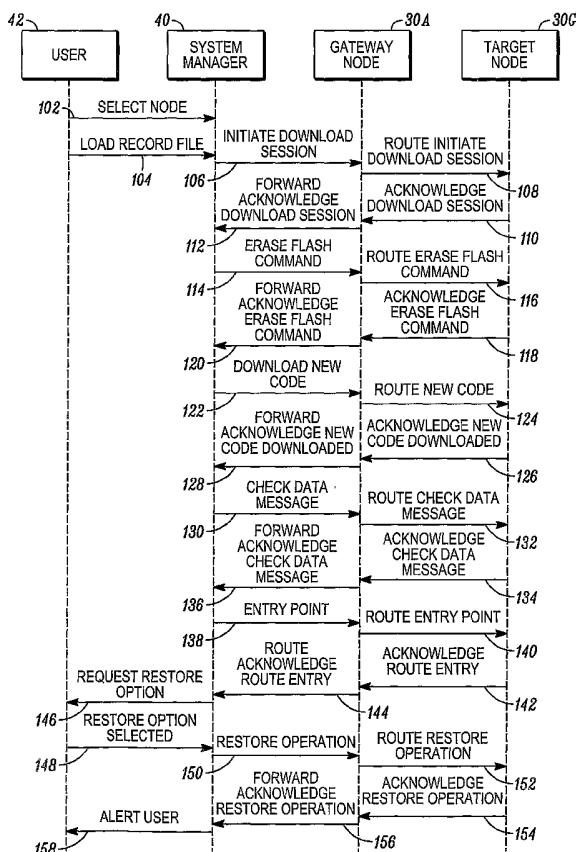
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(54) Title: SYSTEM AND METHOD FOR REPROGRAMMING NODES IN AN AUTOMOTIVE SWITCH FABRIC NETWORK



(57) Abstract: A system and method for reprogramming nodes in an automotive switch fabric network using a diagnostic interface. The switch fabric network includes a plurality of nodes joined by communication links for the transmission of data there between. The plurality of nodes includes at least one target node. The target node includes a processor, a transceiver, and a memory. The memory includes an erasable memory portion and a protected memory portion. The processor in the target node switches from executing instructions in the erasable memory portion to executing instructions in the protected memory portion during a reprogramming period when the target node erases a current software component and stores a new software component in its erasable memory portion. The diagnostic interface is adapted to transmit the new software component to the target node.

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**SYSTEM AND METHOD FOR REPROGRAMMING NODES
IN AN AUTOMOTIVE SWITCH FABRIC NETWORK**

The present application claims priority from provisional application, Serial
5 No. 60/618,726, entitled "System and Method for Reprogramming Nodes in an
Automotive Switch Fabric Network," filed October 14, 2004, which is commonly
owned and incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

10 This invention in general relates to in-vehicle communication networks and
particularly to a system and method for reprogramming nodes in an automotive switch
fabric network using a diagnostic interface.

BACKGROUND OF THE INVENTION

15 The commonly assigned United States patent application entitled "Vehicle
Active Network," serial no. 09/945,581, Publication Number US 20030043793, filed
August 31, 2001, the disclosure of which is hereby expressly incorporated herein by
reference, introduces the concept of an active network that includes a switch fabric.
The switch fabric is a web of interconnected switching devices or nodes. Control
20 devices, sensors, actuators and the like are coupled to the switch fabric, and the switch
fabric facilitates communication between these coupled devices.

The coupled devices may be indicator lights, vehicle control systems, vehicle
safety systems, and comfort and convenience systems. A command to actuate a

device or devices may be generated by a control element coupled to the switch fabric and is communicated to the device or devices via the switch fabric nodes.

In the context of vehicular switch fabric networks, a challenge is presented in terms of how data is transported across the switch fabric network to reprogram switch fabric nodes and to maintain communication while memory is being re-flashed. A
5 need exists for the ability to reprogram switch fabric nodes when upgrading software components as well as reprogramming when a diagnosis detects a fault or problem.

It is, therefore, desirable to provide a system and method to overcome or minimize most, if not all, of the preceding problems especially in the area of
10 reprogramming nodes in an automotive switch fabric network.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram illustrating an embodiment of a vehicle switch fabric network;

15 FIG. 2 is a diagram illustrating a portion of the switch fabric network connected to a plurality of interfaces and devices;

FIG. 3 is a diagram illustrating a portion of the switch fabric network connected to a diagnostic device and interface;

20 FIG. 4 is a diagram illustrating one embodiment of the components of a target node in the switch fabric network;

FIG. 5 is a diagram illustrating two memory portions of the target node in the switch fabric network; and

FIG. 6 is a message flow diagram illustrating one embodiment of the types of message that may be exchanged during the reprogramming of the target node.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, it should be understood that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION

What is described is a system and method for reprogramming nodes in an automotive switch fabric network using a diagnostic device and interface. In sum, a diagnostic device is used to download one or more record files containing software components to remote nodes in an automotive switch fabric network. The reprogramming instructions and record file(s) are routed from the diagnostic device and interface to a target switch fabric node through a gateway node. Two separate memory partitions are created in each target switch fabric node. One memory partition is erasable and contains the standard switch fabric networking software and applications (code block). The other memory partition is permanent and contains abridged switch fabric software that allows the node to function as a stand alone switch (boot block).

In one embodiment, the download process begins at the diagnostic device instructing a target node to initiate a reprogramming session. The node will switch from the code block to the boot block while continuing to function as a stand alone switch in the network. The diagnostic device may be configured to analyze the current existing software components to determine contiguous memory blocks and

send individual erase flash messages for each memory block that needs to be erased. The target node will erase the memory as instructed and then send an acknowledgement to the diagnostic device. The diagnostic device then sends one or more record files to the target node, which copies the data to memory after verifying the checksum. After all records have been sent, the diagnostic device sends the entry point for the code block and instructs the target node to restore normal operations. The target node then switches back to the code block from the boot block and re-starts applications.

