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(54) SHARED PORT ADDRESS TRANSLATION ON A ROUTER BEHAVING AS NAT & NAT-PT GATEWAY

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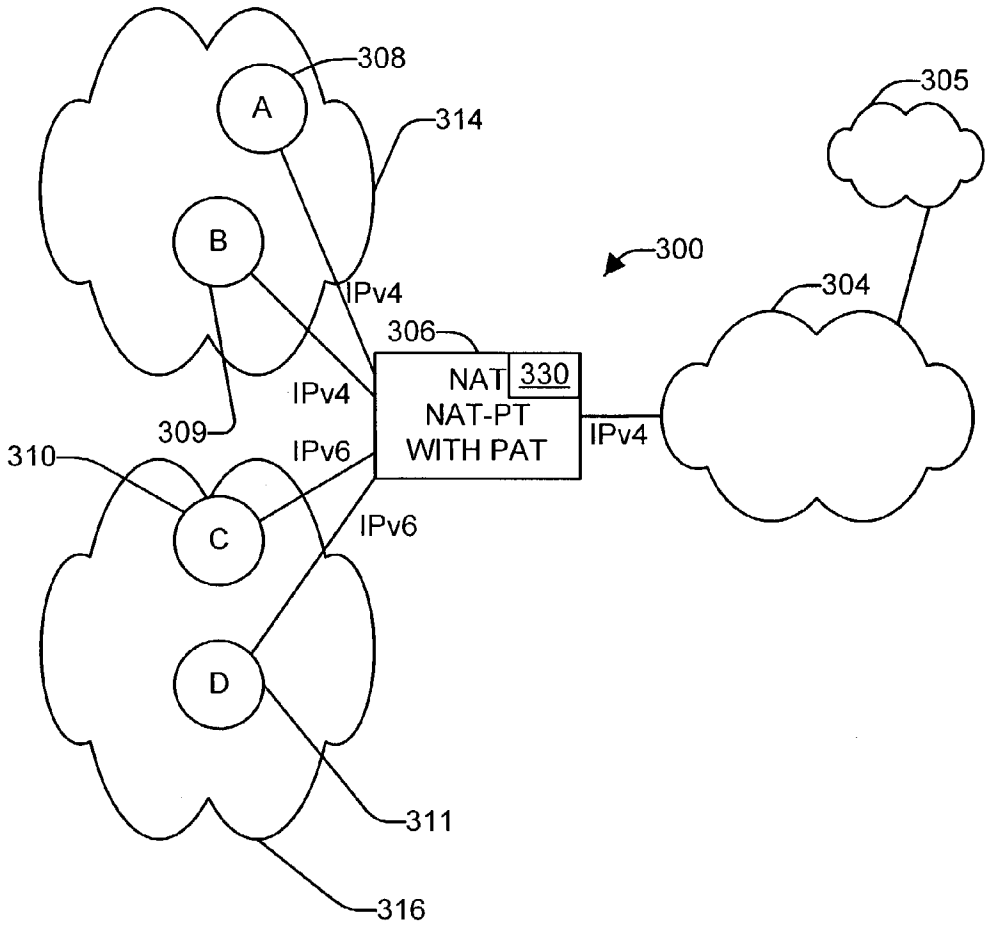
(52) **U.S. Cl.** **370/467**; 370/389

(57) **ABSTRACT**

A method for transparently sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol is provided. A first data having a first source address and a first destination address is received. A network address translation with port address translation is performed, if the first data is in an IPv4 protocol. A network address translation protocol translation with port address translation is performed, if the first data is in an IPv6 protocol.



FreeWheel, Ex. 1013

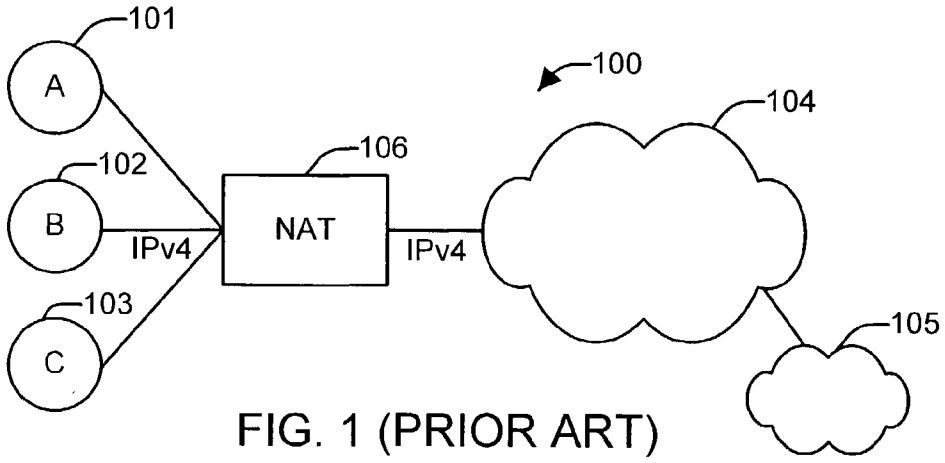


FIG. 1 (PRIOR ART)

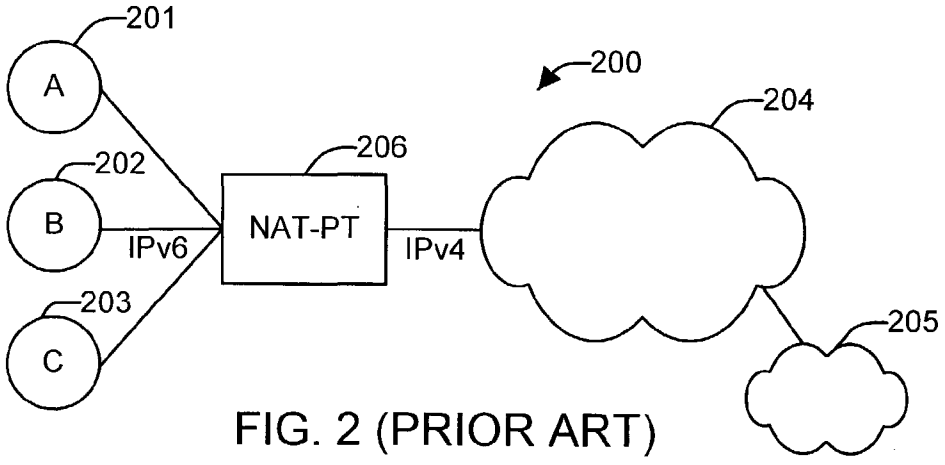


FIG. 2 (PRIOR ART)

