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Huang et al.

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(54) **SYSTEM AND METHOD FOR MAINTAINING PROTOCOL STATUS INFORMATION IN A NETWORK DEVICE**

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H04L 9/00 (2006.01)

(52) **U.S. Cl.** **713/153**; 726/14

(58) **Field of Classification Search** 726/12, 726/13, 14

See application file for complete search history.

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Configuring Unicast Reverse Path Forwarding; Aug. 21, 2003; 16 pages; http://www.cisco.com/univercd/cc/td/doc/product/software/ios122/122cgcr/fsecur_c/fothersf/scfrpf.htm (printed Oct. 18. 2004).

Understanding and Configuring IGMP Snooping and Filtering; Cisco IOS Software Configuration Guide—Release 12.1(12c)EW, Jul. 11, 2003, Updated Aug. 24, 2004; 16 pages; http://www.cisco.com/univercd/cc/td/doc/product/lan/cat4000/12_1_12/config/multi.pdf (printed Oct. 22, 2004).

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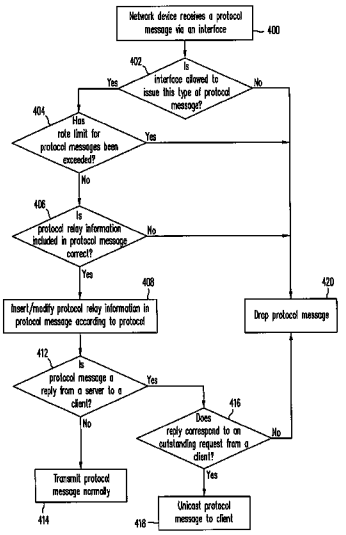
Primary Examiner—Matthew B Smithers
(74) *Attorney, Agent, or Firm*—Campbell Stephenson LLP; Brenna A. Brock

(57) **ABSTRACT**

A method may involve: maintaining protocol status information for a network protocol, where the protocol status information includes protocol information generated by a protocol server and network traffic information indicative of how messages are conveyed from the protocol client to a network, and updating the protocol status information in response to intercepting a protocol message being conveyed between a protocol client and a protocol server. For example, the network protocol can be DHCP (Dynamic Host Configuration Protocol) and the protocol status information can be updated to include an IP (Internet Protocol) address assigned to the protocol client by the protocol server in the protocol message. Such a method may inhibit the misuse of one or more network protocols and/or attacks on protocol servers.

84 Claims, 7 Drawing Sheets



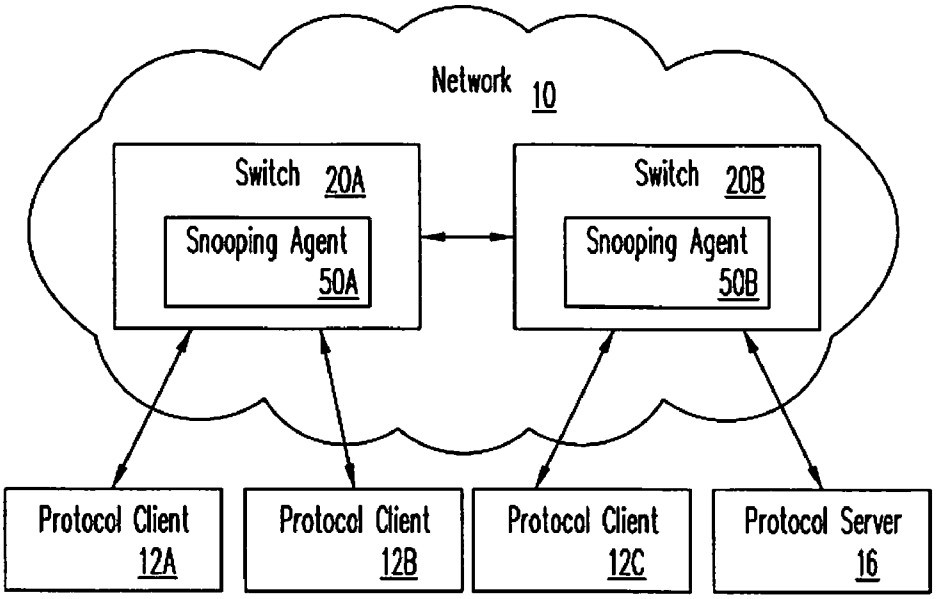

Network 10
Switch 20A
Snooping Agent 50A
Switch 20B
Snooping Agent 50B
Protocol Client 12A
Protocol Client 12B
Protocol Client 12C
Protocol Server 16

FIG. 1

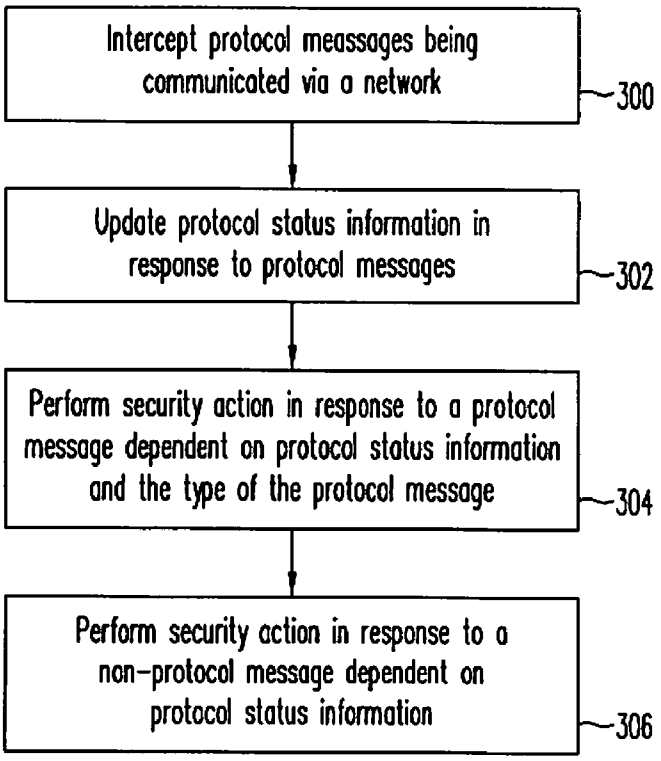

Intercept protocol meassages being communicated via a network
300
Update protocol status information in response to protocol messages
302
Perform security action in response to a protocol message dependent on protocol status information and the type of the protocol message
304
Perform security action in response to a non-protocol message dependent on protocol status information
306

FIG. 3

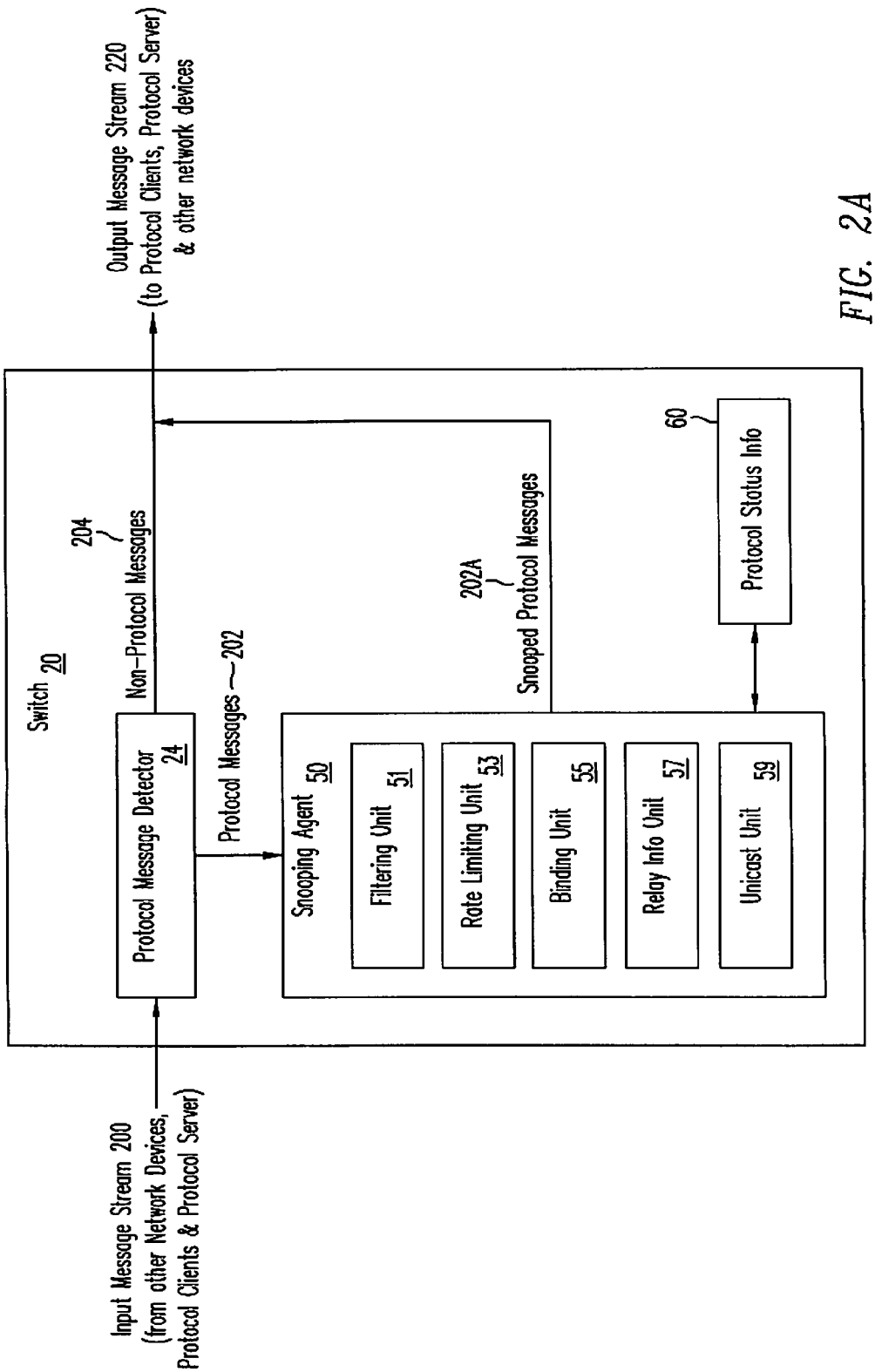

Output Message Stream 220
(to Protocol Clients, Protocol Server)
& other network devices
Switch 20
204
Non-Protocol Messages
Protocol Message Detector 24
Protocol Messages 202
Snooping Agent 50
Filtering Unit 51
Rate Limiting Unit 53
Binding Unit 55
Relay Info Unit 57
Unicast Unit 59
202A
Snooped Protocol Messages
60
Protocol Status Info
Input Message Stream 200
(from other Network Devices,
Protocol Clients & Protocol Server)