Now, turning to the drawings, FIG. 1 illustrates a vehicle 20 including a network 22 to which various vehicle devices 24a-d are coupled via respective interfaces 26a-d. The vehicle devices 24a-d may be sensors, actuators, and processors used in connection with various vehicle functional systems and sub-systems, such as, but not limited to, diagnostic, control-by-wire applications for throttle, braking and steering control, adaptive suspension, power accessory control, communications, entertainment, and the like. The devices 24a-d may be external or internal to the vehicle. The embodiment in FIG. 1 includes an external device 24a and several internal devices 24b-d.

The interfaces 26a-d are any suitable interface for coupling the particular vehicle device 24a-d to the network 22, and may be wire, optical, wireless or combinations thereof. The vehicle device 24a-d is particularly adapted to provide one or more functions associated with the vehicle 20. These vehicle devices 24a-d may be data producing, such as a sensor, data consuming, such as an actuator, or processing, which both produces and consumes data. In one embodiment, the external device 24a is a diagnostic device that permits a user to exchange data with the network of the

vehicle, as will be explained further below. Data produced by or provided to a vehicle device 24a-d, and carried by the network 22, is independent of the function of the vehicle device 24a-d itself. That is, the interfaces 26a-d provides independent data exchange between the coupled device 24a-d and the network 22.

5 The connection between the devices 24a-d and the interfaces 26a-d may be a wired or wireless connection. FIG. 1 illustrates both types of connections between the diagnostic device 24a and its interface 26a, a wired connection 25 and a wireless connection 27. In the wireless connection, the device 24a and the interface 26a include wireless communication transceivers permitting the units to communicate
10 with each other via an optical or radio frequency transmission. Additionally, the interface 26a may be a single device or incorporated as a single assembly as part of a gateway node 30a. Irregardless of the type of connection or type of assembly, the interface 26a to the diagnostic device 24a should arbitrate the linking of the device 24a to the network 22 through an authentication, security and encryption process.

15 The network 22 may include a switch fabric 28 defining a plurality of communication paths between the vehicle devices 24a-d. The communication paths permit multiple simultaneous peer-to-peer, one-to-many, many-to-many, etc. communications between the vehicle devices 24a-d. During operation of the vehicle 20, data exchanged, for example, between devices 24a and 24d may utilize any available path or paths between the vehicle devices 24a, 24d. In operation, a single path through the switch fabric 28 may carry all of a single data communication between one vehicle device 24a and another vehicle device 24d, or several communication paths may carry portions of the data communication. Subsequent communications may use the same path or other paths as dictated by the then state of

the network 22. This provides reliability and speed advantages over bus architectures that provide single communication paths between devices, and hence are subject to failure with failure of the single path. Moreover, communications between other of the devices 24b, 24c may occur simultaneously using the communication paths within
5 the switch fabric 28.

The network 22 may comply with transmission control protocol/Internet (TCP/IP), asynchronous transfer mode (ATM), Infiniband, RapidIO, or other packet data protocols. As such, the network 22 utilizes data packets, having fixed or variable length, defined by the applicable protocol. For example, if the network 22 uses
10 asynchronous transfer mode (ATM) communication protocol, ATM standard data cells are used.

The internal vehicle devices 24b-d need not be discrete devices. Instead, the devices may be systems or subsystems of the vehicle and may include one or more legacy communication media, i.e., legacy bus architectures such as the Controller
15 Area Network (CAN) protocol, the SAE J1850 Communications Standard, the Local Interconnect Network (LIN) protocol, the FLEXRAY Communications System Standard, the Media Oriented Systems Transport or MOST Protocol, or similar bus structures. In such embodiments, the respective interface 26b-d may be configured as a proxy or gateway to permit communication between the network 22 and the legacy
20 device.

Referring to FIG. 2, an active network 22 in accordance with one embodiment of the present invention includes a switch fabric 28 of nodes 30a-h that communicatively couples a plurality of devices 24a-d via respective interfaces 26a-d. Connection media 32 interconnects the nodes 30a-h. The connection media 32 may

be bounded media, such as wire or optical fiber, unbounded media, such as free optical or radio frequency, or combinations thereof. In addition, the term node is used broadly in connection with the definition of the switch fabric 28 to include any number of intelligent structures for communicating data packets within the network 22 without an arbiter or other network controller and may include: switches, intelligent switches, routers, bridges, gateways and the like. For instance, in the embodiment shown in FIG. 2, the node 30a may be a gateway node that connects the diagnostic interface 26a (and the diagnostic device 24a) to the switch fabric 28. Data is carried through the network 22 in data packet form guided by the nodes 30a-h.

10 The cooperation of the nodes 30a-h and the connection media 32 define a plurality of communication paths between the devices 24a-d that are communicatively coupled to the network 22. For example, a route 34 defines a communication path from the gateway node 30a to a target node 30g. If there is a disruption along the route 34 inhibiting communication of the data packets from the gateway node 30a to the target node 30g, for example, if one or more nodes are at capacity or have become disabled or there is a disruption in the connection media joining the nodes along route 34, a new route, illustrated as route 36, can be used. The route 36 may be dynamically generated or previously defined as a possible communication path, to ensure the communication between the gateway node 30a and the target node 30g.

20 Some applications may require reprogramming of one or more nodes 30a-h in the switch fabric 28. The embodiment and topology shown in FIG. 3 advantageously permits the ability to upgrade or replace software and code in the switch fabric 28, including reprogramming software and code residing in the nodes 30a-h. FIG. 3 shows a user 42 that can interact with a diagnostic device 24a. The diagnostic device

24a contains a software manager 40 that includes instructions for initiating and controlling a reprogramming process of upgrading or replacing software and code in the switch fabric 28. The diagnostic device 24a is connected via a wired link 25 or a wireless link 27 to diagnostic interface 26a. The diagnostic interface 26a couples the diagnostic device 24a to the vehicle network 22 (and the switch fabric 28) through one of the nodes 30a-h, for example a gateway node 30a. In one embodiment, the diagnostic interface 26 is separate from the nodes 30a-h in the switch fabric network 28. However, in other embodiment, the diagnostic interface 26a and its functions may be incorporated into the gateway node 30a.

