



System i  
Networking  
TCP/IP routing and workload balancing

*Version 5 Release 4*







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**Note**

Before using this information and the product it supports, read the information in "Notices," on page 29.

**Sixth Edition (February 2006)**

This edition applies to version 5, release 4, modification 0 of IBM i5/OS (product number 5722-SS1) and to all subsequent releases and modifications until otherwise indicated in new editions. This version does not run on all reduced instruction set computer (RISC) models nor does it run on CISC models.

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## TCP/IP routing and workload balancing

You can route and balance the TCP/IP traffic of your system by using its integrated routing capabilities to eliminate the need for an external router.

The routing and workload balancing methods, as well as the background information, can help you understand the options available for you to use on your system. Each method is described using a figure so that you can see how the connections are made. These methods do not include instructions on configuring the routing techniques. The focus of this topic collection is on the routing principles and concepts you should know so that your system works better for you.

### Why these methods are important to you

The techniques in these methods might cut down the overall cost of your connections because you can use fewer external routers and servers. Using these routing methods, you can free up IP addresses because you will be managing them in a more effective way. By reading the workload balancing methods, you can get better overall system performance by balancing the communications workload on your system.

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## What's new for V5R4

This topic highlights the changes made to this topic collection for V5R4.

### Preferred interface list

You can manually select which adapters and IP addresses are the preferred interface for virtual Ethernet and virtual IP address (VIPA) Proxy Address Resolution Protocol (ARP) agent selection. You can now create a preferred interface list to select the adapters and IP addresses for the ARP proxy agent. The preferred interface list is configurable for both virtual Ethernet and virtual IP address interfaces. To find more detailed information about this new function, see "Scenario: Adapter failover using virtual IP and proxy ARP" on page 24.

### How to see what's new or changed

To help you see where technical changes have been made, this information uses:

- The  image to mark where new or changed information begins.
- The  image to mark where new or changed information ends.

To find other information about what's new or changed this release, see the Memo to users.

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## Printable PDF

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To view or download the PDF version of this document, select TCP/IP Routing and workload balancing (about 1.40 MB).

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## TCP/IP routing functions by release

Before you plan to use a routing function, make sure that your system is at the correct release to support the function that you want to perform.

**V3R1:** Static route-based packet forwarding is introduced.

**V3R7/V3R2:** Serial Line Internet Protocol (SLIP), Proxy Address Resolution Protocol (ARP) routing, and unnumbered connection network support.

**V4R1:** Dynamic Routing Information Protocol Version 1 (RIPv1).

**V4R2:** Dynamic Routing Information Protocol Version 2 (RIPv2), transparent subnetting, and duplicated route-based load-balancing.

**V4R3:** Virtual IP addresses, IP address masquerading, network address translation (NAT), and Classless Inter-Domain Routing (CIDR).