FIG. 2A

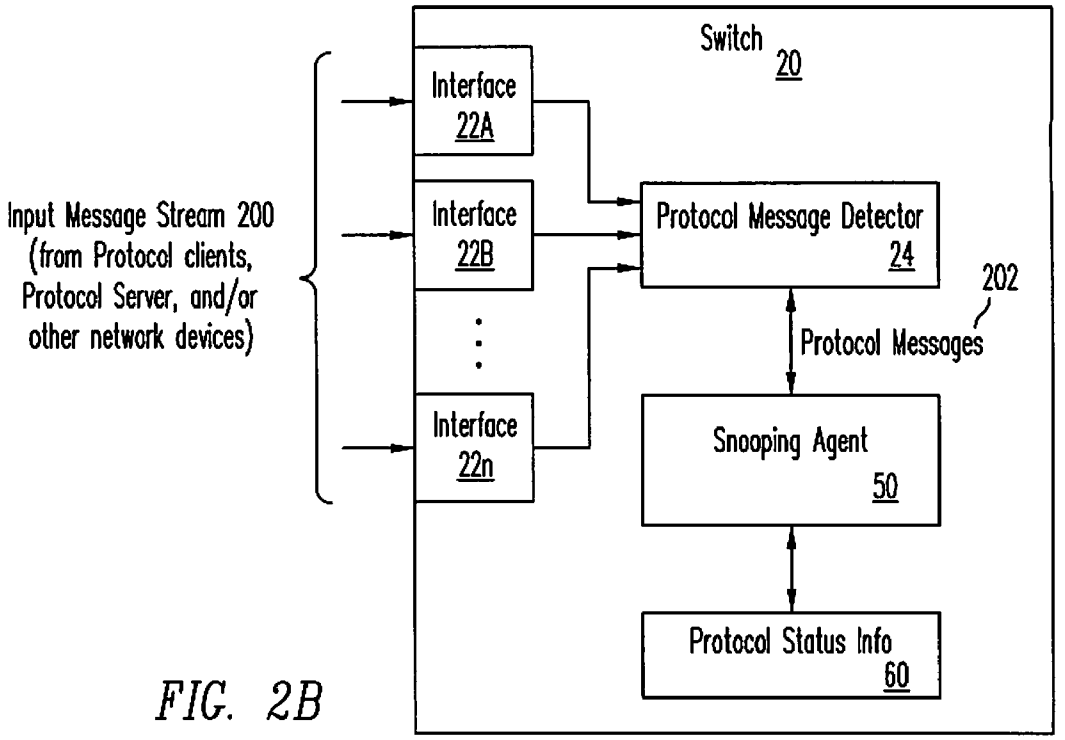

Switch 20
Interface 22A
Interface 22B
Interface 22n
Input Message Stream 200 (from Protocol clients, Protocol Server, and/or other network devices)
Protocol Message Detector 24
202
Protocol Messages
Snooping Agent 50
Protocol Status Info 60

FIG. 2B

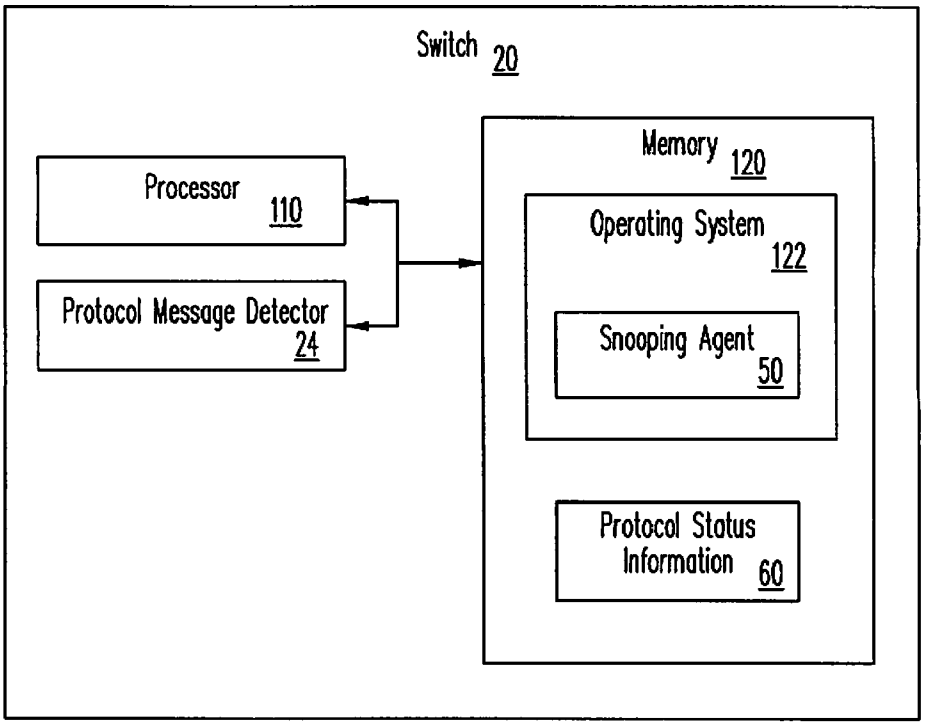

Switch 20
Processor 110
Protocol Message Detector 24
Memory 120
Operating System 122
Snooping Agent 50
Protocol Status Information 60

FIG. 6

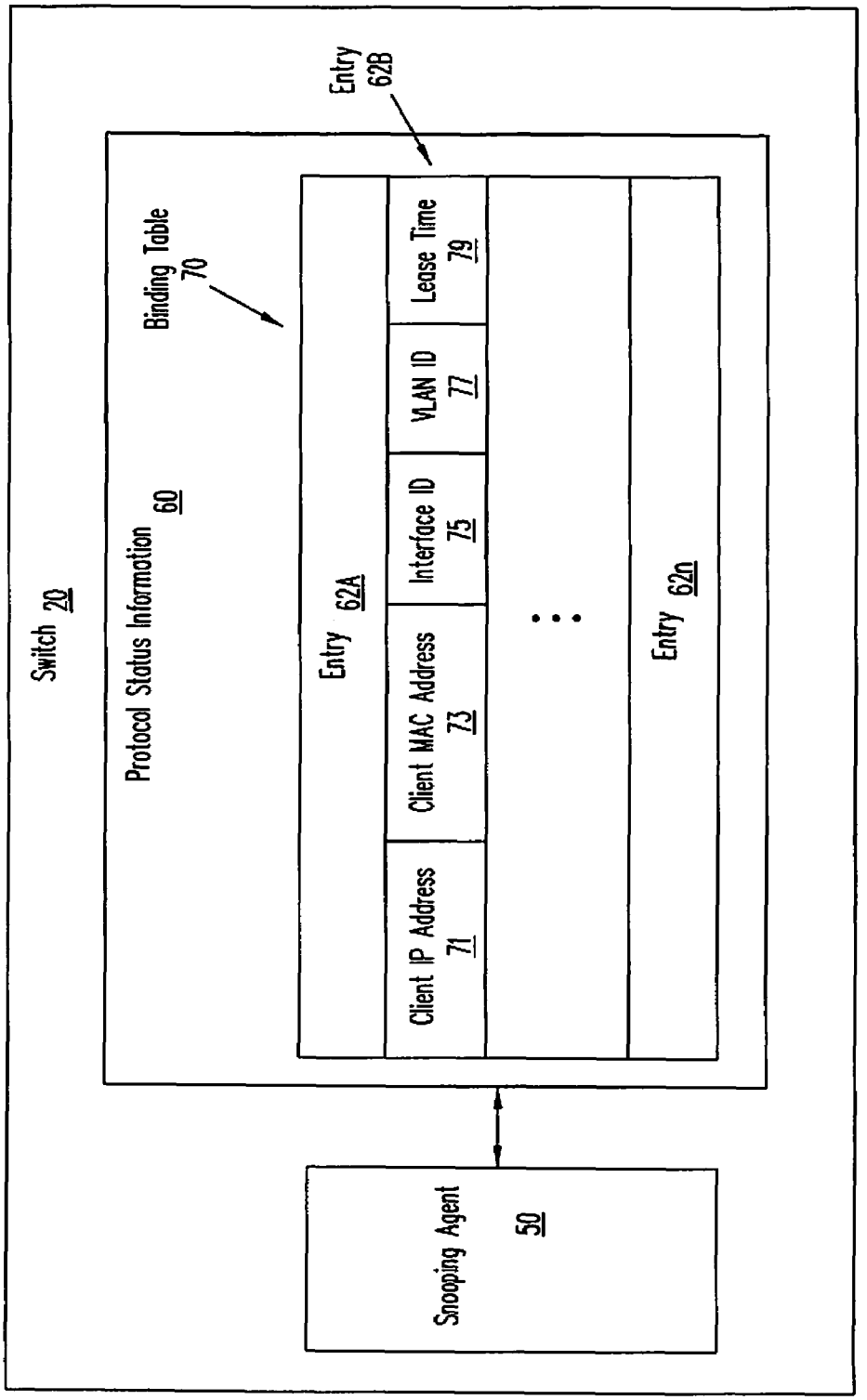

Switch 20
Protocol Status Information 60
Binding Table 70
Entry 62A
Client IP Address 71
Client MAC Address 73
Interface ID 75
VLAN ID 77
Lease Time 79
Entry 62B
Entry 62n
Snooping Agent 50