Each of the nodes 30a-h in the switch fabric 28 contain software components to enable data communications between the nodes 30a-h and devices 24a-d. A user 42 may use the diagnostic device 24a and the system manager 40 to send commands to upgrade or replace software and code in the switch fabric 28, including reprogramming software and code residing in the nodes 30a-h. For purposes of illustrating the present invention, assume that a user 42 desires to reprogram software components residing in a target node 30g. FIG. 4 shows one embodiment of a target node 30g that may be in need of new software components.

To illustrate the functionality and the adaptability of the target node 30g, it is shown to include a plurality of input/output ports 50a-d although separate input and output ports could also be used. Various configurations of the target node 30g having more or fewer ports may be used in the network 22 depending on the application. The target node 30g includes a processor 52, at least one transceiver 54, and a memory 56. The memory 56 includes an erasable memory portion 62 and a protected memory portion 64. The processor 52 is configured to transfer control and execute instructions

from software components residing in either the erasable memory portion 62 or the protected memory portion 64. The erasable memory portion 62 contains a set of software components (code block) to operate the target node 30g for normal data communications and operation within the switch fabric 28. In one embodiment, as shown in FIG. 5, the software components in the erasable memory portion 62 may include the complete software for an application layer 72, a network layer 74, and a link (or bus) layer 78. The erasable memory portion 62 may also include an embedded Distributed System Management (DSM) component 76 that can satisfy or act upon requests from the system manager 40. The DSM component 76 may be configured to work at one or more of the layers 72, 74, 78.

The protected memory portion 64 contains a set of software components (boot block) that includes functions to load software components safely and securely to the erasable memory portion 62. In one embodiment, as shown in FIG. 5, the software components residing on the protected memory portion 64 include a flash memory loader module 80, a system manager agent 82 (that can communicate with the system manager 40), and standard components for a network layer 84, and a link (or bus) layer 88. The protected memory portion 64 may also include an embedded Distributed System Management (DSM) component 86 that is similar to the DSM component 76 in the erasable memory portion 62. The protected memory portion 64 cannot be erased by the user 42, the diagnostic device 24a, or the system manager 40. The protected memory portion 64 is also not accessible from the software components residing on the erasable memory portion 62.

Upon startup of the target node 30g, control should go directly to the software components residing on the protected memory portion 64, including the flash memory

loader module 80 mentioned above. If the flash memory loader module 80 fails to initialize hardware in the target node 30g, the target node 30g may be configured to go to a low power standby. In one embodiment, the flash memory loader 80, upon node startup, will determine if valid software components reside (and is available) in the erasable memory portion 62. This will ensure that corrupted or partial software components in the erasable memory portion 62 does not deadlock the target node 30g. This determination may be done by checking a key number stored in a prescribed location in the erasable memory portion 62. If the key number is stored in the prescribed location, the processor 50 may be configured to switch control of the target node 30g from executing the software components residing on its protected memory portion 64 to the software components residing on its erasable memory portion 62.

If, however, the key number is not stored in the prescribed location, the flash memory loader 80 may assume that the software components in the erasable memory portion 62 is not valid and send a notification that the target node 30g needs to be reprogrammed. This notification may be sent to the gateway node 30a that will then forward the request to the system manager 40 residing on the diagnostic device 24a. The flash memory loader 80 should then remain in an idle state to await instructions from the system manager 40 to initiate reprogramming of the software components in the erasable memory portion 62, as will be explained in more detail below.

Additionally, the diagnostic system may be configured to allow the system manager 40 to query each node 30a-h in the switch fabric 28 to determine whether a node needs to be reprogrammed. In one embodiment, the system manager 40 may initiate a status dialogue with a target node 30g by sending a status request message to the gateway node 30a. The gateway node 30a will then route the status request

message to the target node 30g. The target node 30g may then be configured to respond to the status request message by transmitting a status response message to the gateway node 30a, who may then forward the message back to the system manager 40. Depending on the content of the status response message, a user 42 may decide to reprogram a specific target node 30g.

FIG. 6 is a message flow diagram that illustrates one embodiment of a sequence of steps that a user 42 may take in reprogramming a target node 30g. The message flow diagram shows messages that may be exchanged between the user 42, the system manager 40 (residing on the diagnostic device 24a), the gateway node 30a, and the target node 30g. The user 42 may initiate the reprogramming operation using the system manager 42 by selecting the node identification of the target node 30g to be reprogrammed (arrow 102). The user 42 may then load a record file in the system manager 40 from a host's file system (arrow 104).

The system manager 40, residing on the diagnostic device 24a, will then initiate a download session with the target node 30g. In one embodiment, the system manager 40 may send an initiate download session message through the diagnostic interface 26a to the gateway node 30a (arrow 106). The gateway node 30a will then route the initiate download session message to the target node 30g (arrow 108).

In response to receiving an initiate download session message, the target node 30g, including processor 50, may be configured to switch from executing the software components residing on its erasable memory portion 62 to the software components residing on its protected memory portion 64. As mentioned above, it is preferred that software components in both the erasable memory portion 62 and the protected memory portion 64 include at least standard software components for the network

layer 74, the Distributed System Management (DSM) component 76, and the link (or bus) layer 78. This will cause normal network functions to continue uninterrupted.

However, any applications running on the target node 30g will not be available. After switching control from the software components residing on its erasable memory

5 portion 62 to the software components residing on its protected memory portion 64, the target node 30g may then send an acknowledge download session message to the gateway node 30a (arrow 110), who will then forward the message to the system manager 40 (arrow 112).