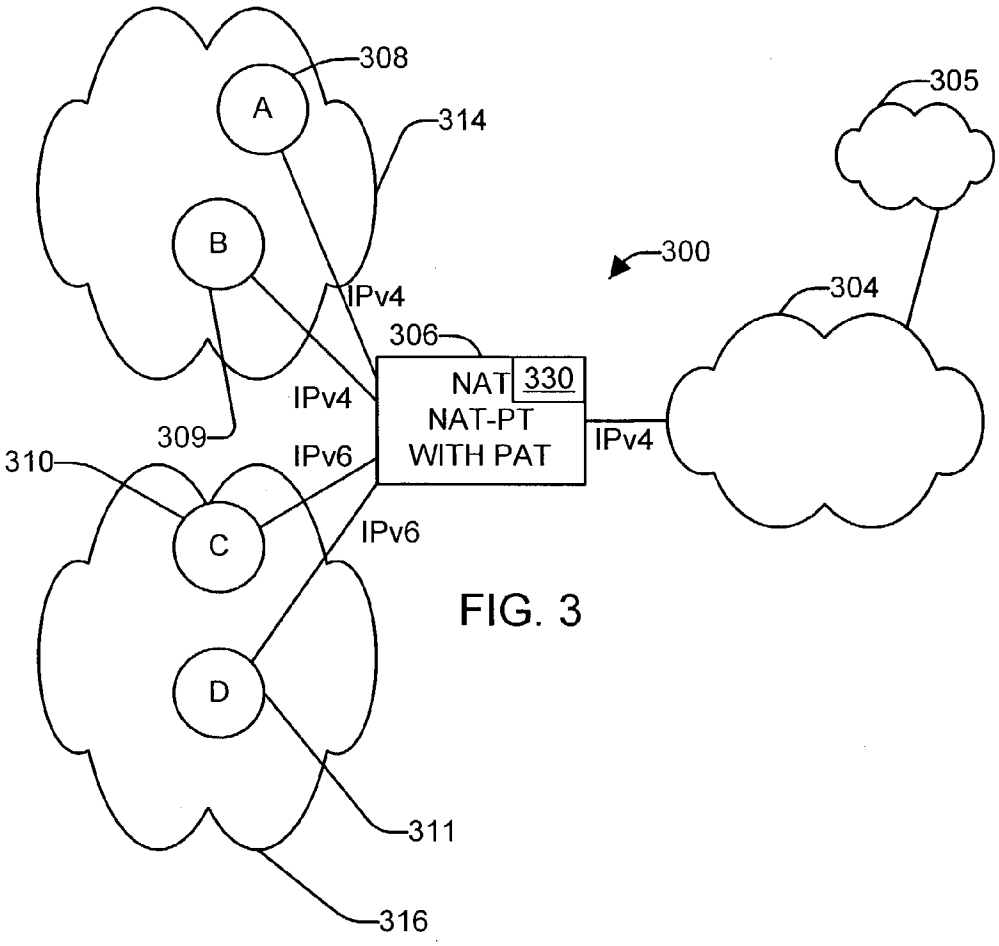

308
A
314
305
B
300
IPv4
304
306
NAT
330
IPv4
NAT-PT
WITH PAT
IPv4
309
310
IPv6
C
IPv6
D
311
316

FIG. 3

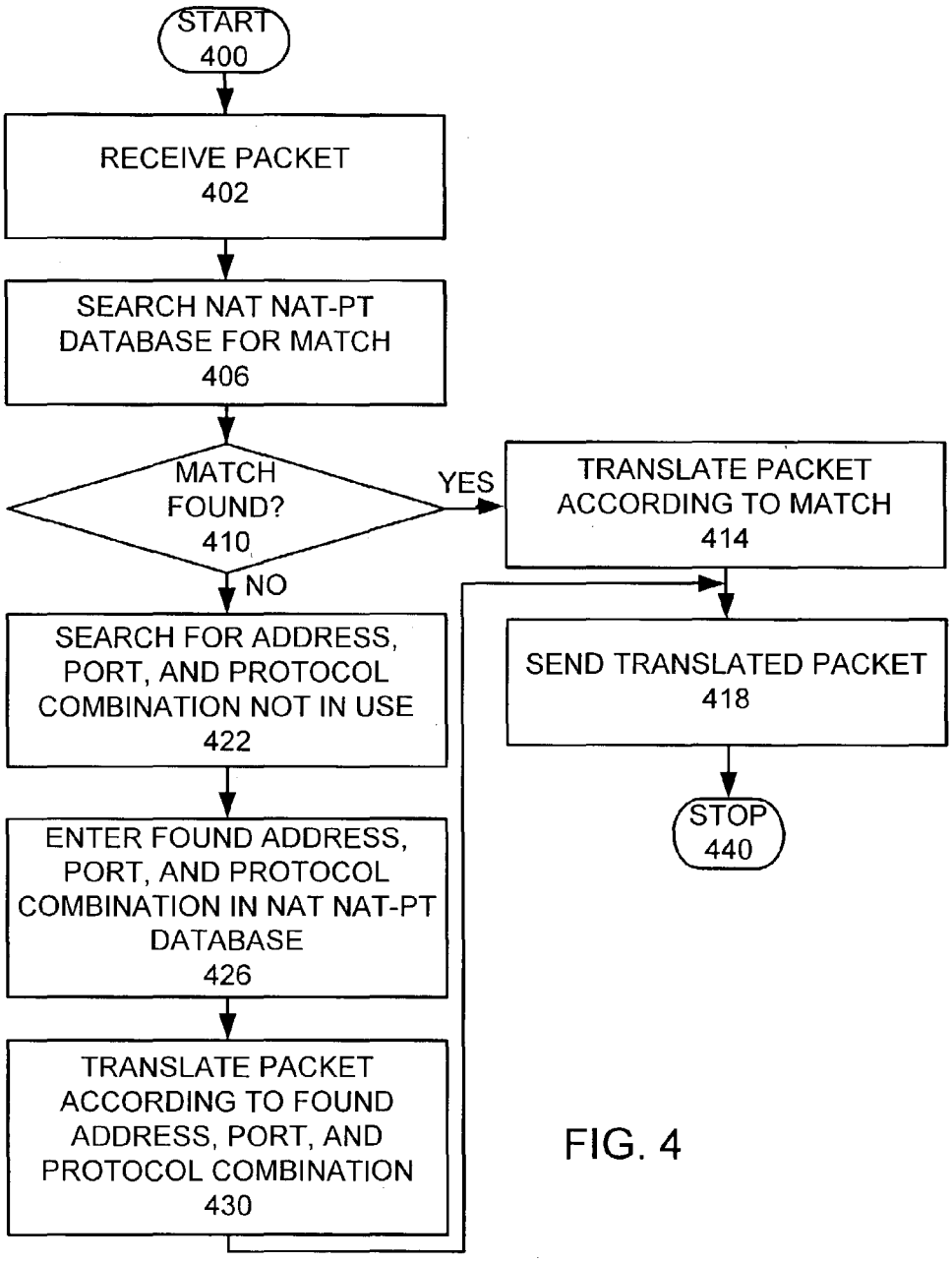

START
400
RECEIVE PACKET
402
SEARCH NAT NAT-PT DATABASE FOR MATCH
406
MATCH FOUND?
410
YES
NO
TRANSLATE PACKET ACCORDING TO MATCH
414
SEND TRANSLATED PACKET
418
STOP
440
SEARCH FOR ADDRESS, PORT, AND PROTOCOL COMBINATION NOT IN USE
422
ENTER FOUND ADDRESS, PORT, AND PROTOCOL COMBINATION IN NAT NAT-PT DATABASE
426
TRANSLATE PACKET ACCORDING TO FOUND ADDRESS, PORT, AND PROTOCOL COMBINATION
430