FIG. 2C

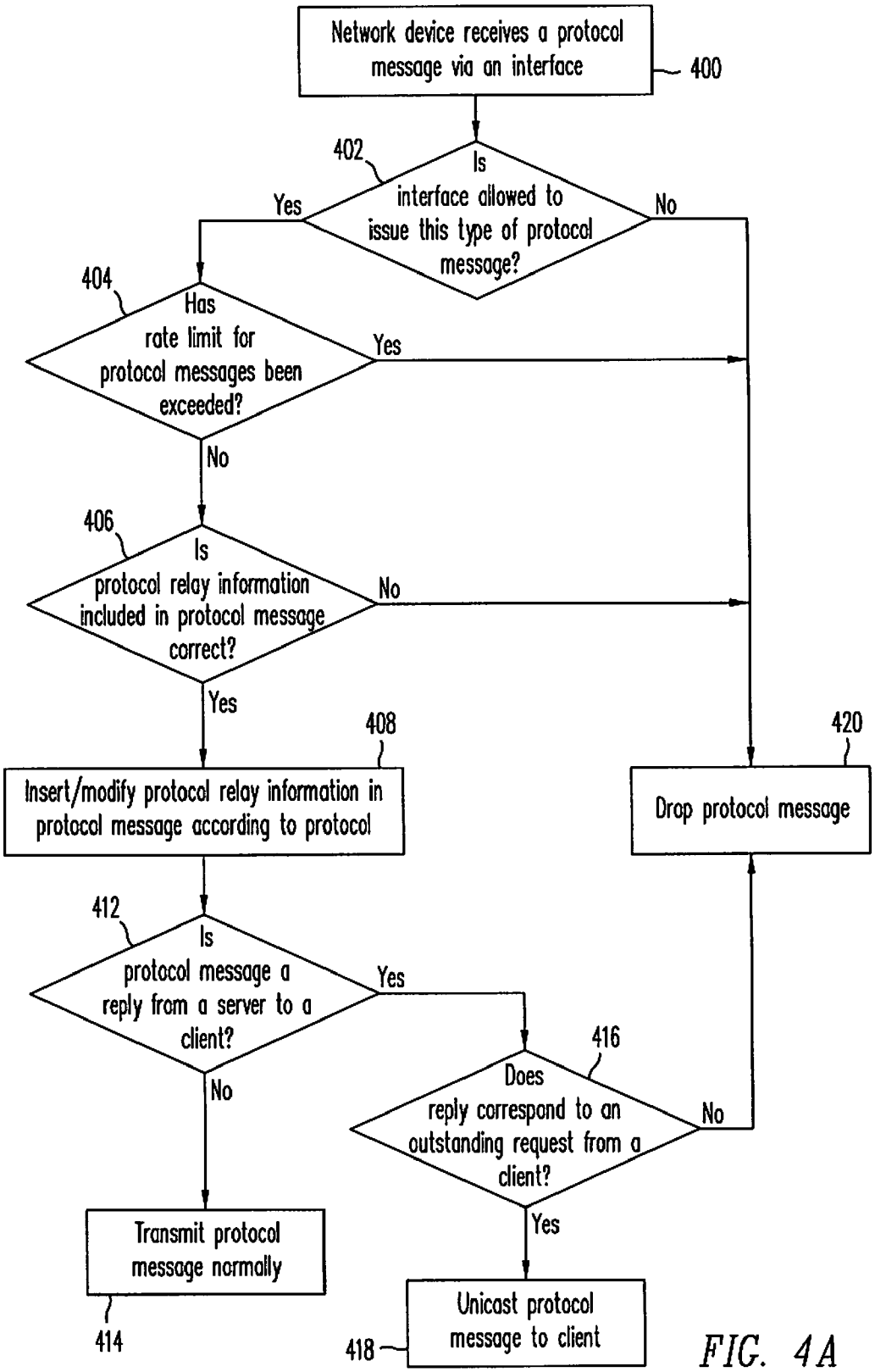

Network device receives a protocol message via an interface
400
402
Is interface allowed to issue this type of protocol message?
Yes
No
404
Has rate limit for protocol messages been exceeded?
Yes
No
406
Is protocol relay information included in protocol message correct?
No
Yes
408
Insert/modify protocol relay information in protocol message according to protocol
420
Drop protocol message
412
Is protocol message a reply from a server to a client?
Yes
No
416
Does reply correspond to an outstanding request from a client?
No
Yes
Transmit protocol message normally
414
Unicast protocol message to client
418

FIG. 4A

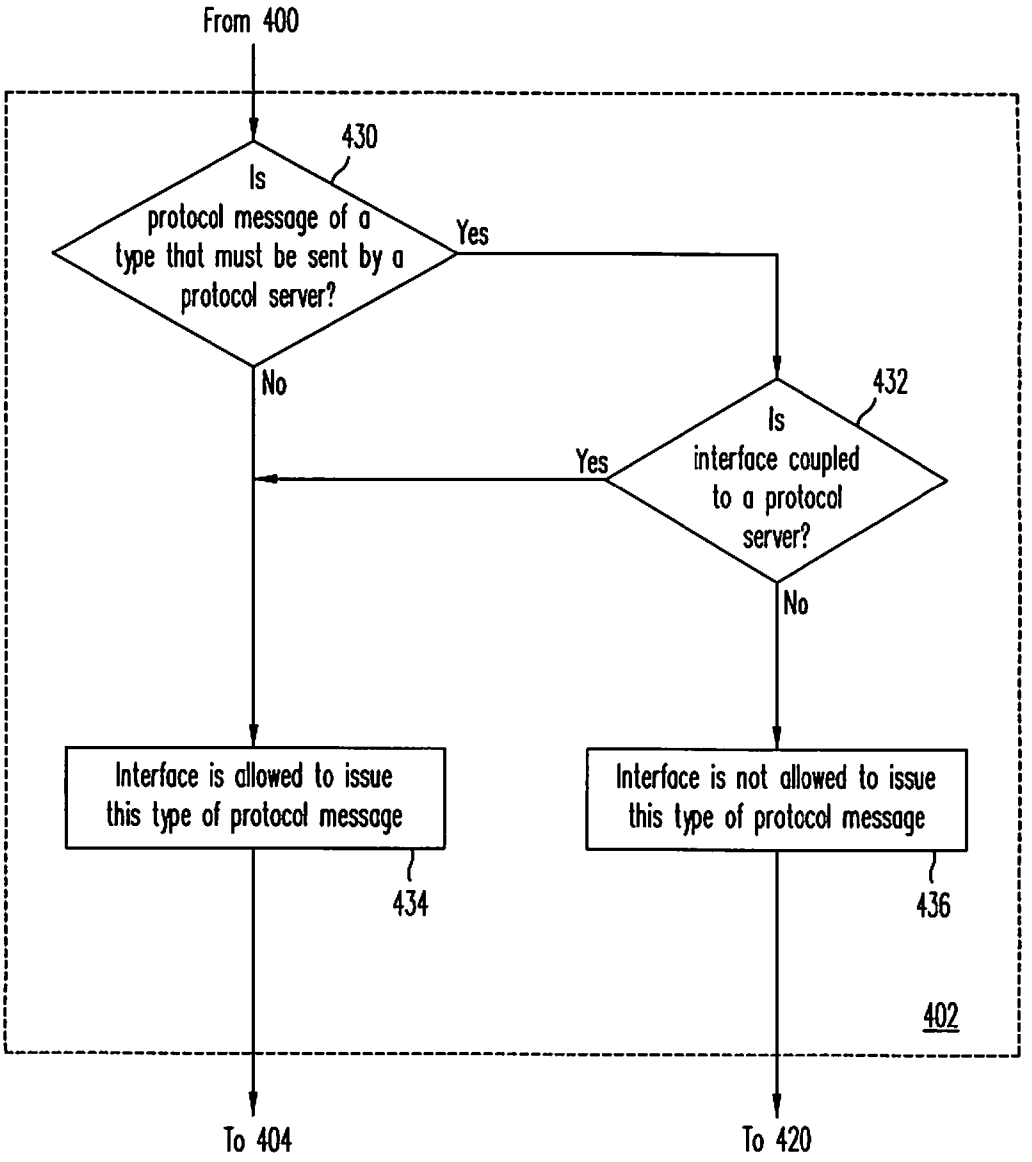

From 400
430
Is protocol message of a type that must be sent by a protocol server?
Yes
No
432
Is interface coupled to a protocol server?
Yes
No
Interface is allowed to issue this type of protocol message
Interface is not allowed to issue this type of protocol message
434
436
402
To 404
To 420

FIG. 4B

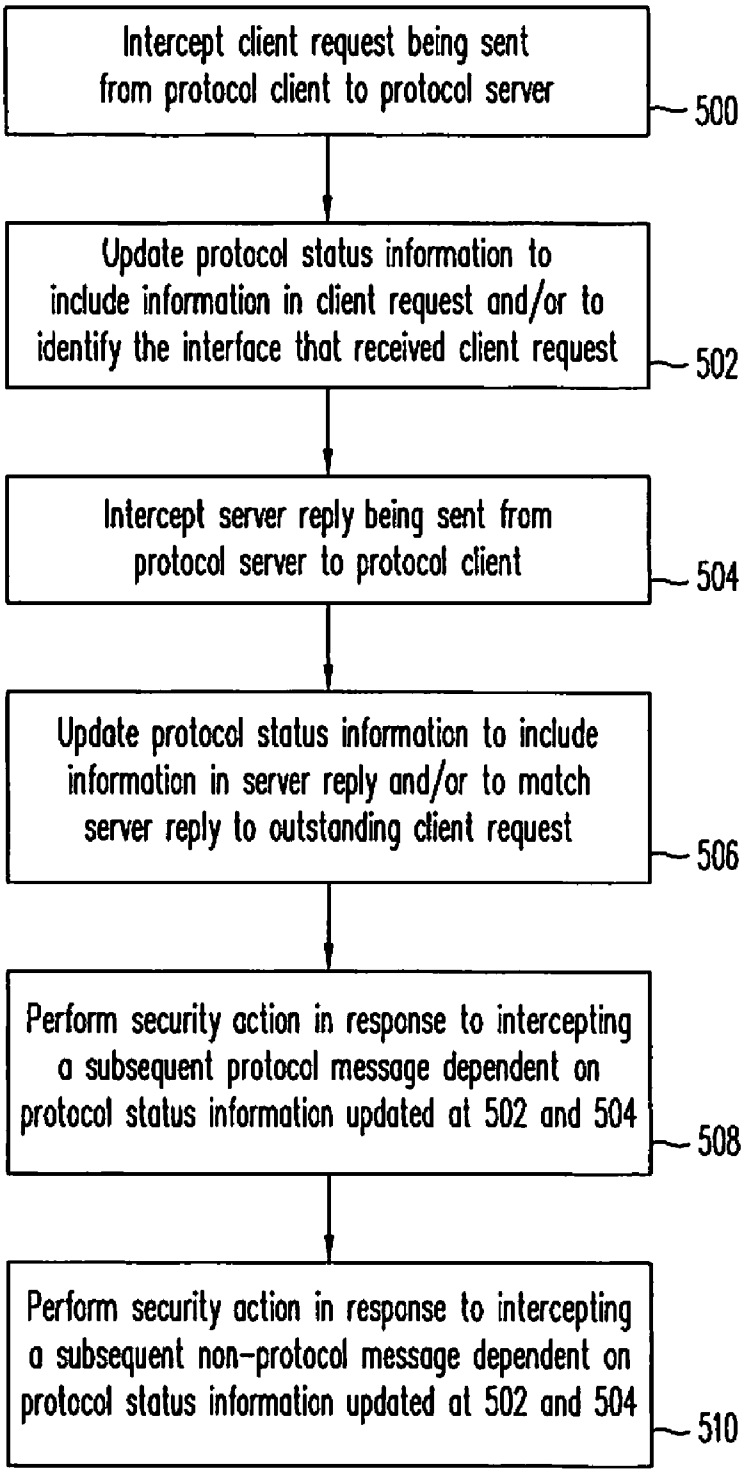

Intercept client request being sent from protocol client to protocol server
500
Update protocol status information to include information in client request and/or to identify the interface that received client request
502
Intercept server reply being sent from protocol server to protocol client
504
Update protocol status information to include information in server reply and/or to match server reply to outstanding client request
506
Perform security action in response to intercepting a subsequent protocol message dependent on protocol status information updated at 502 and 504
508
Perform security action in response to intercepting a subsequent non-protocol message dependent on protocol status information updated at 502 and 504
510

FIG. 5

SYSTEM AND METHOD FOR MAINTAINING PROTOCOL STATUS INFORMATION IN A NETWORK DEVICE

FIELD OF THE INVENTION

The present invention relates to networking and, more specifically, to network devices that convey protocol messages implementing a network protocol between protocol clients and protocol servers and that use information in those protocol messages to restrict traffic between a protocol client and a network.