After receiving the acknowledgement from the target node 30g, the system
10 manager 40 will then send an erase flash command to the gateway node 30a for each block of memory that needs to be erased (arrow 114). The diagnostic device 24a may be configured to analyze the current software components and send one or more commands to erase some or all of the memory blocks in erasable memory portion 62. The gateway node 30a will route the erase flash command to the target node 30g
15 (arrow 116). Upon receipt of the erase flash command, the target node 30g will erase the corresponding memory locations in the command. The target node 30g may then send an acknowledge erase flash command to the gateway node 30a (arrow 118), who will then forward the message to the system manager 40 (arrow 120).

The system manager 40 may then send a new set of compiled software
20 components to the gateway node 30a (arrow 122). The gateway node 30a will route the new set of compiled software components to the target node 30g (arrow 124). The target node 30g may then send an acknowledge new software components to the gateway node 30a (arrow 126), who will then forward the message to the system manager 40 (arrow 128). The system manager 40 may repeat the process of

downloading software components until all necessary components are received by the target node 30g.

The system manager 40 may then send a check data message to the gateway node 30a (arrow 130). In one embodiment, the check data message includes a
5 checksum for the new downloaded software components. The gateway node 30a will route the check data message to the target node 30g (arrow 132). The target node 30g will then calculate the checksum for the new set of software components into its erasable memory portion 62 and compare it against checksum received from the system manager 40. Assuming that the checksum matches, the target node 30g will
10 then write the new set of software components into its erasable memory portion 62. The target node 30g may then send an acknowledge check data message to the gateway node 30a (arrow 134), who will then forward the message to the system manager 40 (arrow 136).

The system manager 40 may then send an entry point message to the gateway
15 node 30a (arrow 138). In one embodiment, the entry point message includes an entry point for the code block. The gateway node 30a will route the entry point message to the target node 30g (arrow 140). In response, the target node 30g sends an acknowledge entry point message to the gateway node 30a (arrow 142), who will then forward the message to the system manager 40 (arrow 144).

20 Upon receiving the acknowledgement for the entry point message, the system manager 40 may then inform the user 42 about the successful completion of the download operation and provide the user 42 with an option to restore or reset the target node 30g (arrow 146). The user 42 may wish to postpone the restoration of the node until diagnosis of other nodes is complete. However, when the user 42 desires

to restore the node, the user 42 may select a restore option to the system manager 40 (arrow 148). At this point, the system manager 40 may then send a restore operation message to the gateway node 30a (arrow 150). The gateway node 30a will then route the restore operation message to the target node 30g (arrow 152).

5 After receiving the restore operation message, the target node 30g, including processor 50, will then switch from executing the software components residing on its protected memory portion 64 to the software components residing on its erasable memory portion 62. This will allow normal operation of applications to run again on the target node 30g. The target node 30g may then send an acknowledge restore
10 operation message to the gateway node 30a (arrow 154), who will then forward the message to the system manager 40 (arrow 156). The system manager 40 may then alert the user 42 that the acknowledgement was received from the target node 30g (arrow 158).

What has been described is a system and method for reprogramming nodes in
15 an automotive switch fabric network using a diagnostic interface. A diagnostic device and interface is used to download one or more record files containing software components to remote nodes in an automotive switch fabric network. The reprogramming instructions and record files are routed from the diagnostic device and interface to a target switch fabric node through a gateway node. Two separate
20 memory partitions are created in each target switch fabric node. One memory partition is erasable and contains the standard switch fabric networking software and applications (code block). The other memory partition is permanent and contains abridged switch fabric software that allows the node to function as a stand alone switch (boot block). The node will switch from the code block to the boot block

while continuing to function as a stand alone switch in the network. The target node will erase the memory as instructed and then send an acknowledgement to the diagnostic device. The diagnostic device then sends one or more record files to the target node, which copies the data to memory after verifying the checksum. The

5 target node then switches back to the code block from the boot block and re-starts applications. The above description of the present invention is intended to be exemplary only and is not intended to limit the scope of any patent issuing from this application. The present invention is intended to be limited only by the scope and spirit of the following claims.

What is claimed is:

1. A vehicle network comprising:
a plurality of nodes joined by communication links for the transmission
of data there between, the plurality of nodes including at least
5 one target node, the target node including a processor, a
transceiver, and a memory, the memory including an erasable
memory portion and a protected memory portion;
a diagnostic interface adapted to transmit a new software component to
the target node;
10 wherein the processor in the target node switches from executing
instructions in the erasable memory portion to executing
instructions in the protected memory portin during a
reprogramming period when the target node erases a current
software component and stores the new software component in
15 its erasable memory portion.

2. The vehicle network in claim 1 further comprising a gateway node that
is adapted to receive the new software component from the diagnostic interface and
route the new software component to the target node.

3. The vehicle network in claim 1 wherein the processor in the target node performs at least one of the following steps:

switches from executing instructions in the erasable memory portion to
5 executing instructions in the protected memory portion in response to
reprogramming message received from the diagnostic interface; or

stores the new software component in its erasable memory portion after
verifying a checksum received from the diagnostic interface.

10

4. A diagnostic system for a vehicle network, the vehicle network including a plurality of nodes joined by communication links for the transmission of data there between, the plurality of nodes including at least one target node and a gateway node, the target node including a processor, a transceiver, and a memory, the
15 memory including an erasable memory portion and a protected memory portion, the diagnostic system comprising:

a diagnostic interface connected to the gateway node;

a diagnostic device connected to the diagnostic interface, the

diagnostic device having a system manager for controlling a
20 reprogramming process to replace at least one current software
component residing in the erasable memory portion with at
least one new software component;

wherein the reprogramming process includes a message transmitted
from the system manager to the target node, the message

18

causing the target node to switch from executing instructions in the erasable memory portion to executing instruction in the protected memory portion before replacing the at least one current software component residing in the erasable memory portion.

5

5. The vehicle network in claim 1 or the diagnostic system in claim 4, wherein the diagnostic interface receives new software component from the diagnostic device in response to an input from a remote user that identifies the target

10 node.

6. The diagnostic system in claim 5, wherein the gateway node receives the at least one new software component from the diagnostic interface and routes the at least one new software component to the target node.