**V4R4:** IP over OptiConnect.

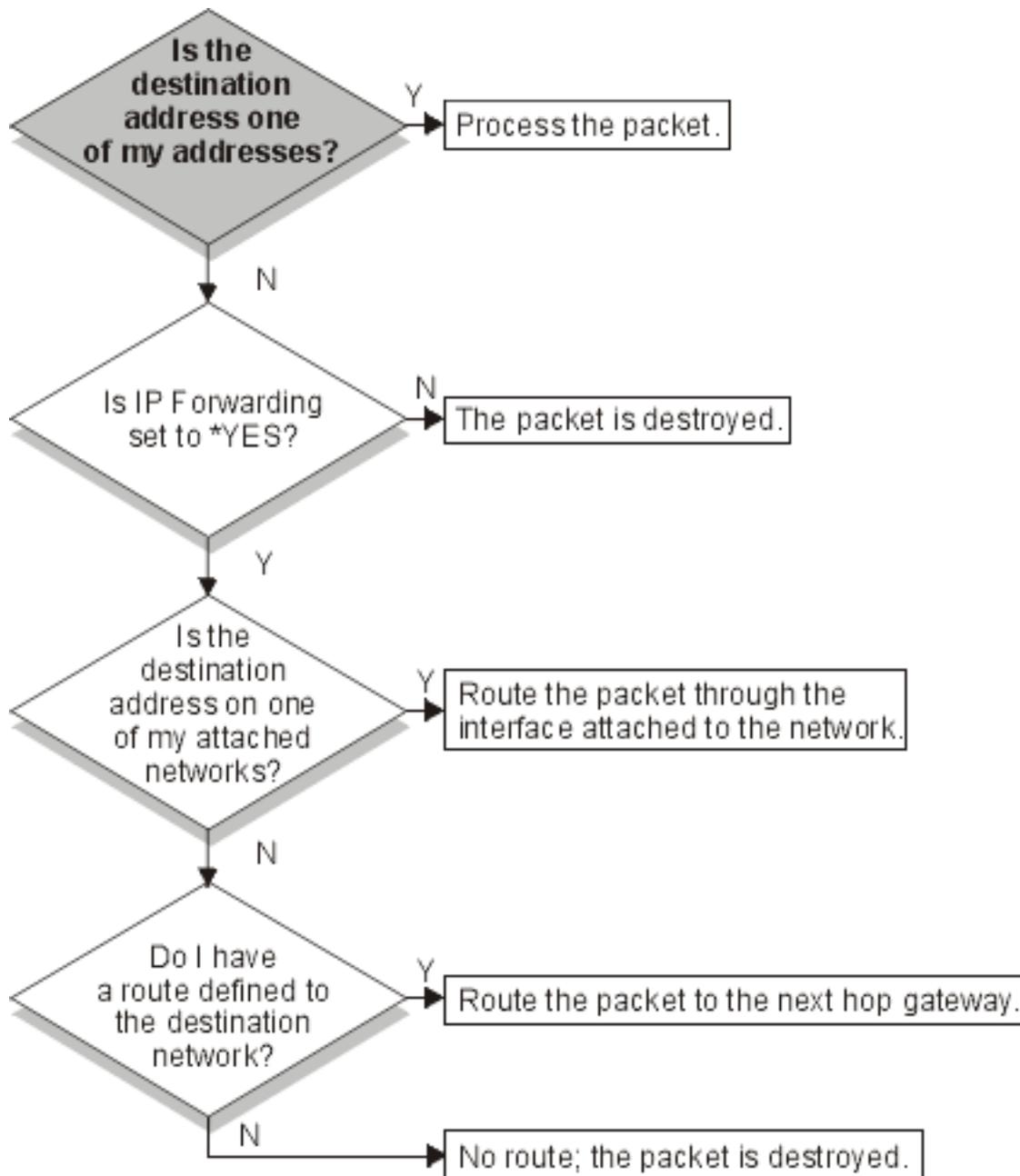
- | **V5R4:** Preferred interface list.

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## Packet processing

Having a better understanding of packet processing helps you decide how to implement routing functions.

The following simplified flow chart shows the logical process that takes place when the i5/OS<sup>®</sup> operating system receives an IP packet (datagram). The actual flow might be different, but the outcome should be the same. The following logic only describes the default packet processing scenarios. If advanced routing techniques are used, packet processing might be slightly different.



First, the destination address in the IP header is compared to all the defined addresses on the system. If it is determined that the packet is destined for your system, the packet is passed up the IP stack to a higher level software, such as TCP, and then to the application that is listening on the destination port.

If the packet is not accepted locally, the next check that is performed is the IP forwarding attribute. If IP forwarding is set to \*YES, then this system is configured to forward packets like a router. If the attribute is set to \*NO in the TCP/IP attributes or in the PPP profile, the packet is destroyed.

The destination address of the packet is compared to all the \*DIRECT routes known to your system. This is done by including the destination address of the packet with the subnet mask specified in the \*DIRECT routing entries of the defined interfaces to determine if the packet is destined for a network that is directly attached to this system. Checking is done from the most specific routes to the least specific.

Then, if i5/OS is not directly connected to the remote host, the routing table is searched. Checking is done from the most specific host (subnet mask 255.255.255.255) to the least specific route (subnet mask 0.0.0.0). If a route is found, the packet is forwarded to the next hop gateway.

The last point in the flow chart shows that if no matching routing entry is found, the packet is destroyed.

---

## General routing rules

These rules apply to TCP/IP in general and to TCP/IP on the i5/OS operating system.

To manage packets on your system, you should consider these rules as you implement routing functions on your system. These rules can help you determine what is happening to the packets on your system and where they might be going. As with most rules, there are exceptions.

- Your system does not have an IP address; only interfaces have IP addresses.

**Note:** Virtual IP (connectionless) addresses are assigned to the system.

- In general, if the destination IP address is defined on your system, your system will process it regardless of what interface a packet comes in on.

The exception in this case is that if the address is associated with an unnumbered interface, or if IP NAT or filtering is active, the packet might be forwarded or discarded.

- The IP address and mask define the address of the attached network.
- The route out of a system is selected based on the network address attached to an interface. The route selected is based on the following items:
  - Route group search order: direct routes, subnetwork routes, and then default routes.
  - Within a group, the route with the most specific subnet mask is chosen.
  - Equally specific routes are subject to list order or load-balancing techniques.
  - Routes can be added manually or dynamically by the system.