FIG. 4

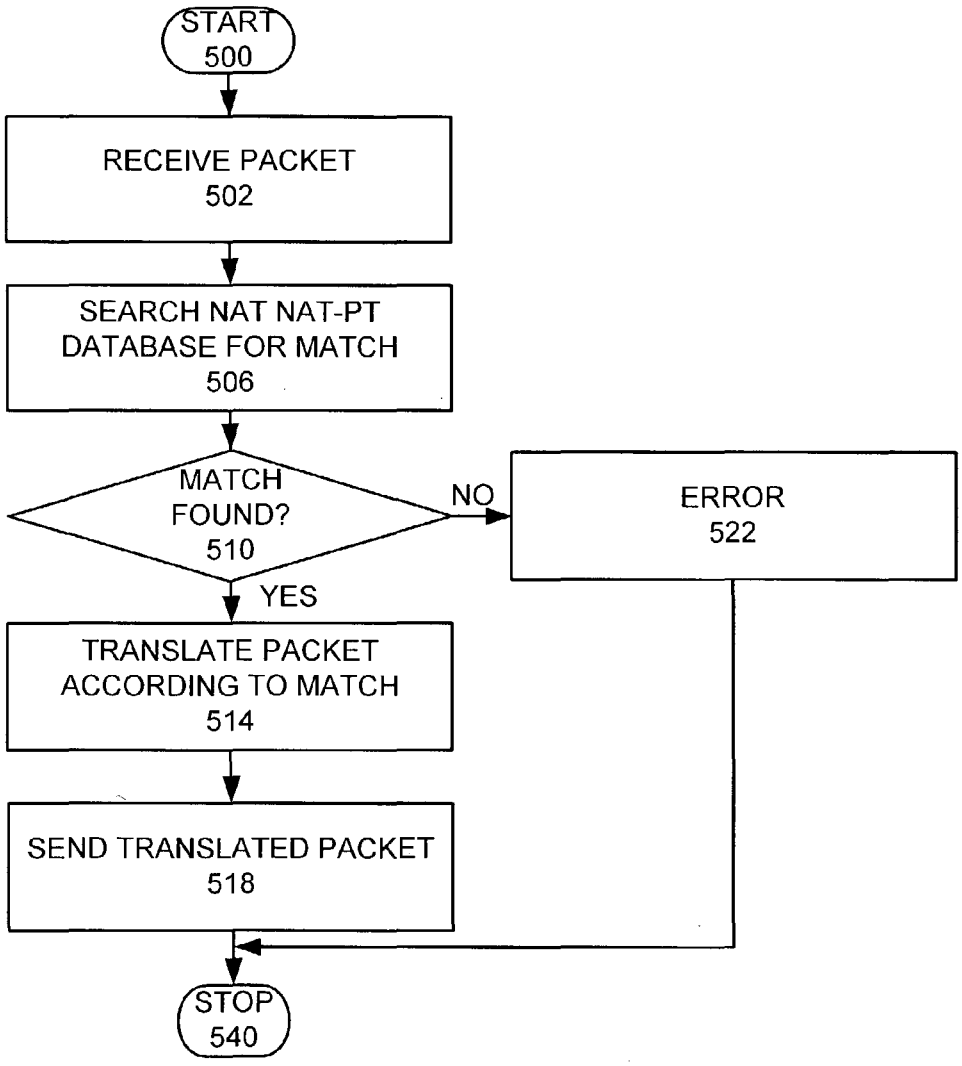

START
500
RECEIVE PACKET
502
SEARCH NAT NAT-PT
DATABASE FOR MATCH
506
MATCH
FOUND?
510
NO
ERROR
522
YES
TRANSLATE PACKET
ACCORDING TO MATCH
514
SEND TRANSLATED PACKET
518
STOP
540

FIG. 5

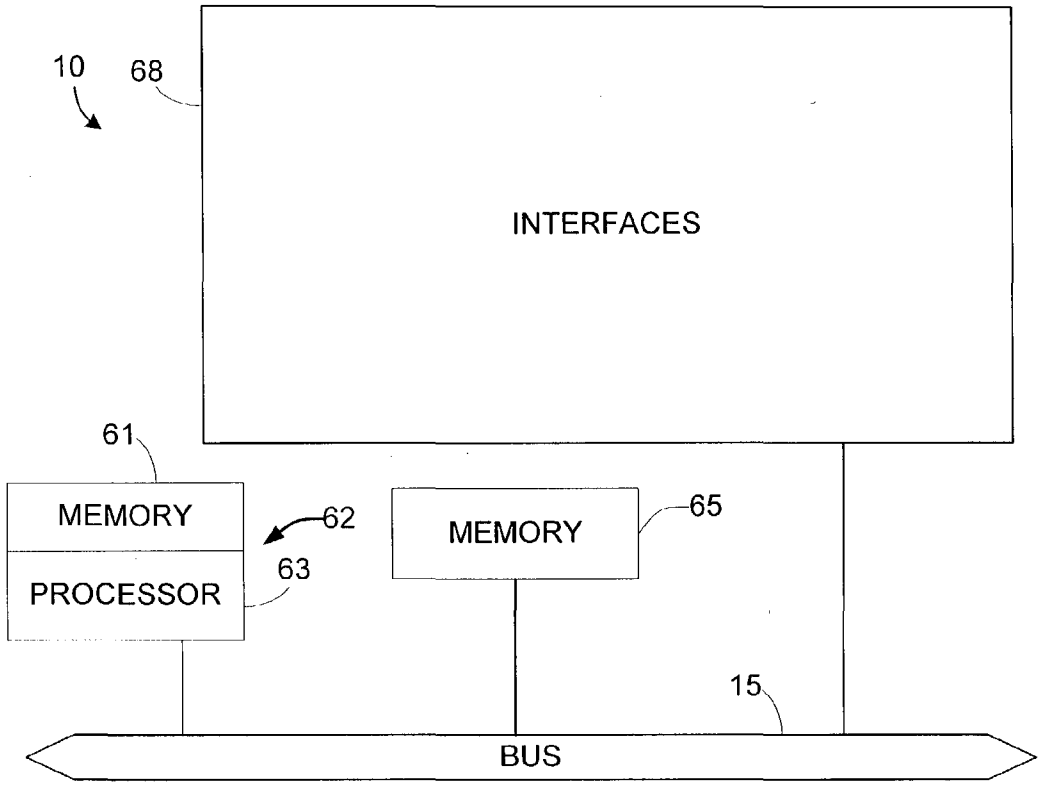


FIG. 6

SHARED PORT ADDRESS TRANSLATION ON A ROUTER BEHAVING AS NAT & NAT-PT GATEWAY

BACKGROUND OF THE INVENTION

[0001] The present invention relates to methods and apparatus for processing data within a computer network. More specifically, this invention relates to performing network address translation on data.