15

7. A method for reprogramming nodes in a switch fabric of a vehicle communication network, the switch fabric including a plurality of nodes joined by communication links for the transmission of data there between, the plurality of nodes including at least one target node and a gateway node, the target node including a processor, a transceiver, and a memory, the memory including an erasable memory portion and a protected memory portion, the method comprising the steps of:
- 5 receiving, at the gateway node, a reprogramming message and routing the reprogramming message to the target node;
- switching, at the target node, from executing instructions in the erasable memory portion to executing instructions in the protected memory portion;
- 10 erasing, at the target node, at least one current software component in the erasable memory portion,
- receiving, at the gateway node, at least one new software component and routing the new software component to the target node;
- 15 storing, at the target node, the new software component in the erasable memory portion; and
- switching, at the target node, from executing instructions in the protected memory portion to executing instructions in the erasable memory portion.
- 20

8. The vehicle network in claim 1, the diagnostic system in claim 4, or the method in claim 7, wherein the erasable memory portion of the memory in the target node includes software for an application layer, a network layer, and a link
5 layer.

9. The vehicle network in claim 1, the diagnostic system in claim 4, or the method in claim 7, wherein the protected memory portion of the memory in the target node includes software for a flash memory loader, a system manager agent, a network
10 layer, and a link layer.

10. The method in claim 7 further comprising the steps of:
receiving, at the gateway node, a checksum message and routing the checksum
message to the target node; and
15 performing, at the target node, a checksum operation prior to the step of
storing the at least one new software component in the erasable memory portion.