BACKGROUND

Various network protocols are used to provide networking services to devices. For example, DHCP (Dynamic Host Configuration Protocol) allows the dynamic assignment of IP (Internet Protocol) addresses to hosts. Network protocols such as DHCP are often implemented using a client-server model in which protocol clients request services from protocol servers, which in turn provide the requested services in accordance with the network protocol. For example, in DHCP, a DHCP client may request an IP address from a DHCP server. In response, the DHCP server sends a reply assigning an IP address to the requesting DHCP client. Thereafter, the DHCP client uses the assigned IP address in a manner consistent with the protocol.

Protocol servers that provide networking services are vulnerable to various attacks. A denial of service attack may involve a user simulating a large number of protocol clients in order to exhaust the server's available pool of resources. A denial of service attack may also involve a user sending a high rate of client requests to the protocol server in order to inhibit the ability of the protocol server to respond to legitimate client requests.

Similarly, some users may falsify or steal protocol information in order to perform undesirable activity via a network. For example, a user may simulate a protocol server and send fake protocol responses. These responses may corrupt legitimate network operation. Similarly, a user may snoop a response sent by a legitimate protocol server to a protocol client and use the network services being provided in those responses. For example, if a DHCP response assigning an IP address to a client is intercepted, the intercepting user may deceptively pretend to be the client by using the IP address obtained from the DHCP response. As these examples show, network protocols may experience various security problems that result from the network protocol misuse and/or attacks on protocol servers.

SUMMARY

Various embodiments of systems and methods for maintaining protocol status information that includes protocol information generated by a protocol server and information indicative of how messages are conveyed via a network are disclosed. Such systems and methods may be used to inhibit the misuse of one or more network protocols and/or attacks on protocol servers.

A method may involve: maintaining protocol status information for a network protocol, where the protocol status information includes protocol information generated by a protocol server and network traffic information indicative of how messages are conveyed from the protocol client to a network, and updating the protocol status information in response to intercepting a protocol message being conveyed between a protocol client and a protocol server. Such a method can be performed by a network switch or other system. In some embodiments, the network protocol is DHCP (Dynamic Host Configuration Protocol) and the protocol status information can be updated to include an EP (Internet Protocol) address assigned to the protocol client by the protocol server in the protocol message. Program instructions executable to implement such a method can be stored on a computer readable medium.

The protocol status information can include information indicating which one of several interfaces included in a network switch is coupled to convey messages to and from a particular protocol client and/or protocol server. This information can be used to verify that a protocol reply from the protocol server is received via a network interface coupled to the protocol server.

Such a method can involve initiating a security action in response to intercepting a subsequent protocol and/or non-protocol message dependent on the protocol status information. The security action may involve dropping the subsequent protocol message if the subsequent protocol message is inconsistent with the protocol status information. For example, the subsequent protocol message can be dropped if the subsequent protocol message is a type of protocol message required to be generated by the protocol server and the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol server. Similarly, the subsequent protocol message can be dropped if the subsequent protocol message identifies the protocol client as a sender of the subsequent protocol message and the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol client.

Several other security actions can be performed based on the protocol status information. For example, the subsequent protocol message may be dropped if the protocol status information indicates that a maximum rate of protocol messages has been exceeded. Also, if the subsequent protocol message is a protocol reply from the protocol server to a particular one of several protocol clients, the security action may involve unicasting the protocol reply to that particular protocol client.

The protocol status information can be accessed to determine whether a protocol client that sent a subsequent protocol message is using protocol information sent to that protocol client by the protocol server. If the protocol status information indicates that the protocol clients that sent the subsequent protocol message is using protocol information sent to a different one of the protocol clients by the protocol server, the subsequent protocol message may be dropped. Similarly, if the protocol status information indicates that the protocol client that sent the subsequent protocol message is not using protocol information generated by the protocol server according to policies associated with the protocol information, the subsequent protocol message may be dropped.

The foregoing is a summary and thus contains, by necessity, simplifications, generalizations and omissions of detail; consequently, those skilled in the art will appreciate that the summary is illustrative only and is not intended to be in any way limiting. The operations disclosed herein may be implemented in a number of ways, and such changes and modifications may be made without departing from this invention and its broader aspects. Other aspects of the present invention, as defined solely by the claims, will become apparent in the non-limiting detailed description set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present invention may be acquired by referring to the following description and the accompanying drawings, in which like reference numbers indicate like features.

FIG. **1** is a block diagram of network coupling protocol clients to a protocol server, according to one embodiment.

FIG. **2**A shows a block diagram of a switch configured to snoop protocol messages being conveyed via a network and to update protocol status information in response to the snooped protocol messages, according to one embodiment.

FIG. **2**B shows another block diagram of a switch configured to snoop protocol messages being conveyed via a network and to update protocol status information in response to the snooped protocol messages, according to one embodiment.

FIG. **2**C is yet another block diagram illustrating an example of protocol status information maintained by a network device, according to one embodiment.

FIG. **3** is a flowchart illustrating one embodiment of a method of snooping protocol messages in order to update protocol status information and to perform security actions dependent on the protocol status information.

FIG. **4**A is a flowchart illustrating various security actions that can be performed dependent upon protocol status information, according to one embodiment.

FIG. **4**B is a flowchart illustrating additional details of how protocol status information is used to verify protocol messages in the embodiment of FIG. **4**A.

FIG. **5** is a flowchart illustrating how protocol status information is obtained by intercepting a protocol request from a protocol client and a protocol reply from a protocol server and how this protocol status information is then used to verify other protocol messages, according to one embodiment.

FIG. **6** is a block diagram of a switch illustrating how a snooping agent can be implemented in software executing on the switch, according to one embodiment.

While the invention is susceptible to various modifications and alternative forms, specific embodiments of the invention are provided as examples in the drawings and detailed description. It should be understood that the drawings and detailed description are not intended to limit the invention to the particular form disclosed. Instead, the intention 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

The following sets forth a detailed description of at least the best contemplated mode for implementing the devices and/or processes described herein. The description is intended to be illustrative and should not be taken to be limiting.

FIG. **1** is a block diagram of network **10** coupling protocol clients **12**A-**12**C (collectively, protocol clients **12**) to protocol server **16**, according to one embodiment. Network **10** includes several network devices, including switches **20**A-**20**B (collectively, switches **20**). Note that other embodiments may include significantly more network devices (and network devices of different types, such as routers) in network **10**. Each switch **20** in network **10** may be configured to handle messages from other network devices and from various computing devices coupled by the network **10**. At least some of these messages may be protocol messages being sent between protocol clients **12** and protocol server **16**.

In a communications network such as network **10**, switching devices such as switches **20** operate by receiving data at one of a set of input interfaces and forwarding the data on to one or more of a set of output interfaces. Users typically require that such switching devices operate as quickly as possible in order to maintain a high throughput. Switches are typically data-link layer devices that enable multiple physical network (e.g., local area network (LAN) or wide area network (WAN)) segments to be interconnected into a single larger network. Switches **20** are, in some embodiments, implemented as OSI (Open Systems Interconnection) layer **2** devices. Switches **20** can include logic and/or software that provides for the forwarding of messages based on the messages' destination information.

The data received and forwarded by switches **20** is logically grouped into one or more messages. Throughout this disclosure, the term "message" is used to refer to a logical grouping of information sent as a data unit over a transmission medium. Messages may include header and/or trailer information that surrounds user data contained in the data unit. For purposes of this disclosure, a "message" may include a cell, datagram, frame, packet, segment, or any other logical group of information.

Switches **20** include various interfaces to protocol clients **12** and protocol server **16**. These interfaces may include physical interfaces (e.g., on a line card internal to a switch) and/or logical interfaces (also referred to as virtual interfaces). For example, a physical interface that receives messages for several VLANs (Virtual Local Area Networks) can include several logical interfaces, one for each VLAN. Alternatively, a logical interface can be an interface that is located on a physically separate intermediate network device, coupled between the switch and a group of protocol clients, that passes messages sent by the protocol clients to the switch without making forwarding decisions (this type of interface is also described as a remote interface). Furthermore, the interfaces may be organized in various ways. For example, in some embodiments, interfaces are organized hierarchically. In one such embodiment, physical interfaces within a switch reside at the top level of the hierarchy. A physical interface to devices in several different VLANs can include several VLAN-specific logical interfaces that are organized beneath the physical interface in the switch's interface hierarchy.

In some embodiments, protocol clients **12** and protocol server **16** each include one or more of various types of computing devices. For example, protocol clients **12** and/or protocol server **16** can each be a personal computer, a workstation, an Internet server, a network appliance, a handheld computing device such as a cell phone or PDA (Personal Data Assistant), or any other type of computing device. Protocol clients **12** and protocol server **16** can also be implemented in software processes executing on such computing devices.

Protocol clients **12** and protocol server **16** can each be directly or indirectly connected to one of switches **20**. For example, in some embodiments, protocol clients **12**A and **12**B are coupled directly to switch **20**A (e.g., switch **20**A is included in a wiring closet on the same site as protocol clients **12**A and **12**B). In other embodiments, protocol clients **12**A and **12**B are indirectly coupled to switch **20**A through one or more intermediate network devices that send messages received from protocol clients **12**A and **12**B to switch **20**A. Similarly, switches **20**A and **20**B can be directly

or indirectly coupled to each other. For example, one or more routers (as well as one or more other switches or other network devices) can be interposed between switch **20**A and switch **20**B.

Protocol server **16** provides network services to protocol clients according to a network protocol. For example, in one embodiment, protocol server **16** is configured to implement a DNS (Domain Name System) server. A protocol client **12** can request an IP (Internet Protocol) address that corresponds to a particular domain name from DNS protocol server **16**. DNS protocol server **16** responds by sending the protocol client **12** a message that includes the requested IP address according to the DNS protocol. Protocol client **12** can then use the IP address assigned by the DNS protocol server **16** to communicate with other clients via network **10**.

In another embodiment, protocol server **16** is configured to implement a DHCP (Dynamic Host Configuration Protocol) server. A protocol client **12** may send a message requesting an IP address from protocol server **16**. In response to the request, protocol server **16** sends a message assigning an IP address to the protocol client **12**.

In other embodiments, many additional network service protocols can be implemented in addition to and/or instead of DNS and DHCP. For example, in another embodiment, protocol server **16** is a Reverse ARP (Address Resolution Protocol) server.