[0002] In a network, devices on the network are provided network addresses, which are used to identify the different devices, when devices communicate between each other. IP protocol version 4 (IPv4) is a protocol used to provide addresses for public and private networks. A private network, such as an enterprise system, may be connected to a public network, such as the Internet. Such private networks may have more devices than available Internet IPv4 addresses allocated to the private network. In such a situation, a network address translator (NAT) may be connected between the private network and the Internet. The NAT may dynamically assign IPv4 addresses, so that the number of devices using the Internet at one time is limited to the available number of IPv4 addresses allocated to the private network. In the alternative, the NAT may use port address translation, where port numbers are used to further identify different devices with the same address.

[0003] IPv4 uses a 32-bit address. Even with these various multiplexing methods to allow multiple devices for each Internet IPv4 address, the number of devices that are desired to be connected to the Internet will exceed the limits of a 32-bit address. IPv6 is a protocol that is designed to replace IPv4. IPv6 provides for a 128-bit address to overcome address depletion and other problems caused by IPv4. Because a large number of devices and routers using IPv4 are in existence, IPv6 should replace IPv4 gradually, instead of instantaneously. As a result, networks using IPv6 need to be able to communicate with networks using IPv4 for a long period of time.

[0004] **FIG. 1** is a schematic illustration of a system **100** that allows a network address translator (NAT) **106** to provide network address translations between a private IPv4 network with a plurality of IPv4 users **101**, **102**, **103** and a public network **104**, such as an Internet, which is connected to a plurality of web servers **105**, using the IPv4 protocol. The NAT **106** is able to provide a plurality of users Internet access, using a small number of IPv4 addresses. In this example, a single IPv4 address of 128.1.1.1 is assigned to the NAT **106**. The NAT **106** may assign the plurality of users **101**, **102**, **103** private network addresses. For example, a user A **101** may be assigned a private network address of 10.1.1.1, a user B **102** may be assigned a private network address of 10.1.1.2, and a user C **103** may be assigned a private network address of 10.1.1.3. In this example, the web server **105** has a public address of 130.1.1.10. In this example, since the NAT **106** has a single Internet public address, the NAT **106** uses port address translation (PAT) to multiplex the single address by port number. In IPv4, the port number is 16 bits, providing 65,536 port numbers. Generally, port numbers 0-1024 are reserved for defined standard Internet uses. Therefore, the NAT **106** may use user definable ports **1025-65,535** for port address translation.

[0005] If user A **101** sends a packet to the web server **105**, the packet sent from user A **101** to the NAT **106** may have the following protocol, source address, source port, destination address, and destination port numbers.

Protocol	SA	SP	DA	DP
TCP	10.1.1.1	10,000	130.1.1.10	80

[0006] The NAT **106** uses a lookup table such as Table 1 to translate the packet source and destination address and ports.

TABLE 1

	Private				Public			
Protocol	SA	SP	DA	DP	SA	SP	DA	DP
TCP	10.1.1.1	10,000	130.1.1.10	80	128.1.1.1	10,000	130.1.1.10	80

[0007] As a result, the packet's destination and source address and ports are translated to:

SA	SP	DA	DP
128.1.1.1	10,000	130.1.1.10	80

[0008] Then the packet is sent from the NAT **106** to the web server **105** at the destination address.

[0009] The web server **105** may then send a packet back to user A **101** in reply. The packet sent from the web server **105** to the NAT **106** may have address and port designations as follows:

Protocol	SA	SP	DA	DP
TCP	130.1.1.10	80	128.1.1.1	10,000

[0010] Using Table 1, the NAT **106** translates the destination and source address and port of the packet to:

SA	SP	DA	DP
130.1.1.10	80	10.1.1.1	10,000

[0011] **FIG. 2** is a schematic illustration of a system **200** that allows a network address translator-protocol translator

(NAT-PT) **206** to provide network address and protocol translations between an IPv6 network with a plurality of IPv6 users **201**, **202**, **203** and a public network **204**, such as an Internet, which is connected to a plurality of web servers **205**, using the IPv4 protocol. The NAT-PT **206** is able to provide a protocol translation to a plurality of IPv6 users, using a small number of IPv4 addresses. In this example, a single IPv4 address of 128.1.1.1 is assigned to the NAT-PT **206** host. The plurality of users **201**, **202**, **203** may be assigned public IPv6 addresses. For example, a user A **201** may be assigned an IPv6 network address of 3000::1, a user B **202** may be assigned an IPv6 network address of 3000::2, and a user C **203** may be assigned an IPv6 network address of 3000::3. In this example, the web server **205** has a public IPv4 address of 130.1.1.10. In this example, since the NAT-PT **206** has a single Internet public address, the NAT-PT **206** uses port address translation (PAT) to multiplex the single address by port number.

[**0012**] If user A **201** sends an IPv6 packet to the web server **205**, the packet sent from user A **201** to the NAT-PT **206** may have the following protocol, source address, source port, destination address, and destination port numbers:

Protocol	SA	SP	DA	DP
TCP	3000::1	20,000	5000::10	80

[**0013**] Although the web server **205** has an IPv4 address of 130.1.1.10, the NAT-PT **206** assigns an IPv6 address of 5000::10 to it, so that user A **201** may address the web server **205** in an IPv6 format. This IPv6 address assignment to the web server could be due to prior configuration on the NAT-PT device, statistically or through a dynamic binding.

[**0014**] The NAT-PT **206** uses a lookup table such as Table 2 to translate the packet source and destination address and ports.

TABLE 2

	Protocol	SA	SP	DA	DP
IPv6	TCP	3000::1	20,000	5000::10	80
IPv4	TCP	128.1.1.1	20,000	130.1.1.10	80

[**0015**] As a result, the packet's destination and source address and ports are translated to:

SA	SP	DA	DP
128.1.1.1	20,000	130.1.1.10	80

[**0016**] Then the IPv4 packet is sent from the NAT-PT **206** to the web server **205** at the destination address.

[**0017**] The web server **205** may then send a packet back to user A **201** in reply. The IPv4 packet sent from the web server **205** to the NAT-PT **206** may have protocol, address and port designations as follows:

Protocol	SA	SP	DA	DP
TCP	130.1.1.10	80	128.1.1.1	10,000

[**0018**] Using Table 2, the NAT-PT **206** translates the destination and source address and port of the packet to:

SA	SP	DA	DP
5000::10	80	3000::1	20,000

[**0019**] Therefore, the prior art NAT with PAT is able to connect a plurality of IPv4 users to the Internet and the prior art NAT-PT with PAT is able to connect a plurality of IPv6 users to IPv4 web servers on the Internet.

BRIEF SUMMARY OF THE INVENTION

[**0020**] To achieve the foregoing, and in accordance with the purpose of the present invention, a method for transparently sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol is provided. A first data having a first source address and a first destination address is received. A network address translation with port address translation is performed, if the first data is in an IPv4 protocol. A network address translation-protocol translation with port address translation is performed, if the first data is in an IPv6 protocol.

[**0021**] In another embodiment of the invention, the invention pertains to a computer system operable for transparently sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol. The computer system includes one or more processors and one or more memory. At least one of the memory processors is adapted to provide at least some of the above-described method operations. In yet a further embodiment of the invention, the invention pertains to a computer program product for transparently sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol. The computer program product has at least one computer readable medium and computer program instructions stored within at least one of the computer readable product configured to perform at least some of the described method operations. In yet another embodiment, the invention pertains to an apparatus that includes one or more means for transparently sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol.