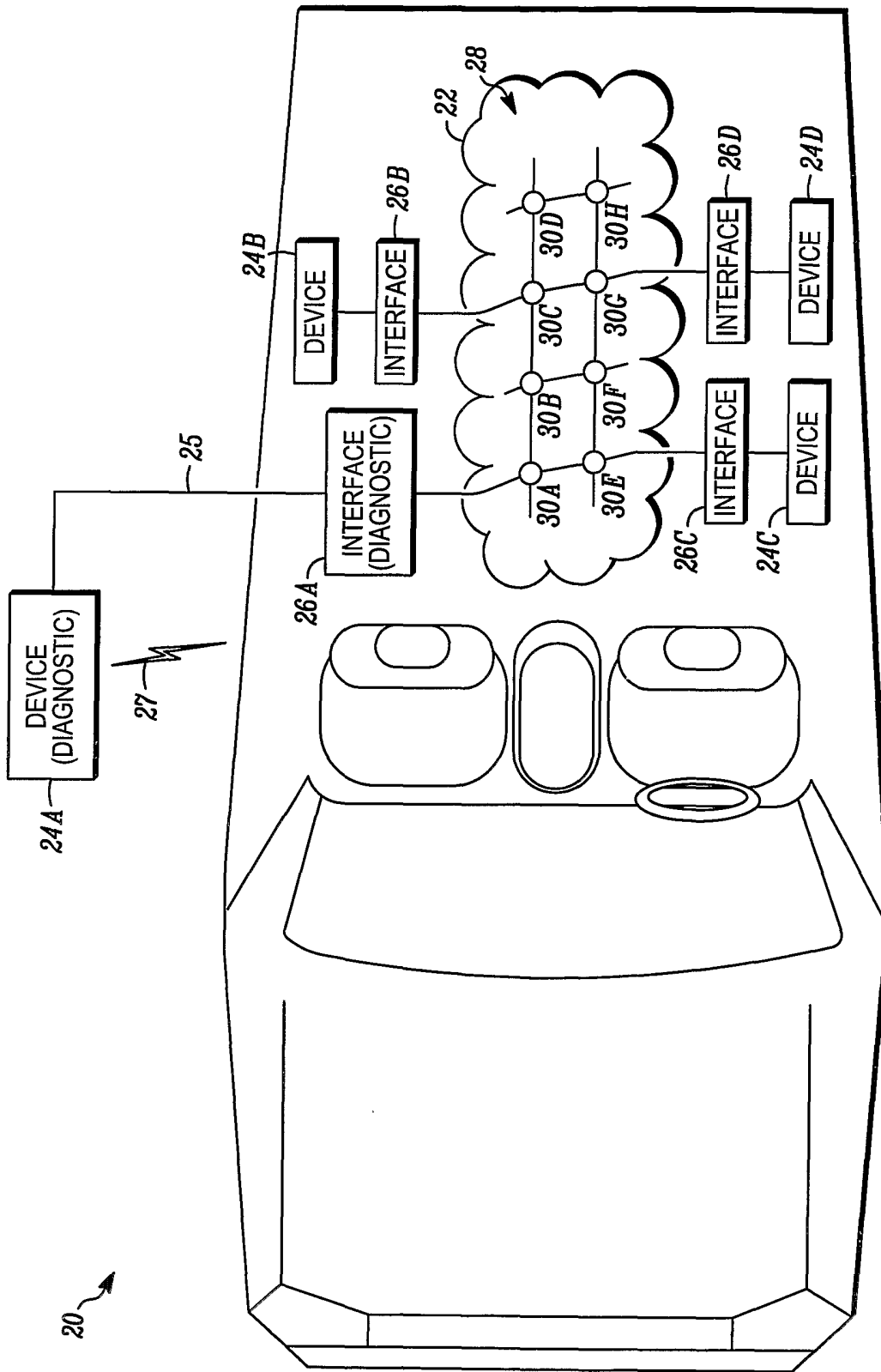


FIG. 1

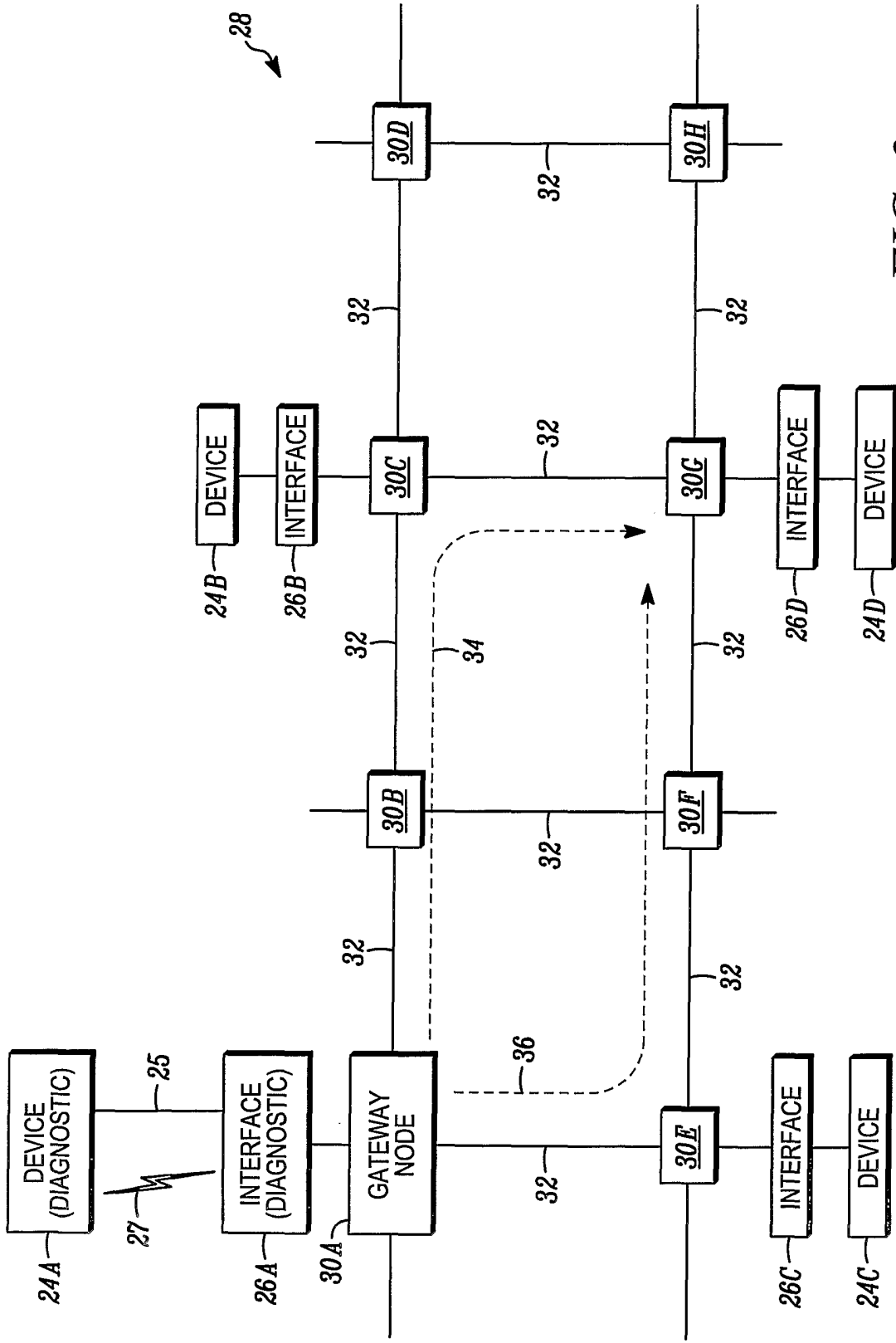


FIG. 2

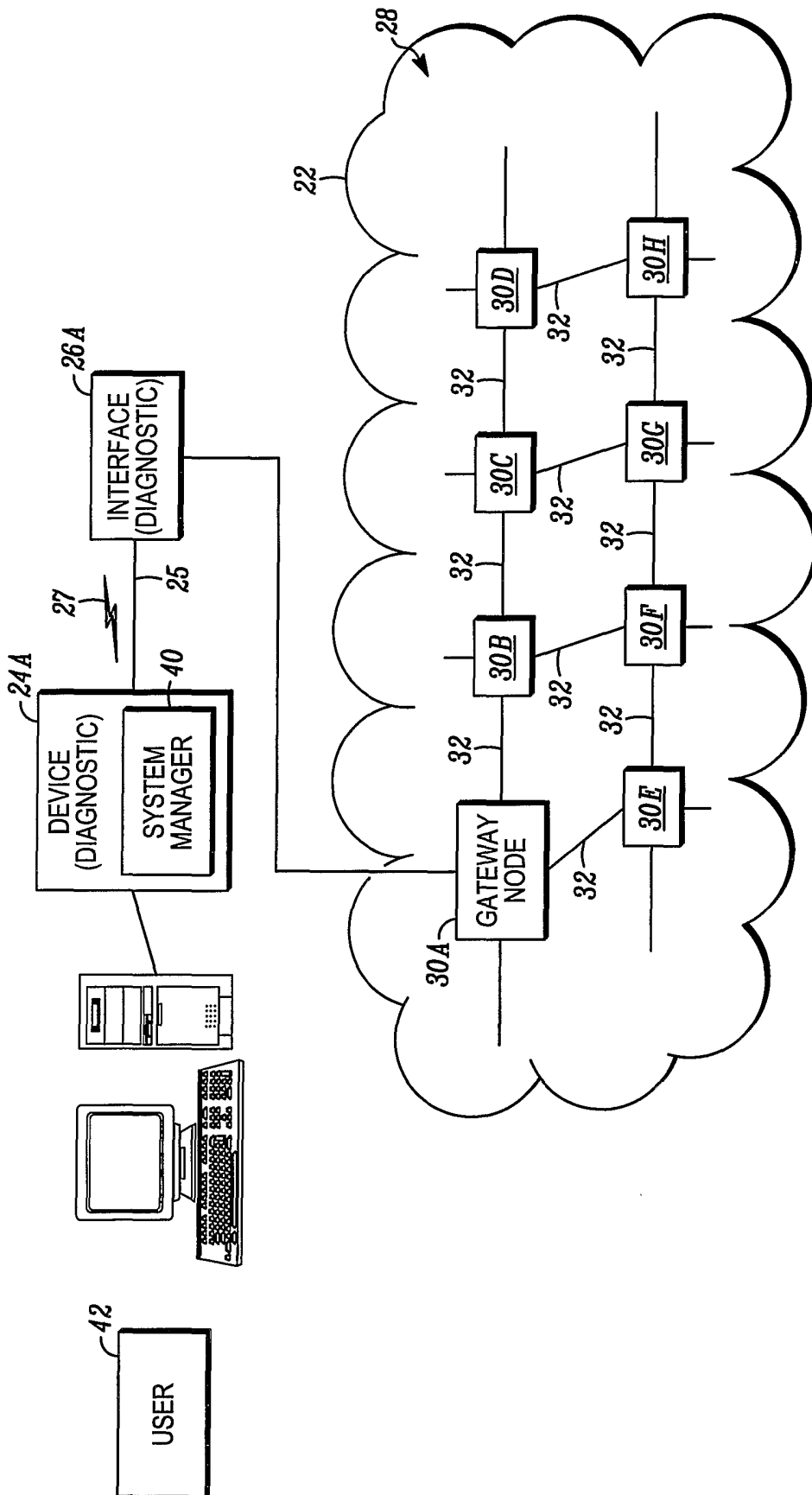