Each switch **20** (and/or router or other network device in network **10**) includes a snooping agent **50**. As shown in FIG. **1**, switch **20**A includes snooping agent **50**A and switch **20**B includes snooping agent **50**B.

Each snooping agent **50** is configured to intercept protocol messages being sent between protocol clients **12** and protocol server **16** via network **10**. In response to the intercepted protocol messages, snooping agent **50** updates protocol status information locally to a network device (e.g., switch **20** or a router) in which snooping agent **50** is implemented. Thus, each snooping agent **50** is an example of a means for updating protocol status information in response to intercepting a protocol message being conveyed between a protocol client and a protocol server. This protocol status information includes network traffic information indicative of how messages (both protocol messages and non-protocol messages) are conveyed to network **10** by each of protocol clients **12**. For example, snooping agent **50**A can store information indicating which of the physical and/or logical interfaces included in switch **20**A received a protocol message from client **12**B requesting a network service. The protocol status information may also include information included in the protocol messages themselves. For example, snooping agent **50**A can store information, such as an IP address, included in protocol server **16**'s reply to the protocol request from client **12**B. Thus, the protocol status information can also include protocol information generated by protocol server **16**. Each snooping agent **50** can then use its protocol status information to determine whether to perform various security actions such as dropping messages.

FIG. **2**A shows a block diagram of a switch **20** that snoops protocol messages being conveyed via a network and updates protocol status information in response to the snooped protocol messages. As shown in FIG. **2**A, switch **20** includes a protocol message detector **24**, a snooping agent **50**, and a storage unit that stores protocol status information **60**. Protocol status information **60** can be stored in various types of memory, including ROM (Read Only Memory), RAM (Random Access Memory), MEMS (Micro Electro-Mechanical Systems) memory, Flash memory, and the like.

As shown in FIG. **2**A, switch **20** may receive an input message stream **200** via various logical and/or physical interfaces. The input message stream **200** may include various protocol messages **202** being conveyed between protocol server **16** and protocol clients **12** of FIG. **1**. Additional messages **204** (e.g., data messages or messages implementing other protocols that are not intercepted by snooping agent **50**) being conveyed via network **10** of FIG. **1** may also be included in the input message stream **200**. Once the protocol messages **202** identified by protocol message detector **24** are processed by snooping agent **50**, snooped protocol messages **202**A (which may include modified versions of the protocol messages **202** input to snooping agent **500** and/or fewer messages than input protocol messages **202**) are output with non-protocol messages **204** as part of output message stream **220** to other network devices, protocol clients, and/or protocol servers).

FIG. **2**B illustrates how switch **20** may include several interfaces **22**A-**22***n* (collectively, interfaces **22**) that each interface to one or more other network devices, protocol clients, and/or protocol servers. Interfaces **22** can each be a logical or a physical interface. For example, interfaces **22**A-**22**B can be included in the same physical interface, but interface **22**A may handle messages being conveyed in one VLAN while interface **22**B handles messages being conveyed in another VLAN. As noted above, in some embodiments, interfaces **22** can be organized hierarchically.

Returning to FIG. **2**A, protocol message detector **24** is configured to identify protocol messages **202** that are received in input message stream **200**. In one embodiment, protocol message detector **24** can be implemented using a CAM (Content Addressable Memory) and/or ACL (Access Control List). For example, information from each message can be input into a CAM, which responds by outputting a corresponding index, which is then used to lookup information in an ACL. If the message is a protocol message, the indexed information in the ACL may indicate that the protocol message should be handled by snooping agent **50**. Alternatively, protocol message detector **24** can be implemented as a software process that analyzes each message in order to identify which messages are protocol messages. In other embodiments, other types of software and/or hardware can be used to implement protocol message detector **24**.

In some embodiments, information in each message that identifies a source and/or destination software port is used by protocol message detector **24** to identify protocol messages. For example, if protocol messages requesting network services provided by the DNS protocol are addressed to server port **53**, protocol message detector **24** can readily identify protocol messages to server port **53** as DNS protocol messages.

Whenever protocol message detector **24** identifies a protocol message (e.g., if the protocol being snooped is DHCP, protocol message detector **24** can identify DHCP messages in the message stream based on the software port to or from which the messages are addressed, as described above), the protocol message detector **24** causes the identified protocol message to be forwarded to snooping agent **50**. For example, in one embodiment, protocol message detector **24** generates an interrupt, causing a software process implementing all or part of snooping agent **50** to be initiated to handle the identified protocol message. Snooping agent **50** can include a queue (not shown) to temporarily buffer protocol messages identified by protocol message detector **24**.

In some embodiments, protocol message snooping is limited to a particular VLAN (Virtual Local Area Network) or performed differently depending on the VLAN in which

the protocol message is being conveyed. In these situations, protocol message detector **24** also takes VLAN into account when identifying protocol messages within the input message stream. For example, if protocol message snooping is enabled for one VLAN but not for another, protocol message detector **24** only identifies protocol messages being conveyed in the VLAN for which snooping is enabled.

In response to receiving protocol messages detected by protocol message detector **24**, snooping agent **50** performs various functions on and/or in response to the protocol messages. In the embodiment of FIG. **2**A, snooping agent **50** includes filtering unit **51**, rate limiting unit **53**, binding unit **55**, relay information unit **57**, and unicast unit **59**. In other embodiments, snooping agent **50** may include fewer or additional functional units. Snooping agent **50** can be implemented in hardware, software, or a combination of the two.

Filtering unit **51** filters protocol messages that are not consistent with protocol status information **60** from the message stream (e.g., by dropping those messages). In one embodiment, filtering unit **51** can verify a protocol message by comparing information included in a particular protocol message with information stored in protocol status information **60**. If the information does not match, filtering unit **51** drops the message. For example, filtering unit **51** can handle a protocol message that includes information indicating that the protocol message is a reply from a protocol server to a protocol client. Filtering unit **51** accesses information included in protocol status information **60** to determine whether the protocol client currently has an outstanding protocol request. If there is no corresponding outstanding request, filtering unit **51** drops the reply. In some embodiments, performing this type of filtering makes it more difficult for a protocol server to be imitated by another device coupled to the network.

Similarly, filtering unit **51** can determine whether a protocol message (or non-protocol message) that includes information indicating that the message was sent by a particular client or server was actually sent by that client or server. This determination is based on information in protocol status information **60** indicating what network services (e.g., IP addresses) have been provided to particular clients and how protocol clients convey messages to the network. For example, protocol status information **60** can include network traffic information associating each client and each server with a particular interface **22** of switch **20**. This information is typically obtained by snooping agent **50** the first time a protocol message from each client and each server is received into the switch **20** (in some embodiments, such information may also be obtained in response to non-protocol messages). This information is then maintained in protocol status information **60**.

If a subsequent protocol or non-protocol message purporting to be from a particular client or server is received via a different interface than the interface identified in protocol status information **60** as being associated with that client or server, filtering unit **51** drops the message. This type of filtering interferes with the ability of a device coupled to the network to imitate a legitimate protocol client or server. Types of filtering such as this can be used to verify non-protocol messages being sent by a protocol client to a device other than a protocol server.

Rate limiting unit **53** drops protocol messages if a rate limit for protocol messages is exceeded. Information indicating the rate limit is included in protocol status information **60** in some embodiments. Depending on the embodiment, rate limiting may be performed on a per interface and/or per type (e.g., client-generated or server-generated) of protocol message basis. For example, client-generated protocol messages can be rate limited, while server-generated protocol messages are not rate limited. Alternatively, an independent rate limit can be associated with each interface (or group of interfaces). The rate limiting unit **53** applies the associated rate limit to protocol messages being communicated via a particular interface. If the rate limit at a particular interface (or group of interfaces) is exceeded, rate limiting unit **53** can disable that interface (or group of interfaces).

In one embodiment, rate limiting unit **53** implements a rate limiting algorithm based on the time at which a protocol message is received and the current value of a counter indicative of how many protocol messages have already been received during a given time interval. The counter can be associated with a particular interface (e.g., each interface **22** of FIG. **2**B can have an associated counter, in one embodiment) or with a group of interfaces. The counter is reset periodically or reset based on certain conditions. Each time a new protocol message is received via an associated interface, rate limiting unit **53** increments the counter. For each protocol message received via the associated interface, rate limiting unit **53** compares the value in the counter to the rate limit for the associated interface. If the comparison indicates that the rate limit is exceeded, rate limiting unit **53** drops the protocol message, disables the associated interface, and/or logs an error message.

Binding unit **55** stores information obtained from intercepted protocol messages as part of protocol status information **60**. For example, in an embodiment in which snooping agent **50** snoops DHCP messages, binding unit **55** can store an IP address assigned to a DHCP client by a DHCP server as part of protocol status information **60**. Binding unit **55** can also store additional information identifying the DHCP client with that IP address. For example, binding unit **55** can store the DHCP client's MAC (Media Access Control) address and information identifying the VLAN in which that DHCP client is included. Binding unit **55** can also store information indicating how messages are communicated to that DHCP client. For example, binding unit **55** can store information identifying which interface **22** is coupled to receive messages from that DHCP client. Binding unit **55** also modifies (e.g., by changing, supplementing, and/or deleting) existing protocol status information **60** in response to subsequent protocol messages.

The integrity of protocol status information **60** affects how well filtering unit **51** identifies protocol messages to filter from the message stream. Accordingly, binding unit **55** can be configured to only modify protocol status information **60** in response to a snooped protocol message if that message has already been verified as being consistent with protocol status information **60** by filtering unit **51**. This way, binding unit **55** will not modify protocol status information **60** in response to a protocol message that is filtered by filtering unit **51**.

In some embodiments, binding unit **55** updates protocol status information **60** in response to protocol messages that are received via an interface to protocol clients and/or servers but does not update protocol status information **60** in response to protocol messages received via an interface to another network device that includes its own snooping agent **50**. Stated another way, if switch **20** is the first switch (or other network device that includes snooping agent **50**) in network **10** to handle messages sent by a particular protocol client, binding unit **55** updates protocol status information **60** in response to messages sent to and/or from that protocol client. If switch **20** is not the first switch in network **10** to handle messages sent by that protocol client, binding unit **55**

will not update protocol status information **60** in response to messages to and from that protocol client. In this way, each switch in network **10** may be responsible for maintaining protocol status information **60** for a subset of the total group of protocol clients and/or servers coupled by the network. For example, looking at FIG. **1**, switch **20**A is responsible for updating its protocol status information in response to protocol messages to and from protocol clients **12**A and **12**B, while switch **20**B is responsible for updating its protocol status information in response to protocol messages to and from protocol client **12**C and protocol server **16**.

Information indicating which interfaces **22** are coupled to protocol clients and/or servers and which interfaces **22** are coupled to other network devices may be programmed into switch **20** in some embodiments. For example, configuration information indicating which interfaces **22** are coupled to other network devices that include snooping agents **50** and which interfaces **22** are coupled to protocol clients may be loaded into a memory device included in switch **20** by a network administrator. Alternatively, each switch can learn which of its interfaces are coupled to protocol clients and/or servers, as opposed to being coupled to other network devices, by snooping protocol and/or non-protocol messages and updating protocol status information **60** to include information indicative of network traffic in response to the snooped messages, as described above.