[**0022**] These and other features of the present invention will be described in more detail below in the detailed description of the invention and in conjunction with the following figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

[0024] **FIG. 1** is a schematic illustration of a system that allows a network address translator (NAT) to provide network address translations between a private IPv4 network with a plurality of IPv4 users and a public network such as an Internet in the prior art.

[0025] **FIG. 2** is a schematic illustration of a system that allows a network address translator-protocol translator (NAT-PT) to provide network address translations between an IPv6 network with a plurality of IPv6 users and a public IPv4 network.

[0026] **FIG. 3** is a schematic illustration of a system that allows at least a first device and second device of a first protocol, such as IPv4, and at least a third device and a fourth device of a second protocol, such as IPv6, to communicate with devices of the first protocol, through a router behaving as a gateway.

[0027] **FIG. 4** is a high level flow chart of a process that may be used in an embodiment of the invention for sending packets to a public Internet.

[0028] **FIG. 5** is a high level flow chart of a process for receiving packets from the public Internet.

[0029] **FIG. 6** is a diagrammatic representation of a router in which embodiments of the present invention may be implemented.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] The present invention will now be described in detail with reference to a few preferred embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention.

[0031] It is desirable to have a combination NAT and NAT-PT with PAT that is able to connect a combination of both IPv4 and IPv6 users to the Internet.

[0032] To facilitate understanding, **FIG. 3** is a schematic illustration of a system **300** that allows a first device **308** and second device **309** of a first protocol, such as IPv4, and a third device **310** and a fourth device **311** of a second protocol, such as IPv6, to communicate with devices of the first protocol, through a Network Address Translation and Network Address Translation-Protocol Translation with Port Address Translation (NAT NAT-PT with PAT) device or NAT-PAT NAT-PT-PAT device, which in this embodiment is a router **306** behaving as a gateway. In the specification and claims, a router is defined as any device that performs routing/forwarding. The router may be an independent device or may be part of a larger device that does other functions. To facilitate understanding, devices such as the first device **308** and the second device **309**, which use the IPv4 protocol, are drawn as part of an IPv4 network **314** and devices such as the third device **310** and the fourth device **311**, which use the IPv6 protocol, are drawn as part of an IPv6 network **316**. In the illustrated embodiment, although two devices are shown for each network having a different protocol, of course any suitable number of devices may be coupled with each network. Additionally, the devices coupled with router **306** may implement any suitable number and type of protocol, besides IPv4 and IPv6.

[0033] The router **306** may assign the first device **308** a private IPv4 address, such as 10.1.1.1 and the second device **309** a private IPv4 address, such as 10.1.1.2, since the first device **308** and the second device **309** are IPv4 devices. The router **306** may assign the third device **310** an IPv6 address, such as 3000::1 and the fourth device **311** an IPv6 address, such as 3000::2, since the third device **310** and the fourth device **311** are IPv6 devices. The router **306** is connected to the public Internet **304** or a network consisting of devices that have been assigned unique IPv4 addresses.

[0034] In a preferred embodiment, the router **306** may have an NAT NAT-PT database **330**, which is able to hold NAT entries and NAT-PT entries. The NAT NAT-PT database may comprise smaller databases or tables, such as a NAT table for the NAT entries that lists all network address translations for current connections from private IPv4 devices to public IPv4 devices and a NAT-PT table for NAT-PT entries that lists all network address translation-protocol translations for current connections from IPv6 devices to IPv4 devices. An example of a NAT table that lists all network address translations (NAT entries) for current connections from private IPv4 devices to public IPv4 devices is shown in Table 3.

TABLE 3

	Private				Public			
Protocol	SA	SP	DA	DP	SA	SP	DA	DP
TCP	10.1.1.1	10,000	130.1.1.20	80	128.1.1.1	10,000	130.1.1.20	80

[0035] Table 3 shows an existing connection for the first device **308**, which is assigned the single public IPv4 address 128.1.1.1, with a port designation of 10,000.

[0036] An example of a NAT-PT table that lists all network address translations-protocol translations (NAT-PT entries) for current connections from private IPv4 and IPv6 devices to public IPv4 devices is shown in Table 4.

TABLE 4

	IPv6				IPv4			
Protocol	SA	SP	DA	DP	SA	SP	DA	DP
TCP	3000::1	10,001	5000::10	80	128.1.1.1	10,001	130.1.2.1	80

[0037] Table 4 shows an existing connection for the third device **310**, which is assigned the single public IPv4 address 128.1.1.1 with a port designation of 10,001.

[0038] User A

[0039] **FIG. 4** is a high level flow chart of a process that may be used by the router **306** in an embodiment of the invention for sending packets to a public Internet. In an example of the operation of the invention with an NAT NAT-PT database comprising Table 3 and Table 4, if user A, at the first device **308**, sends a packet to the web server **305**, the packet sent from the first device **308** to the router **306** may have the following protocol source address, source port, destination address, and destination port numbers:

Protocol	SA	SP	DA	DP
TCP	10.1.1.1	10,000	130.1.1.20	80

[0040] The router **306** receives the data packet (step **402**). A search is made of the NAT NAT-PT database for a match (step **406**). Since the packet is from the private network and is in IPv4 format, only the NAT entries in the NAT table, shown as Table 3, part of the NAT NAT-PT database, are searched. This is because such packets should only come from an IPv4 device, in this example. It is found that the NAT entry in the NAT table, shown as Table 3, matches the data packet (step **410**). The packet is then translated (step **414**) according to Table 3, so that the resulting packet has the protocol, source address, source port, destination address, and destination port of:

Protocol	SA	SP	DA	DP
TCP	128.1.1.1	10,000	130.1.1.20	80

[0041] Then the packet is sent from the router **306** to the web server **305** at the destination address (step **418**).

[0042] The web server **305** may then send a packet back to user A in reply. **FIG. 5** is a high level flow chart of a process used by the router **306** for receiving packets from the public Internet. The packet is sent from the web server **305** to the router **306**. The router **306** receives the packet (step **502**). The packet may have protocol, address and port designations as follows:

Protocol	SA	SP	DA	DP
TCP	130.1.1.20	80	128.1.1.1	10,000

[0043] The NAT NAT-PT database **330** is searched for a match (step **506**). Since the packet is from the Internet side of the router **306**, in this example both NAT entries and NAT-PT entries are searched. This is because the packet could be going to either an IPv4 or IPv6 device. It is found that the entry in the NAT table, shown as Table 3, matches the packet (step **510**). The entry in the NAT table is used to translate the packet (step **514**) to:

Protocol	SA	SP	DA	DP
TCP	130.1.1.20	80	10.1.1.1	10,000

[0044] The packet is then sent to the first device **308** from the router **306** (step **518**). If a match is not found, an error step may be done (step **522**), such as dropping the packet.