---

## Routing connectivity methods

Routing deals with what path the network traffic follows from its source to its destination and how that path is connected.

### Routing with point-to-point connections

Using point-to-point connections, you can send your data from your local system to a remote system or from a local network to a remote network.

Point-to-point connections are typically used to connect two systems together over a wide area network (WAN). You can use a point-to-point connection to get data from your local system to a remote system or to get data from a local network to a remote network. Do not confuse point-to-point connections with Point-to-Point Protocol. Point-to-Point Protocol (PPP) is one type of a point-to-point connection that is commonly used to connect a computer to the Internet. See PPP connections for more information about how to set up and manage your PPP connections.

You can use point-to-point connections across dial-up lines, leased lines, and other types of networks such as frame relay. There are two ways that you can configure the IP addresses for a point-to-point connection: a numbered connection or an unnumbered connection. As the names imply, a numbered connection has a unique IP address defined for each interface. An unnumbered connection does not use additional IP addresses for a connection.

## Numbered network connections

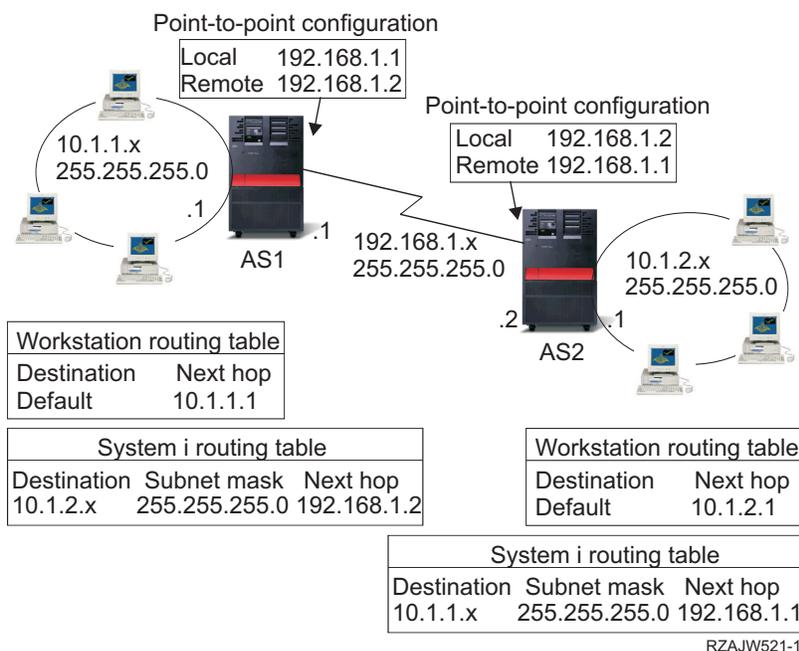
On the surface, it seems that the simplest way to configure a point-to-point connection is by using a numbered connection. A numbered connection is a point-to-point definition that has a unique IP address defined for each end of a connection.

Here are some points to keep in mind when you consider a numbered point-to-point connection:

- Each end of the connection has a unique IP address.
- Routing statements must be added to your system to flow the traffic to the remote system.
- Addresses on the point-to-point link must be managed by your network administrator.
- Addresses are used up just to connect two systems.

When each point-to-point connection is defined to your system, a routing entry must be made on each end to describe how to get to any network at the other end of the connection. The routing selection process on your system depends on having an IP address for each interface. These addresses and routes must be managed by your network administrator. In a small network, these addresses are easy to keep track of and do not use many additional addresses. In a large network, however, it might take an entire subnet of addresses just to define an interface at each end.

The following figure shows a numbered network connection between two System i™ platforms. A routing entry is not needed if all you want to do is to communicate from AS1 to AS2. If you want to communicate with systems in the remote network (10.1.2.x), the routing entry included in the figure must be added to each system. This is because the remote network, 10.1.2.x, is part of the 192.168.1.x connection.