Binding unit **55** may store information, generated by a protocol server, indicating how assigned network services may be used by a protocol client to which those services are assigned (such information may be stored in binding table **70**, as described below with respect to FIG. **2**C). For example, in certain protocols such as DHCP, assigned network services can be associated with lease times indicative of how long a client is allowed to continue using its assigned network services. In embodiments in which protocol messages for such a protocol are being snooped, binding unit **55** establishes a lease timer (e.g., as a value or set of values in protocol status information **60** that is incremented or decremented periodically). Similar information indicative of how a protocol server has indicated that a network service may be used by a client to which that network service is assigned may also be stored in protocol status information **60**. Filtering unit **51** can use this information to determine whether a client is using its assigned network services consistently with the protocol server's limitations on those network services. If a protocol client that sends a protocol message is not using an assigned network service consistently with the information stored by binding unit **55**, filtering unit **51** may drop the protocol message.

Relay information unit **57** verifies and/or modifies relay information included in protocol messages. Relay information is information that is be added to protocol messages by network devices (e.g., routers and switches) and used by various network devices to verify certain protocol message behavior. Relay information can be removed from protocol messages before those protocol messages are conveyed to protocol clients. One example of such relay information is provided in RFC 3046, which describes relay information that can be added to DHCP messages. Relay information unit **57** (and/or filtering unit **51**) verifies protocol messages based on relay information included within those protocol messages. Relay information unit **57** can also remove relay information from a protocol message before that protocol message is sent to a protocol client. In one embodiment, relay information unit **57** adds relay information to the protocol message if switch **20** is the first network device with a snooping agent in network **10** to handle the protocol message. If switch **20** is not the first network device with a snooping agent in network **10** to handle the protocol message, relay information unit **57** verifies any preexisting relay information.

Unicast unit **59** detects protocol messages being sent from a protocol server to a protocol client and causes the detected messages to be unicast to the destination protocol client instead of being broadcast or multicast to multiple recipients. By unicasting the protocol messages, the ability of a device other than the destination client to snoop the information being provided to the client by the protocol server is inhibited. For example, if a DHCP Ack message is being sent, unicasting the message to the destination client makes it more difficult for another device (which might have received the DHCP Ack if the DHCP Ack had been multicast) to obtain the IP address being assigned to that client. This in turn makes it more difficult for the non-destination client to imitate the destination client device on the network.

In one embodiment, snooping agent **50** performs its various functions in the following order: rate limiting, filtering, binding, add/modify relay information, and unicasting. However, this order is merely an example. Other embodiments may order these functions differently.

In some embodiments, switch **20** snoops protocol messages being sent to implement several different protocols. For example, switch **20** can snoop DHCP, DNS, and Reverse ARP messages, generate protocol status information in response to the snooped messages, and perform security actions based on the protocol status information. In some such embodiments, switch **20** includes multiple protocol message detectors **24** (e.g., one protocol message detector **24** for each protocol being snooped), a single protocol message detector **24** configured to identify protocol messages for multiple different protocols, or a combination of such protocol detectors. Similarly, switch **20** can include multiple protocol-specific snooping agents **50** or, alternatively, one snooping agent **50** can maintain protocol status information for multiple different protocols. In some embodiments, protocol status information for each protocol is maintained independently. In other embodiments, protocol status information for the different protocols is collectively maintained and used to perform security actions. For example, information obtained by snooping DHCP messages can be used to filter DNS messages.

It is noted that snooping agent **50** and/or protocol message detector **24** can be implemented differently in different types of network devices. For example, protocol message detector **24** can be implemented in hardware within a switch **20** while being implemented in software within a router.

FIG. **2**C is a block diagram illustrating an example of protocol status information that can be maintained by a network device such as switch **20**. In this embodiment, snooping agent **50** intercepts DHCP messages and updates binding table **70** in protocol status information **60** in response to the snooped DHCP messages. Binding table **70** is similar to a binding table typically maintained by a DHCP server. Binding table **70** includes one or more entries **62**A-**62***n* (collectively, entries **62**) that each correspond to a particular protocol client. As represented by entry **62**B, an entry **62** includes client IP address **71**, client MAC address **73**, interface ID **75** (e.g., identifying the logical and/or physical interface **22** via which messages sent by the client are received into the switch that includes binding table **70**), VLAN (Virtual Local Area Network) ID **77** (identifying a VLAN in which the client to which entry **62** corresponds sends protocol messages), and lease time **79**. The information illustrated as being included in binding table **70** is

merely an example. In other embodiments, different information can be included in a binding table in addition to and/or instead of the information shown in FIG. **2**C.

Client IP address **71** may have been generated by protocol server **16** (in this example, a DHCP server) of FIG. **1**. Snooping agent **50** obtains client IP address **71** from a protocol message being sent from protocol server **16** to a particular protocol client **12** and stores client IP address **71** in a binding table entry corresponding to that protocol client. Lease time **79** is a value representing the length of time that client IP address **71** may be used by the client to which that IP address is assigned. Snooping agent **50** also obtains this information from the DHCP server reply assigning the IP address to the client.

Snooping agent **50** can obtain other information for storage in binding table **70** from protocol messages generated by clients **12**. For example, snooping agent **50** may allocate a binding table entry **62** to a particular client in response to intercepting a DHCP request from that client requesting an IP address from a DHCP server. Snooping agent **50** can obtain client MAC address **73**, interface ID **75**, and/or VLAN ID **77** from the DHCP request and store this information in the allocated binding table entry.

In one embodiment in which DHCP messages are being intercepted, snooping agent **50** responds to a DHCP ACK message (sent from a DHCP server to a DHCP client to assign an IP address to that client) by allocating an entry **62** in binding table **70** to the DHCP client, if such an entry does not already exist. In response to a DHCP NAK message (sent from a DHCP server to a DHCP client to deny assigning an IP address to that client), snooping agent **50** deletes an existing binding table entry (if any) corresponding to that client. A DHCP NAK message is sent when a client attempts to reuse an IP address and the DHCP server determines that the IP address is not applicable to the client (e.g., because the client has moved to a new subnet). Similarly, in response to a DHCP RELEASE message (sent from a client to a DHCP server to relinquish an IP address assigned to that client), snooping agent **50** deletes an existing binding table entry corresponding to that client. If a DHCP DECLINE message (sent from a client to a DHCP server in response to the client discovering that an IP address is already assigned to another device) is received, snooping agent **50** deletes an existing binding table entry (if any) corresponding to that client.

Generally, snooping agent **50** stores various information, such as an IP address, identifying a network service provided by a protocol server to a protocol client in a binding table entry associated with a particular client. Snooping agent **50** can also store other information identifying that client, such as a client MAC address and an interface ID, in the binding table entry. Snooping agent **50** may use this information to verify subsequent protocol messages. For example, snooping agent **50** can verify the sender of a particular protocol message by comparing the source IP address, MAC address, and interface ID in a particular message with the information stored in binding table **70**. If no entry **62** in binding table **70** includes the same combination of source IP address, MAC address, and interface ID, snooping agent **50** determines that the protocol message was not sent by the client identified as the sender and, in response to that determination, drop the protocol message.

A binding table **70** can also be used to store information, such as lease time **79**, indicating how network services provided by a particular protocol are to be used. Snooping agent **50** may use this information to verify that network services (e.g., IP addresses) are being used in a manner that is consistent with the protocol. For example, using lease time information **79**, snooping agent **50** can examine intercepted protocol messages to determine whether a client is attempting to use an IP address for longer than the client is allowed. If a protocol violation is detected (e.g., if a message sent by a client having a particular IP address is received subsequent to the expiration of the lease time associated with that IP address in the binding table) in a particular message, snooping agent **50** drops that message.

In some embodiments, binding table **70** is implemented as a hash table. To access a binding table entry associated with a particular client, information such as the client's MAC address and VLAN ID is used as a hash key.

FIG. **3** is a flowchart illustrating one embodiment of a method of snooping protocol messages in order to update protocol status information and to perform security actions dependent on the protocol status information. At **300**, one or more protocol messages being communicated via a network are intercepted by a network device. The protocol messages are included in a stream of messages input to the network device. In some embodiments, the network device may detect protocol messages based on a server port indicated in the protocol messages.

In response to the intercepted protocol messages, the network device updates protocol status information, as indicated at **302**. The protocol status information includes both information included in the protocol messages and information indicative of how the protocol messages are conveyed from one or more protocol clients to the network. For example, in response to receiving a protocol message sent by a protocol client to request a network service, the network device can store information indicating that the protocol request was received via a particular logical and/or physical interface of the network device. The network device can store information indicating that the protocol client has an outstanding protocol request. The network device can also store information included in the protocol request that identifies the client device (e.g., a VLAN ID and/or MAC address). Similarly, in response to a protocol message sent by a protocol server to provide a network service to a client, the network device stores information identifying the network service (e.g., an IP address), the client to which that service is being provided, and/or information (e.g., a lease time) indicating how the client may use the service. The protocol status information can also include information indicative of the rate at which protocol messages are being received from a particular client or group of clients or via a particular interface or group of interfaces.

The network device then uses the protocol status information updated at **302** to determine whether to perform security actions for subsequently received messages. As indicated at **304**, the network device performs a security action for a subsequent protocol message dependent on the protocol status information and the type (e.g., client request, server response, and the like) of the subsequent protocol message. Security actions include dropping the protocol message if it includes information that is inconsistent with the protocol status information, updating information included in the protocol message, and/or updating an error log. Note that the network device can also update the protocol status information in response to the subsequently received protocol message.

In some embodiments, the network device also uses the protocol status information to determine whether to perform security actions in response to non-protocol messages, as indicated at **306**. For example, a network device may receive, via one of the network device's interfaces, a mes-

sage containing information indicating that it was sent by a client having a certain IP address, assigned using the network protocol. The network device can verify whether the protocol server assigned that IP address to a client that sends messages to the network via that interface of the network device. If the protocol status information indicates that the client assigned that IP address sends messages to the network via another interface of the network device, or that no client has been assigned that IP address, the network device performs a security action such as dropping the message and/or updating an error log. If the protocol status information instead indicates that the client assigned that IP address does convey messages to the network via that interface of the network device, the network device may allow the message to continue its progress through the network.

FIG. **4**A is a flowchart illustrating various security actions that can be performed dependent upon protocol status information. In this embodiment, a network device receives a protocol message via a particular logical and/or physical interface, as indicated at **400**. Based on protocol status information maintained by that network device, the network device determines whether the interface that received the protocol message is allowed to issue that type of protocol message, as shown at **402**. If the interface is not allowed to issue that type of protocol message (e.g., if the interface is not coupled to receive messages from a protocol server, and if the message is of a type that is only allowed to be sent by a protocol server), the network device drops the message, as shown at **420**. Otherwise, the network device proceeds to further verify the protocol message at **404**.