[0045] User B

[0046] In another example, a TCP data packet is sent from user B at the second device to an IPv4 web server with an address 130.1.1.10 through the Internet **304**. The packet may have the following protocol source address, source port, destination address, and destination port numbers:

Protocol	SA	SP	DA	DP
TCP	10.1.1.2	10,000	130.1.1.10	80

[0047] The router receives the packet (step **402**). The router **306** searches the NAT NAT-PT database to see if such a connection already exists (step **406**). Since the packet is from the private network and is in IPv4 format, only the NAT entries in the NAT table, shown as Table 3, part of the NAT NAT-PT database, are searched. Since a match is not found in the NAT NAT-PT database (step **410**), the router **306** designates the packet as a new connection. The router **306** assigns a port number to the data packet.

[0048] The assignment of a port number not in use may first require a search for a protocol, address, and port combination that is not in use (step **422**). This search searches both NAT and NAT-PT entries. This is to avoid conflicts with both IPv4 and IPv6 devices. In one embodiment of the invention, the router **306** may first try to use the

port number designated by the packet. In another embodiment, the router **306** may assign a port number, ignoring the port number designate by the packet. In this example, an attempt to assign a port number of 10,000 for a TCP protocol for address 128.1.1.1 may first be performed either because it is the port number designated by the packet or as a default choice by the router. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database (if any NAT entries or any NAT-PT entries) use port 10,000 of the router **306** for a TCP connection for address 128.1.1.1. It is found that the NAT entry in the NAT table (Table 3) uses port 10,000 for a TCP connection for address 128.1.1.1. Another port is then designated and checked to see if it matches any existing connection. In this embodiment, the port number is incremented from 10,000 to 10,001 for a TCP protocol for address 128.1.1.1. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database use port 10,001 of the router **306** for a TCP connection for address 128.1.1.1. It is found that the NAT-PT entry in NAT-PT table (Table 4) uses port 10,001 for a TCP connection for address 128.1.1.1. In this embodiment, the port number is incremented from 10,001 to 10,002. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database **330** use port 10,002 of the router **306** for a TCP connection for address 128.1.1.1. Since no such connection is found, the new connection is assigned the port number of 10,002 for a TCP protocol for address 128.1.1.1. An address, port, and protocol combination not in use has been successfully found.

[**0049**] The address, port, and protocol combination is placed in NAT NAT-PT database (step **426**) by being placed in the NAT table, resulting in Table 5.

TABLE 5

	Private				Public			
Protocol	SA	SP	DA	DP	SA	SP	DA	DP
TCP	10.1.1.1	10,000	130.1.1.20	80	128.1.1.1	10,000	130.1.1.20	80
TCP	10.1.1.2	10,000	130.1.1.30	80	128.1.1.1	10,002	130.1.1.30	80

[**0050**] The data packet is then translated, providing a new source address and source port, according to the entry in Table 5 (step **430**), to yield:

Protocol	SA	SP	DA	DP
TCP	128.1.1.1	10,002	130.1.1.30	80

[**0051**] Then the packet is sent from the router **306** to the web server at the destination address (step **418**).

[**0052**] The web server may then send a packet back to user B in reply. The packet sent from the web server to the router **306** may have address and port designations as follows:

SA	SP	DA	DP
130.1.1.30	80	128.1.1.1	10,002

[**0053**] The router **306** receives the packet (step **502**). A search for a match in the NAT NAT-PT database is made (step **506**). Both NAT entries and NAT-PT entries are searched in this example, since the packet is from the Internet and it is not known if the destination is an IPv4 or IPv6 device. It is found that the second NAT entry in the NAT table, shown as Table 5, matches the packet (step **510**). Using Table 5, the router **306** translates the destination and source address and port of the packet (step **514**) to:

Protocol	SA	SP	DA	DP
TCP	130.1.1.30	80	10.1.1.2	10,000

[**0054**] The packet is sent to the second device **309** (step **518**).

[**0055**] User C

[**0056**] Now if user C at the third device **310** sends another data packet, the packet is received by the router **306** (step **402**) with the following protocol, addresses, and ports:

Protocol	SA	SP	DA	DP
TCP	3000::1	10,001	5000::10	80

[**0057**] Since the destination of the packet is an IPv4 device with an IPv4 address of 130.1.2.10, the router **306** may need to assign an IPv6 address to it, so that the third device **310** may address the packets in an IPv6 format (e.g., in this example, an address of 5000::1 was previously assigned to the destination device).

[**0058**] A search is made of the NAT NAT-PT database for a match with the packet (step **406**). Since it is known that the packet is in an IPv6 format, the search may only search through the NAT-PT entries in the NAT-PT part of the NAT NAT-PT database. A match is found with the NAT-PT entry in the NAT-PT database as shown in Table 4 (step **410**). The packet is translated according to the match (step **414**) to:

SA	SP	DA	DP
128.1.1.1	10,001	130.1.2.10	80

[0059] Then the packet is sent from the router **306** to the web server at the destination address (step **418**).

[0060] The web server may then send a packet back to user C at the third device **310** in reply. The packet is sent from the web server and received by the router **306** (step **502**). The packet may have the protocol, address, and port designations as follows:

Protocol	SA	SP	DA	DP
TCP	130.1.2.10	80	128.1.1.1	10,001

[0061] A search of the NAT NAT-PT database **330** is made to see if there is a match (step **506**). Since the packet is from the Internet side of the router **306**, a search of both the NAT entries and NAT-PT entries may be performed. It is found that the packet matches the entry in the NAT-PT table, shown in Table 4 (step **510**). The packet is translated (step **514**) to:

Protocol	SA	SP	DA	DP
TCP	5000::10	80	3000::1	10,001

[0062] The IPv6 packet is then sent to the third device **310** (step **518**).

[0063] User D

[0064] In another example, a TCP data packet is sent from user D at the fourth device **311** to an IPv4 web server with an address **130.1.3.10** through the Internet **304**. The packet may have the following protocol source address, source port, destination address, and destination port numbers.

Protocol	SA	SP	DA	DP
TCP	3000::2	10,000	5000::20	80

[0065] The router receives the packet (step **402**). The router **306** searches the NAT NAT-PT database to see if such a connection already exists. Since the packet is in an IPv6 format, in this example only the NAT-PT entries in the NAT-PT table are searched to see if there is a matching entry to the source address, source port, destination address, destination port, and protocol combination (step **406**). Since a match is not found in the NAT NAT-PT database (step **410**), the router **306** designates the packet as a new connection. The router **306** assigns a port number to the data packet.