FIG. 3

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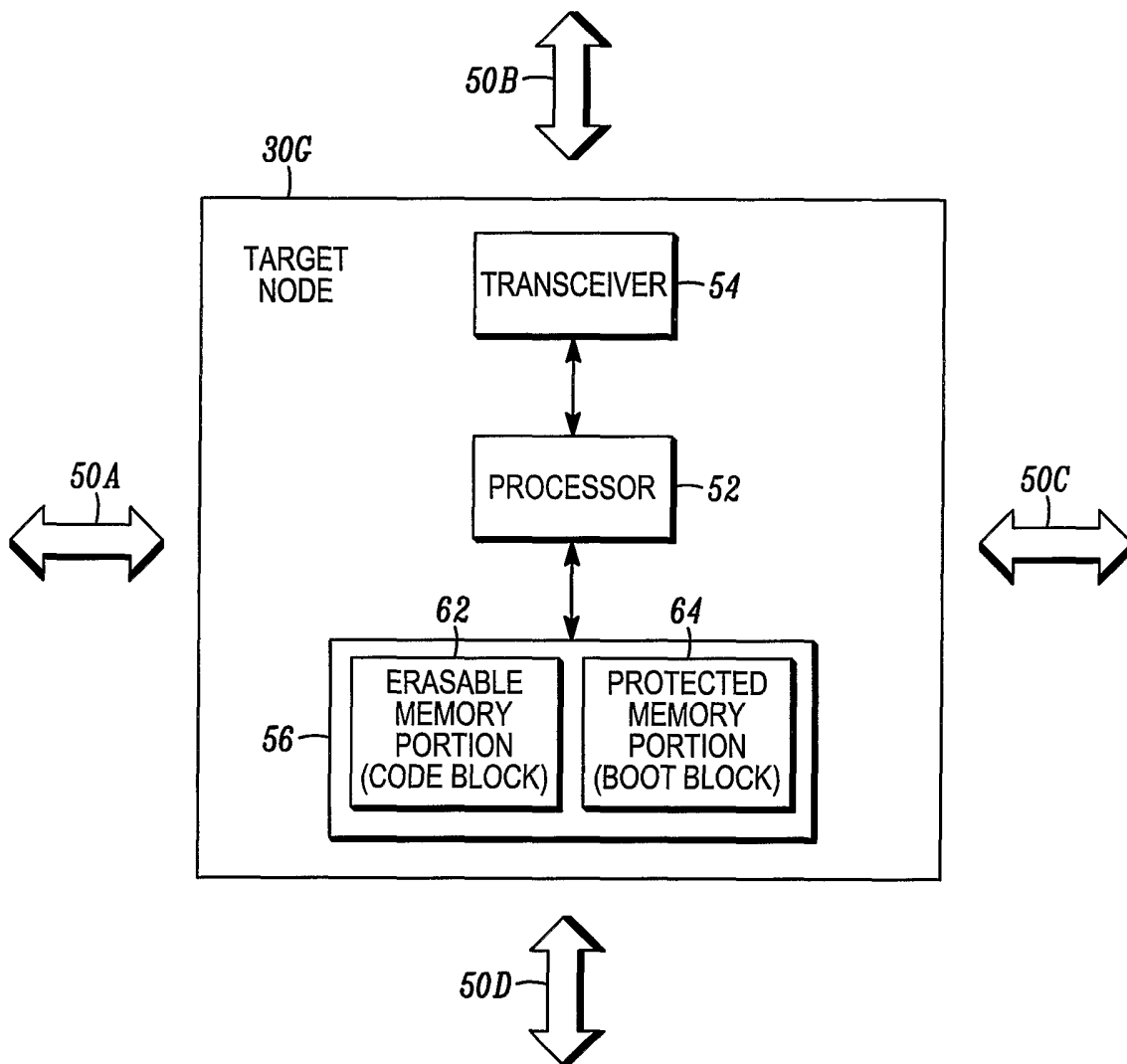