As indicated at **404**, the network device verifies whether a rate limit for protocol messages has been exceeded. If so, the network device drops the protocol message, as shown at **420**. The rate of protocol messages can be limited on a per interface (or group of interfaces) and/or a per client (or group of clients) basis in some embodiments.

At **406**, the network device verifies whether protocol relay information (if any) included in the protocol message is correct. For example, if the protocol message is a DHCP message, the network device can check to see if another network device has inserted relay information into the protocol message. If so, the network device determines whether the protocol relay information is correct, based on information indicative of the interface via which the message was received.

If the protocol relay information (if any) in the protocol message is correct, the network device can modify or add protocol relay information to the protocol message, as indicated at **408**. For example, if no protocol relay information is included in the protocol message (e.g., because this network device is the first network device allowed to add relay information to handle the protocol message), the network device adds protocol relay information to the protocol message. Alternatively, if the network device is outputting the protocol message to a client or server (as opposed to another network device), the network device removes any protocol relay information already included in the message.

If the protocol message is a type of message (e.g., a protocol reply such as a DHCP ACK or DHCP NAK) sent by a protocol server, as determined at **412**, the network device accesses the protocol status information to determine whether the protocol message corresponds to an outstanding protocol request from a client, as shown at **416**. If the protocol message does not correspond to an outstanding request, the network device drops the protocol message, as shown at **420**. Otherwise, the network device unicasts the protocol message to the destination client so that no other clients receive the protocol message, as indicated at **418**. If the protocol message is not a type of message sent by a protocol server, the network device transmits the protocol message normally (e.g., if the protocol message is identified as a message that should be flooded or multicast, the network device will appropriately flood or multicast the protocol message), as shown at **414**.

FIG. **4**B is a flowchart illustrating additional details of how protocol status information is used to verify that a particular interface is allowed to issue a particular type of protocol messages in the embodiment of FIG. **4**A. At **430**, the network device determines whether the protocol message is of a type that must be sent by a protocol server. For example, if the protocol message is a DHCP message, the network device identifies messages of types DHCP OFFER, DHCP ACK, and DHCP NAK as messages that only a DHCP server is allowed to send. If the protocol message is of a type that is not required to be sent by a protocol server, the network device determines that the interface is allowed to issue this type of protocol message, as shown at **434**. Note that in some embodiments, if the protocol message is of a type that may only be sent by a protocol client, the network device additionally verifies whether there are any protocol clients coupled to send messages via that interface before reaching the determination at **434**.

If the protocol message is of a type that can only be sent by a protocol server, the network device accesses protocol status information to determine whether the interface via which the protocol message was received into the network device is coupled to receive messages from a protocol server, as shown at **432**. If the protocol status information indicates that a protocol server is coupled to that interface, then the network device determines that the interface is allowed to issue that type of protocol message. Otherwise, the network device determines that the interface is not allowed to issue that type of protocol message, as indicated at **436**. In response, the protocol message is dropped, as shown at **420** of FIG. **4**A.

FIG. **5** is a flowchart illustrating how protocol status information is obtained from intercepting a protocol request from a protocol client and a protocol reply from a protocol server and how this protocol status information is then used to verify other protocol messages, according to one embodiment. At **500**, a protocol message is intercepted. The protocol message contains a client request for network services that is being sent from a protocol client to a protocol client via a network. In response to the intercepted client request protocol message, protocol status information is updated at **502** to include information in the protocol message and/or to identify the interface that received the client request. The protocol status information can also be updated to indicate that the protocol client has an outstanding protocol request.

At **504**, a protocol message that contains a protocol server reply is intercepted as the protocol message is being sent from the protocol server to the protocol client. In response, the protocol status information is updated at **506** to include information in the server reply and/or to match the server reply to the outstanding client request intercepted at **500**.

Dependent upon the protocol status information updated at **502** and **506**, a security action is performed at **508** in response to intercepting a subsequent protocol message. A security action can involve dropping the subsequent protocol message or logging an error. For example, the protocol status information can be used to verify the identity of the sender of the subsequent protocol message, or to determine that a preset rate limit of protocol messages has not been exceeded. Note that the protocol status information can also

be updated in response to the subsequent protocol message. In some embodiments, the protocol status information updated at **502** and **506** is also used to determine whether to perform a security action in response to intercepting a subsequent non-protocol message, as indicated at **510**.

FIG. **6** is a block diagram of switch **20** illustrating how a snooping agent **50** can be implemented in software executing on the switch. As illustrated, switch **20** includes one or more processors **110** (e.g., microprocessors, PLDs (Programmable Logic Devices), or other ASICs (Application Specific Integrated Circuits)) configured to execute program instructions stored in memory **120**. Memory **120** can include various types of RAM, ROM, Flash memory, MEMS memory, and the like. In the illustrated embodiment, protocol message detector **24** is implemented in hardware (e.g., using a CAM and/or ACL). Processor **110**, protocol message detector **24**, and memory **120** are coupled to send and receive data and control signals by a bus or other interconnect.

Memory **120** stores program instructions executable by processor **110** to implement an operating system **122** configured to control basic functionality of switch **20**. Operating system **122** can include snooping agent **50** (alternatively, snooping agent **50** can be implemented as a program that interacts with, but is not part of, operating system **122**). Memory **120** may also be used to store protocol status information used and maintained by snooping agent **50**. Memory **120** is an example of a means for storing protocol status information for a network protocol

The program instructions and data implementing snooping agent **50** can be stored upon various computer readable media such as memory **120**. In some embodiments, snooping agent **50** software is stored on a computer readable medium such as a CD (Compact Disc), DVD (Digital Versatile Disc), hard disk, optical disk, tape device, floppy disk, and the like). In order be executed by processor **110**, the instructions and data implementing snooping agent **50** are loaded into memory **120** from the other computer readable medium. The instructions and/or data implementing can also be transferred to switch **20** via a network such as the Internet or upon a carrier medium. In some embodiments, a computer readable medium is a carrier medium such as a network and/or a wireless link upon which signals such as electrical, electromagnetic, or digital signals, on which the data and instructions implementing snooping agent **50** are encoded, are conveyed.

Although the present invention has been described with respect to specific embodiments thereof, various changes and modifications may be suggested to one skilled in the art. It is intended such changes and modifications fall within the scope of the appended claims.

What is claimed is:

1. A system, comprising:

a protocol status information storage unit comprising protocol status information for a network protocol, wherein

the protocol status information comprises:

protocol information generated by a protocol server; and

network traffic information indicative of how messages are conveyed from a protocol client to a network;

a snooping agent coupled to the protocol status information storage unit, wherein

the snooping agent is configured to update both the protocol information and the network traffic information in response to intercepting a protocol message being conveyed between the protocol client and the protocol server.

2. The system of claim **1**, wherein:

the protocol status information comprises information generated by the protocol client.

3. The system of claim **1**, further comprising:

a switch, wherein the protocol status information storage unit is comprised in the switch.

4. The system of claim **3**, wherein:

the network switch comprises a plurality of interfaces; and

the protocol status information indicates which one of the plurality of interfaces is coupled to convey messages to and from a particular protocol client.

5. The system of claim **4**, wherein:

at least some of the plurality of interfaces are logical interfaces.

6. The system of claim **4**, wherein:

the plurality of interfaces are implemented in a hierarchy.

7. The system of claim **3**, wherein:

the network switch comprises a plurality of interfaces; and

the protocol status information indicates which one of the plurality of interfaces is coupled to convey messages to and from a particular protocol server.

8. The system of claim **7**, wherein:

in response to intercepting a protocol reply from the protocol server, the snooping agent is configured to verify that the protocol reply is received via a network interface coupled to the protocol server.

9. The system of claim **1**, wherein:

in response to intercepting a protocol reply from the protocol server, the snooping agent is configured to verify that the protocol reply corresponds to an outstanding protocol request generated by one of a plurality of protocol clients.

10. The system of claim **1**, wherein:

the network protocol is DHCP (Dynamic Host Configuration Protocol); and

the snooping agent is configured to update the protocol status information to indicate an IP (Internet Protocol) address assigned to the protocol client by the protocol server in the protocol message.

11. The system of claim **1**, wherein:

the snooping agent is configured to perform a security action in response to intercepting a subsequent non-protocol message sent by the protocol client, dependent on the protocol status information comprised in the protocol status information storage unit.

12. The system of claim **11**, wherein:

if the protocol status information indicates that the protocol client that sent the subsequent non-protocol message is using protocol information sent to a different one of a plurality of protocol clients by the protocol server, the security action comprises dropping the subsequent non-protocol message.

13. The system of claim **1**, wherein:

the snooping agent is configured to perform a security action in response to intercepting a subsequent protocol message, dependent on the protocol status information comprised in the protocol status information storage unit.

14. The system of claim **13**, wherein:

the security action comprises dropping the subsequent protocol message if the subsequent protocol message is inconsistent with the protocol status information.

15. The system of claim 13, wherein:

the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message is a type of protocol message required to be generated by the protocol server, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol server.

16. The system of claim 13, wherein:

the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message identifies the protocol client as a sender of the subsequent protocol message, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol client.

17. The system of claim 13, wherein:

the security action comprises dropping the subsequent protocol message if the protocol status information indicates that a maximum rate of protocol messages has been exceeded.

18. The system of claim 17, wherein:

the protocol status information indicates a maximum rate of protocol requests to be received via a particular interface.

19. The system of claim 13, wherein:

if the subsequent protocol message is a protocol reply from the protocol server to one of a plurality of protocol clients, the security action comprises unicasting the protocol reply to the one of the plurality of protocol clients.

20. The system of claim 13, wherein:

the snooping agent is configured to verify protocol relay information comprised in the subsequent protocol message.

21. The system of claim 20, wherein:

the snooping agent is configured to modify protocol relay information comprised in the subsequent protocol message.

22. The system of claim 13, wherein:

the snooping agent is configured to access the protocol status information to determine whether one of a plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to the one of the plurality of protocol clients by the protocol server.

23. The system of claim 13, wherein:

if the protocol status information indicates that one of a plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to a different one of the plurality of protocol clients by the protocol server, the security action comprises dropping the subsequent protocol message.

24. The system of claim 13, wherein:

the security action comprises dropping the subsequent protocol message if the protocol status information indicates that one of a plurality of protocol clients that sent the subsequent protocol message is not using protocol information generated by the protocol server according to policies associated with the protocol information.

25. The system of claim 13, wherein:

the network protocol is a DHCP (Dynamic Host Configuration Protocol).

26. The system of claim 13, wherein:

the network protocol implements DNS (Domain Name Service).