[0066] The assignment of a port number not in use may first require a search for a protocol, address, and port combination that is not in use (step **422**). In one embodiment of the invention, the router **306** may first try to use the port number designated by the packet. In another embodiment, the router **306** may assign a port number, ignoring the port number designated by the packet. In this example, an attempt to assign a port number of 10,000 for a TCP protocol for address 128.1.1.1 may first be performed either because it is the port number designated by the packet or as a default choice by the router. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database use port 10,000 of the router **306** for a TCP connection for address 128.1.1.1. In this embodiment, both NAT entries and NAT-PT entries are searched to avoid port conflicts with both NAT and NAT-PT connections. It is found that a NAT entry in the NAT table (Table 5) uses port 10,000 for a TCP connection for address 128.1.1.1. Another port is then designated and checked to see if it matches any existing connections. In this embodiment, the port number is incremented from 10,000 to 10,001 for a TCP protocol for address 128.1.1.1. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database use port 10,001 of the router **306** for a TCP connection for address 128.1.1.1. It is found that the NAT-PT entry in NAT-PT table (Table 4) uses port 10,001 for a TCP connection for address 128.1.1.1. In this embodiment, the port number is incremented from 10,001 to 10,002. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database **330** use port 10,002 of the router **306** for a TCP connection for address 128.1.1.1. It is found that a NAT entry in the NAT table (Table 5) uses port 10,002 for a TCP connection for address 128.1.1.1. In this embodiment, the port number is incremented from 10,002 to 10,003. A search of the NAT NAT-PT database is made to see if any existing connections in the NAT NAT-PT database **330** use port 10,003 of the router **306** for a TCP connection for address 128.1.1.1. Since no such connection is found, the new connection is assigned the port number of 10,003 for a TCP protocol for address 128.1.1.1. An address, port, and protocol combination not in use has been successfully found.

[0067] The address, port, and protocol combination is placed in the NAT NAT-PT database (step **426**) by being placed in the NAT-PT table, resulting in Table 6.

TABLE 6

	IPv6				IPv4			
Protocol	SA	SP	DA	DP	SA	SP	DA	DP
TCP	3000::1	10,001	5000::10	80	128.1.1.1	10,001	130.1.2.1	80
TCP	3000::2	10,000	5000::20	80	128.1.1.1	10,003	130.1.3.1	80

[0068] The data packet is then translated, providing a new source address and source port, according to the entry in Table 6 (step **430**), to yield:

Protocol	SA	SP	DA	DP
TCP	128.1.1.1	10,003	130.1.3.1	80

[0069] Then the IPv4 packet is sent from the router **306** to the web server at the destination address (step **418**).

[0070] The web server may then send a packet back to user D in reply. The packet sent from the web server to the router **306** may have address and port designations as follows:

SA	SP	DA	DP
130.1.3.1	80	128.1.1.1	10,003

[0071] The router **306** receives the packet (step **502**). A search for a match in the NAT NAT-PT database is made (step **506**). Since the packet is received from the Internet side of the router **306**, a search of NAT entries and NAT-PT entries is made. It is found that the second entry in the NAT-PT table, shown as Table 6, matches the packet (step **510**). Using Table 6, the router **306** translates the protocol, destination and source address and port of the packet (step **514**) to:

Protocol	SA	SP	DA	DP
TCP	130.1.3.1	80	3000::2	10,000

[0072] The packet is sent to the fourth device **311** (step **518**).

[0073] In this embodiment, different protocols may be assigned the same port and address combinations. For example, a UDP message using port 10,000 for 128.1.1.1 would not be a match with the TCP connection using port 10,000 for 128.1.1.1, so that both sessions may run concurrently.

[0074] A single IPv4 address was used for the router **306** in this example to show that the inventive device is able to provide NAT and NAT-PT with PAT for a mixture of IPv4 and IPv6 devices using a single address. If multiple IPv4 addresses are used, once all the ports for one address are in use, an algorithm may search a next address for available ports. Other searching algorithms for available ports may be used. For example, ports on different addresses may be used so that different addresses may be used equally, in addition to or alternatively to using different ports.

[0075] The invention allows the sharing of IPv4 addresses to provide both NAT and NAT-PT with PAT, instead of requiring that NAT used different IPv4 addresses than NAT-PT. In addition, the invention allows a mixture of IPv4 and IPv6 devices to be connected to the inventive device without needing to know whether a particular device is an IPv4 or IPv6 device, instead of requiring that all IPv4 devices be connected to a NAT device and all IPv6 devices be connected to a separate NAT-PT device or requiring knowledge of the whether a device uses IPv4 or IPv6.

[0076] In other embodiments, the NAT NAT-PT database may be divided according to ports instead of whether the translation is NAT or NAT-PT. In other embodiments, the database may be separated in other ways, however, the overall NAT NAT-PT database has both NAT and NAT-PT entries.

[0077] The NAT-PT may also be used to accomplish other functions. An example of another function provided by the NAT-PT is described in U.S. patent application Ser. No. 09/920,533, filed Jul. 31, 2001, entitled, "MECHANISMS FOR AVOIDING PROBLEMS ASSOCIATED WITH NETWORK ADDRESS PROTOCOL TRANSLATION", by Daniel C. Biederman. Generally, the techniques for providing NAT NAT-PT with PAT of the present invention may be implemented on software and/or hardware. For example, it can be implemented in an operating system kernel, in a separate user process, in a library package bound into network applications, on a specially constructed machine, or on a network interface card. In a specific embodiment of this invention, the technique of the present invention is implemented in software, such as an operating system or in an application running on an operating system.

[0078] A software or software/hardware hybrid packet processing system of this invention is preferably implemented on a general-purpose programmable machine selectively activated or reconfigured by a computer program stored in memory. Such programmable machine may be a network device designed to handle network traffic. Such network devices typically have multiple network interfaces including frame relay and ISDN interfaces, for example. Specific examples of such network devices include routers and switches. For example, the packet processing systems of this invention may be specially configured routers such as specially configured router models 1600, 2500, 2600, 3600, 4500, 4700, 7200, 7500, and 12000 available from Cisco Systems, Inc. of San Jose, Calif. A general architecture for some of these machines will appear from the description given below. In an alternative embodiment, the packet processing system (e.g., NAT NAT-PT with PAT device) may be implemented on a general-purpose network host machine such as a personal computer or workstation.

[0079] Further, the invention may be at least partially implemented on a card (e.g., an interface card) for a network device or a general-purpose computing device.

[0080] Referring now to **FIG. 6, a** router **10** suitable for implementing the present invention includes a master central processing unit (CPU) **62**, interfaces **68**, and a bus **15** (e.g., a PCI bus). When acting under the control of appropriate software or firmware, the CPU **62** is responsible for such router tasks as routing table computations and network management. It may also be responsible for performing protocol conversions between a first and second protocol (e.g, IPv6 and IPv4), performing port translation and address translations, maintaining NAT -PT or NAT tables, etc. It preferably accomplishes all these functions under the control of software including an operating system (e.g., the Internetwork Operating System (IOS®) of Cisco Systems, Inc.) and any appropriate applications software. CPU **62** may

include one or more processors **63**, such as a processor from the Motorola family of microprocessors or the MIPS family of microprocessors. In an alternative embodiment, processor **63** is specially designed hardware for controlling the operations of router **10**. In a specific embodiment, a memory **61** (such as non-volatile RAM and/or ROM) also forms part of CPU **62**. However, there are many different ways in which memory could be coupled to the system. Memory **61** may be used for a variety of purposes such as, for example, caching and/or storing data, programming instructions, etc.