FIG. 4

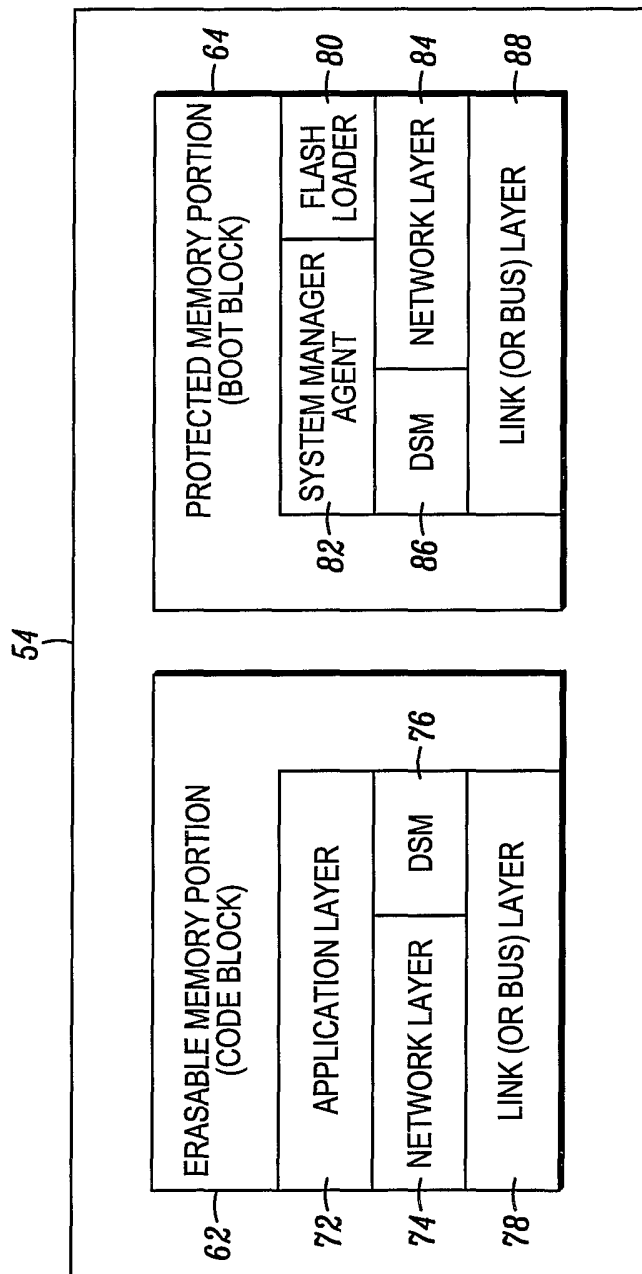


FIG. 5

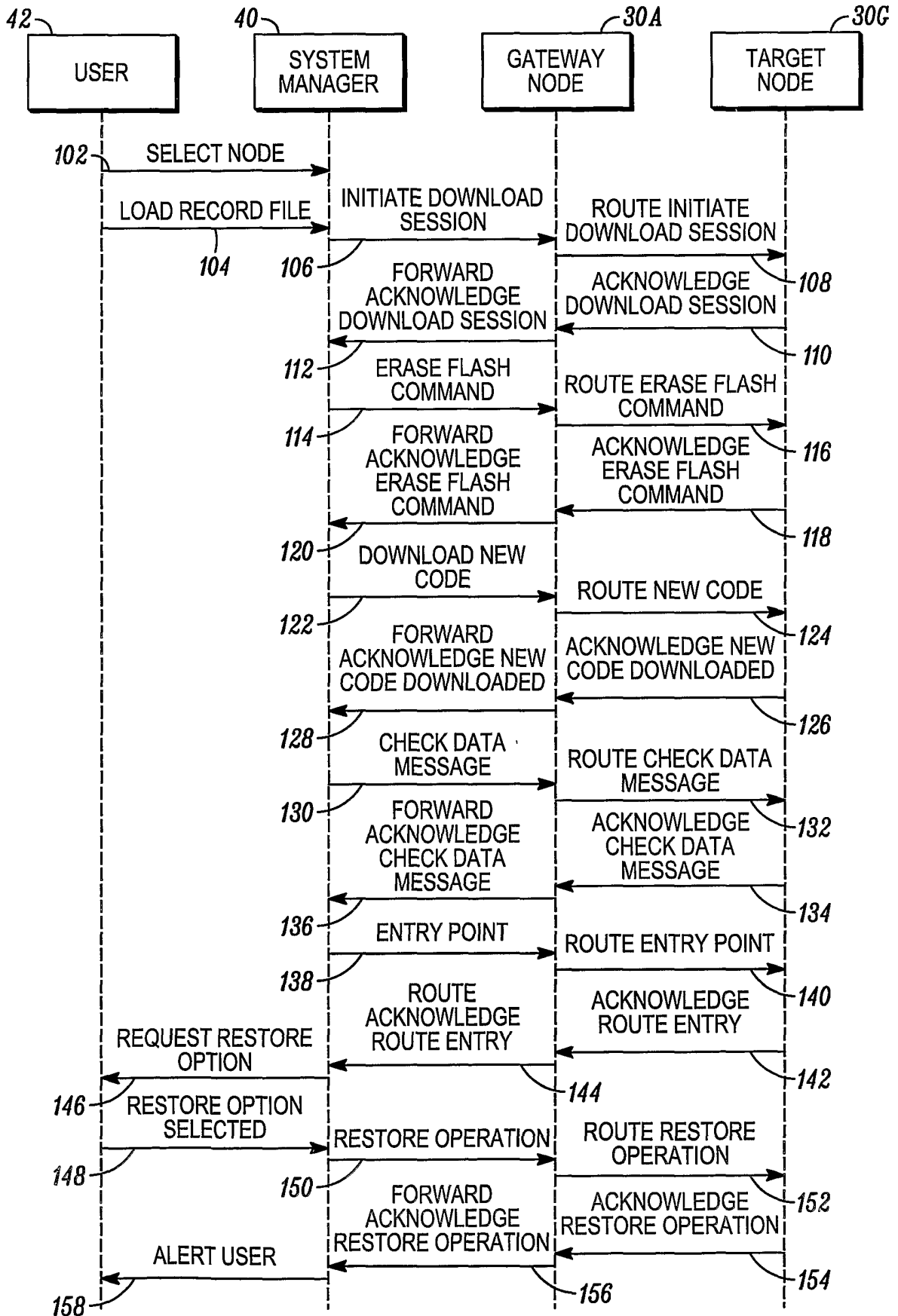


FIG. 6