27. A method, comprising:

maintaining protocol status information for a network protocol, wherein the protocol status information comprises:

protocol information generated by a protocol server, and

network traffic information indicative of how messages are conveyed from a protocol client to a network; and

updating both the protocol information and the network traffic information in response to intercepting a protocol message being conveyed between the protocol client and the protocol server.

28. The method of claim 27, wherein:

the protocol status information comprises protocol information generated by the protocol client.

29. The method of claim 28, wherein:

said maintaining is performed by a network switch.

30. The method of claim 29, wherein:

the protocol status information indicates which one of a plurality of interfaces comprised in the network switch is coupled to convey messages to and from a particular protocol client.

31. The method of claim 30, wherein:

at least some of the plurality of interfaces are logical interfaces.

32. The method of claim 30, wherein:

the plurality of interfaces are implemented in a hierarchy.

33. The method of claim 29, wherein:

the protocol status information indicates which one of a plurality of interfaces comprised in the network switch is coupled to convey messages to and from a particular protocol server.

34. The method of claim 33, further comprising:

in response to intercepting a protocol reply from the protocol server, verifying that the protocol reply is received via a network interface coupled to the protocol server.

35. The method of claim 27, further comprising:

in response to intercepting a protocol reply from the protocol server, verifying that the protocol reply corresponds to an outstanding protocol request generated by one of a plurality of protocol clients.

36. The method of claim 27, wherein:

the network protocol is DHCP (Dynamic Host Configuration Protocol); and

said updating comprises updating the protocol status information to indicate an IP (Internet Protocol) address assigned to the protocol client by the protocol server in the protocol message.

37. The method of claim 27, further comprising:

initiating a security action in response to intercepting a subsequent non-protocol message, dependent on the protocol status information.

38. The method of claim 27, further comprising:

initiating a security action in response to intercepting a subsequent protocol message, dependent on the protocol status information.

39. The method of claim 38, wherein:

said initiating the security action comprises dropping the subsequent protocol message if the subsequent protocol message is inconsistent with the protocol status information.

40. The method of claim 38, wherein:

said initiating the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message is a type of protocol message required to be generated by the protocol server, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol server.

41. The method of claim 38, wherein:

said initiating the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message identifies the protocol client as a sender of the subsequent protocol message, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol client.

42. The method of claim 38, wherein:

said initiating the security action comprises dropping the subsequent protocol message if the protocol status information indicates that a maximum rate of protocol messages has been exceeded.

43. The method of claim 42, wherein:

the protocol status information indicates a maximum rate of protocol requests to be received via a particular interface.

44. The method of claim 38, wherein:

if the subsequent protocol message is a protocol reply from the protocol server to one of a plurality of protocol clients, said performing the security action comprises unicasting the protocol reply to the one of the plurality of protocol clients.

45. The method of claim 38, further comprising:

verifying protocol relay information comprised in the subsequent protocol message.

46. The method of claim 45, further comprising:

modifying protocol relay information comprised in the subsequent protocol message.

47. The method of claim 38, further comprising:

accessing the protocol status information to determine whether one of a plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to the one of the plurality of protocol clients by the protocol server.

48. The method of claim 38, wherein:

if the protocol status information indicates that one of a plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to a different one of the plurality of protocol clients by the protocol server, said initiating the security action comprises dropping the subsequent protocol message.

49. The method of claim 38, wherein:

said initiating the security action comprises dropping the subsequent protocol message if the protocol status information indicates that one of a plurality of protocol clients that sent the subsequent protocol message is not using protocol information generated by the protocol server according to policies associated with the protocol information.

50. The method of claim 38, wherein:

the network protocol is DHCP (Dynamic Host Configuration Protocol).

51. The method of claim 38, wherein:

the network protocol implements DNS (Domain Name Service).

52. The method of claim 38, further comprising:

accessing an access control list to determine whether a message is a protocol message; and

in response to the access control list indicating that the message is a protocol message, initiating the security action for the message dependent upon the protocol status information.

53. A method, comprising:

intercepting one or more protocol messages being communicated via a network;

updating network traffic information in response to the one or more protocol messages, wherein the network traffic information indicates which one of a plurality of interfaces is coupled to convey messages to and from a particular protocol client; and

initiating a security action in response to a protocol message of the one or more protocol messages, dependent on the network traffic information and a type of the protocol message.

54. A system, comprising:

means for storing protocol status information for a network protocol, wherein the protocol status information comprises:

protocol information generated by a protocol server, and

network traffic information indicative of how messages are conveyed from a protocol client to a network; and

means for updating both the protocol information and the network traffic information in response to intercepting a protocol message being conveyed between the protocol client and the protocol server.

55. The system of claim 54, wherein:

the means for storing protocol status information and the means for updating the protocol status information are comprised in a network switch.

56. The system of claim 55, wherein:

the protocol status information indicates which one of a plurality of interfaces comprised in the network switch is coupled to convey messages to and from a particular protocol client.

57. The system of claim 55, further comprising:

in response to intercepting a protocol reply from the protocol server, the means for updating the protocol status information verify that a protocol reply is received via a network interface coupled to the protocol server, wherein

the protocol status information indicates which one of a plurality of interfaces comprised in the network switch is coupled to convey messages to and from the protocol server.

58. The system of claim 54, further comprising:

in response to intercepting a protocol reply from the protocol server, the means for updating the protocol status information verify that the protocol reply corresponds to an outstanding protocol request generated by one of a plurality of protocol clients.

59. The system of claim 54, wherein:

the network protocol is DHCP (Dynamic Host Configuration Protocol); and

the means for updating the protocol status information update the protocol status information to indicate an IP (Internet Protocol) address assigned to the protocol client by the protocol server in the protocol message.

60. The system of claim **54**, wherein:

the means for updating the protocol status information initiate a security action in response to intercepting a subsequent non-protocol message; and

the means for updating the protocol status information initiate the security action dependent on the protocol status information.

61. The system of claim **54**, wherein:

the means for updating the protocol status information initiate the security action in response to intercepting a subsequent protocol message; and

the means for updating the protocol status information initiate the security action dependent on the protocol status information.

62. The system of claim **61**, wherein:

the security action comprises dropping the subsequent protocol message if the subsequent protocol message is inconsistent with the protocol status information.

63. The system of claim **61**, wherein:

the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message is a type of protocol message required to be generated by the protocol server, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol server.

64. The system of claim **61**, wherein:

the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message identifies the protocol client as a sender of the subsequent protocol message, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol client.

65. The system of claim **61**, wherein:

the security action comprises dropping the subsequent protocol message if the protocol status information indicates that a maximum rate of protocol messages has been exceeded.

66. The system of claim **61**, wherein:

if the subsequent protocol message is a protocol reply from the protocol server to one of a plurality of protocol clients, the security action comprises unicasting the protocol reply to the one of the plurality of protocol clients.

67. The system of claim **61**, wherein:

the means for updating the protocol status information verify protocol relay information comprised in the subsequent protocol message.

68. The system of claim **61**, wherein:

the means for updating the protocol status information access the protocol status information to determine whether one of a plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to the one of the plurality of protocol clients by the protocol server; and

if the protocol status information indicates that one of the plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to a different one of the plurality of protocol clients by the protocol server, the security action comprises dropping the subsequent protocol message.

69. The system of claim **61**, wherein:

the security action comprises dropping the subsequent protocol message if the protocol status information indicates that one of a plurality of protocol clients that sent the subsequent protocol message is not using protocol information generated by the protocol server according to policies associated with the protocol information.

70. A computer readable storage medium, comprising program instructions executable to:

maintain protocol status information for a network protocol, wherein the protocol status information comprises:

protocol information generated by a protocol server, and

network traffic information indicative of how messages are conveyed from a protocol client to a network; and

update both the protocol information and the network traffic information in response to intercepting a protocol message being conveyed between the protocol client and the protocol server.

71. The computer readable storage medium of claim **70**, wherein:

the protocol status information indicates which one of a plurality of interfaces comprised in a network switch is coupled to convey messages to and from a particular protocol client.

72. The computer readable storage medium of claim **70**, wherein:

in response to intercepting a protocol reply from the protocol server, the program instructions are executable to verify that a protocol reply is received via a network interface coupled to the protocol server, wherein

the protocol status information indicates which one of a plurality of interfaces comprised in a network switch is coupled to convey messages to and from the protocol server.

73. The computer readable storage medium of claim **70**, wherein in response to intercepting a protocol reply from the protocol server the program instructions are executable to:

verify that the protocol reply corresponds to an outstanding protocol request generated by one of a plurality of protocol clients.

74. The computer readable storage medium of claim **70**, wherein:

the network protocol is DHCP (Dynamic Host Configuration Protocol); and

the program instructions are executable to update the protocol status information to indicate an IP (Internet Protocol) address assigned to the protocol client by the protocol server in the protocol message.

75. The computer readable storage medium of claim **70**, wherein in response to intercepting a subsequent non-protocol message, the program instructions are executable to:

initiate a security action, dependent on the protocol status information.

76. The computer readable storage medium of claim **70**, wherein in response to intercepting a subsequent protocol message, the program instructions are executable to:

initiate a security action, dependent on the protocol status information.

77. The computer readable storage medium of claim **76**, wherein:

the security action comprises dropping the subsequent protocol message if the subsequent protocol message is inconsistent with the protocol status information.

78. The computer readable storage medium of claim **76**, wherein:

the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message is a type of protocol message required to be generated by the protocol server, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol server.

79. The computer readable storage medium of claim **76**, wherein:

the security action comprises dropping the subsequent protocol message if:

the subsequent protocol message identifies the protocol client as a sender of the subsequent protocol message, and

the protocol status information indicates that an interface that received the subsequent protocol message is not coupled to receive messages from the protocol client.

80. The computer readable storage medium of claim **76**, wherein:

the security action comprises dropping the subsequent protocol message if the protocol status information indicates that a maximum rate of protocol messages has been exceeded.

81. The computer readable storage medium of claim **76**, wherein:

if the subsequent protocol message is a protocol reply from the protocol server to one of a plurality of protocol clients, the security action comprises unicasting the protocol reply to the one of the plurality of protocol clients.

82. The computer readable storage medium of claim **76**, wherein the program instructions are executable to:

verify protocol relay information comprised in the subsequent protocol message.

83. The computer readable storage medium of claim **76**, wherein:

the program instructions are executable to access the protocol status information to determine whether one of a plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to the one of the plurality of protocol clients by the protocol server; and

if the protocol status information indicates that the one of the plurality of protocol clients that sent the subsequent protocol message is using protocol information sent to a different one of the plurality of protocol clients by the protocol server, the security action comprises dropping the subsequent protocol message.

84. The computer readable storage medium of claim **76**, wherein:

the security action comprises dropping the subsequent protocol message if the protocol status information indicates that one of a plurality of protocol clients that sent the subsequent protocol message is not using protocol information generated by the protocol server according to policies associated with the protocol information.

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