[**0081**] The interfaces **68** are typically provided as interface cards (sometimes referred to as "line cards"). Generally, they control the sending and receiving of data packets or data segments over the network and sometimes support other peripherals used with the router **10**. Among the interfaces that may be provided are Ethernet interfaces, frame relay interfaces, cable interfaces, DSL interfaces, token ring interfaces, and the like. In addition, various very high-speed interfaces may be provided such as fast Ethernet interfaces, Gigabit Ethernet interfaces, ATM interfaces, HSSI interfaces, POS interfaces, FDDI interfaces and the like. Generally, these interfaces may include ports appropriate for communication with the appropriate media. In some cases, they may also include an independent processor and, in some instances, volatile RAM. The independent processors may control such communications intensive tasks as packet switching, media control, and management. By providing separate processors for the communications intensive tasks, these interfaces allow the master microprocessor **62** to efficiently perform routing computations, network diagnostics, security functions, etc.

[**0082**] Although the system shown in **FIG. 6** is one specific router of the present invention, it is by no means the only router architecture on which the present invention can be implemented. For example, an architecture having a single processor that handles communications as well as routing computations, etc., is often used. Further, other types of interfaces and media could also be used with the router.

[**0083**] Regardless of the network device's configuration, it may employ one or more memories or memory modules (such as, for example, memory block **65**) configured to store data, program instructions for the general-purpose network operations and/or the inventive techniques described herein. The program instructions may control the operation of an operating system and/or one or more applications, for example. The memory or memories may also be configured to store NAT and NAT-PT entries, received packets and identifiers to track each flow and the number of such flows, etc.

[**0084**] Because such information and program instructions may be employed to implement the systems/methods described herein, the present invention relates to machine-readable media that include program instructions, state information, etc. for performing various operations described herein. Examples of machine-readable media include, but are not limited to, magnetic media such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROM disks and DVDs; magneto-optical media such as floptical disks; and hardware devices that are specially configured to store and perform program instructions, such as read-only memory (ROM) and random access memory (RAM) devices. The invention may also be embodied in a carrier wave traveling over an appropriate medium such as airwaves, optical lines, electric lines, etc. Examples of program instructions include both machine code, such as produced by a compiler, and files containing higher level code that may be executed by the computer using an interpreter.

[**0085**] Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. For example, the techniques of the present invention may be applied to other conversions besides IPv4 to IPv6 conversions. Therefore, the described embodiments should be taken as illustrative and not restrictive, and the invention should not be limited to the details given herein but should be defined by the following claims and their full scope of equivalents. There are alterations, permutations, and substitute equivalents, which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. It is therefore intended that the following appended claims be interpreted as including all such alterations, permutations, and substitute equivalents as fall within the true spirit and scope of the present invention.

What is claimed is:

1. A method for transparently sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol, comprising:

receiving a first data having a first source address and a first destination address;

performing a network address translation with port address translation if the first data is in an IPv4 protocol; and

performing a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol.

2. The method, as recited in claim 1, wherein the performing a network address translation with port address translation if the first data is in an IPv4 protocol and the performing a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol can share at least one common IPv4 address, while providing port address translation.

3. The method, as recited in claim 2, further comprising forwarding the first data to an IPv4 service on an Internet.

4. The method, as recited in claim 3, wherein the performing a network address translation with port address translation searches a Network Address Translation and Network Address Translation—Protocol Translation (NAT NAT-PT) database, and wherein the performing a network address translation protocol translation searches the NAT NAT-PT database.

5. The method, as recited in claim 3, wherein the performing the network address translation with port address translation, comprises:

searching at least part of an NAT NAT-PT database for a match with the first data; and

translating the packet if a match to an entry in the NAT NAT-PT is found, wherein the packet is translated according to the found entry.

6. The method, as recited in claim 5, wherein the performing the network address translation protocol translation with port address translation, comprises:

searching at least part of the NAT NAT-PT database for a match with the first data; and

translating the packet if a match to an entry in the NAT NAT-PT is found, wherein the packet is translated according to the found entry.

7. The method, as recited in claim 6, wherein the performing the network address translation with port address translation further comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use if a match with the first data not found.

8. The method, as recited in claim 3, wherein the performing the network address translation with port address translation comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use.

9. The method, as recited in claim 1, wherein the performing the network address translation with port address translation comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use.

10. A computer system operable for providing transparent sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol, comprising:

one or more processors;

one or more memory, wherein at least one of the processors and memory are adapted to:

receive a first data having a first source address and a first destination address;

perform a network address translation with port address translation if the first data is in an IPv4 protocol; and

perform a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol.

11. The computer system, as recited in claim 10, wherein the processors and memory are further adapted to forward the first data to an IPv4 service on an Internet, and wherein the performing a network address translation with port address translation if the first data is in an IPv4 protocol and the performing a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol share at least one common IPv4 address, while providing port address translation.

12. The computer system, as recited in claim 11, wherein the performing a network address translation with port address translation searches an NAT NAT-PT database, and wherein the performing a network address translation protocol translation searches the NAT NAT-PT database.

13. The computer system, as recited in claim 12, wherein the performing the network address translation with port address translation further comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use if a match with the first data is not found.

14. The computer system, as recited in claim 10, wherein the performing the network address translation with port address translation further comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use if a match with the first data is not found.

15. A computer program product for providing transparent sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol, comprising:

at least one computer readable medium;

computer program instructions stored within the at least one computer readable product configured to:

receive a first data having a first source address and a first destination address;

perform a network address translation with port address translation if the first data is in an IPv4 protocol; and

perform a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol.

16. The computer program product, as recited in claim 15, wherein the computer instructions are further configured to forward the first data to an IPv4 service on an Internet, and wherein the performing a network address translation with port address translation if the first data is in an IPv4 protocol and the performing a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol share at least one common IPv4 address, while providing port address translation.

17. The computer program product, as recited in claim 16, wherein the performing a network address translation with port address translation searches an NAT NAT-PT database, and wherein the performing a network address translation protocol translation searches the NAT NAT-PT database.

18. The computer program product, as recited in claim 17, wherein the performing the network address translation with port address translation further comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use.

19. The computer program product, as recited in claim 16, wherein the performing the network address translation with port address translation further comprises searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use.

20. An apparatus for providing transparent sharing at least one IPv4 address among a plurality of hosts wherein at least a first host of the plurality of hosts uses the IPv4 protocol and wherein at least a second host of the plurality of hosts uses an IPv6 protocol, comprising:

means for receiving a first data having a first source address and a first destination address;

means for performing a network address translation with port address translation if the first data is in an IPv4 protocol; and

means for performing a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol.

21. The apparatus, as recited in claim 20, further comprising means for forwarding the first data to an IPv4 service on an Internet, and wherein the means for performing a network address translation with port address translation if the first data is in an IPv4 protocol and the means for performing a network address translation protocol translation with port address translation if the first data is in an IPv6 protocol share at least one common IPv4 address, while providing port address translation.

22. The apparatus, as recited in claim 21, wherein the means for performing a network address translation with port address translation comprises means for searching an NAT NAT-PT database, and wherein the means for performing a network address translation protocol translation comprises means for searching the NAT NAT-PT database.

23. The apparatus, as recited in claim 22, wherein the means for performing the network address translation with port address translation further comprises means for searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use.

24. The apparatus, as recited in claim 21, wherein the means for performing the network address translation with port address translation further comprises means for searching both network address translation entries and network address translation protocol translation entries for a protocol, address, and port combination not in use.

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