## Unnumbered network connections

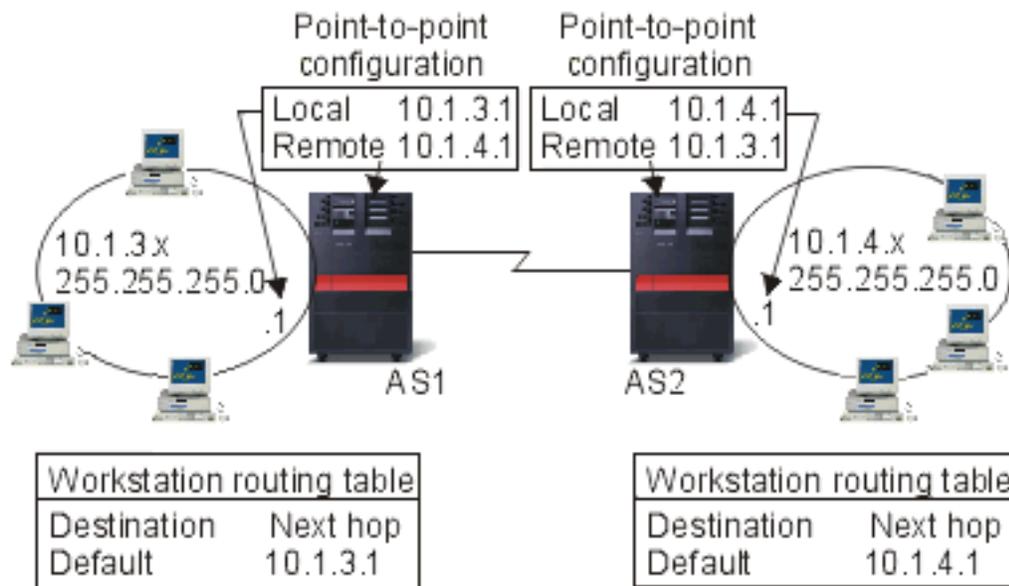
An unnumbered connection is a more complex method of defining a point-to-point connection than a numbered connection. However, you might find the unnumbered connection a simpler and better way to manage your network.

The routing selection process on i5/OS depends on having an IP address for an interface. In an unnumbered connection, the point-to-point interface does not have a unique address. The IP address of your system interface for an unnumbered connection is actually the IP address of the remote system.

Points to keep in mind while considering an unnumbered connection:

- The point-to-point interface has an address that appears to be in the remote network.
- Routing statements are not needed in the system.
- Your network administration is simplified by not using up IP addresses for the link.

In the following example, AS1 appears to have an interface in the 10.1.4.x network and AS2 appears to have an interface in the 10.1.3.x network. The AS1 is connected to LAN network 10.1.3.x with an address of 10.1.3.1. This allows AS1 to communicate with any system on the 10.1.3.x network directly.



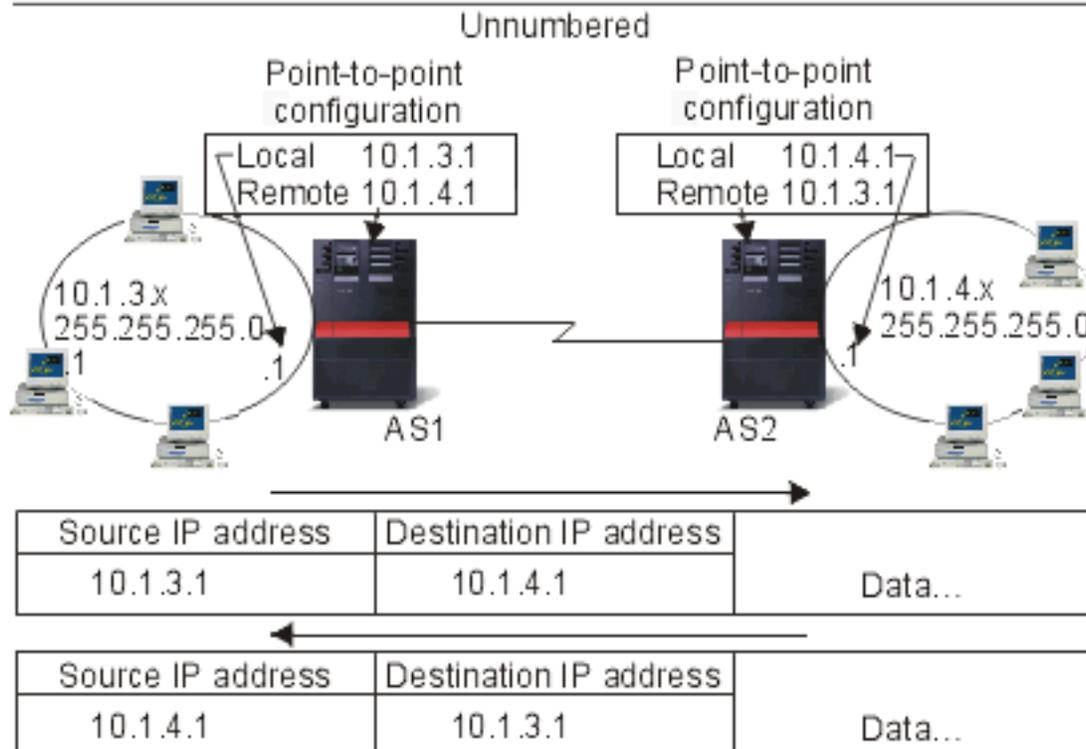
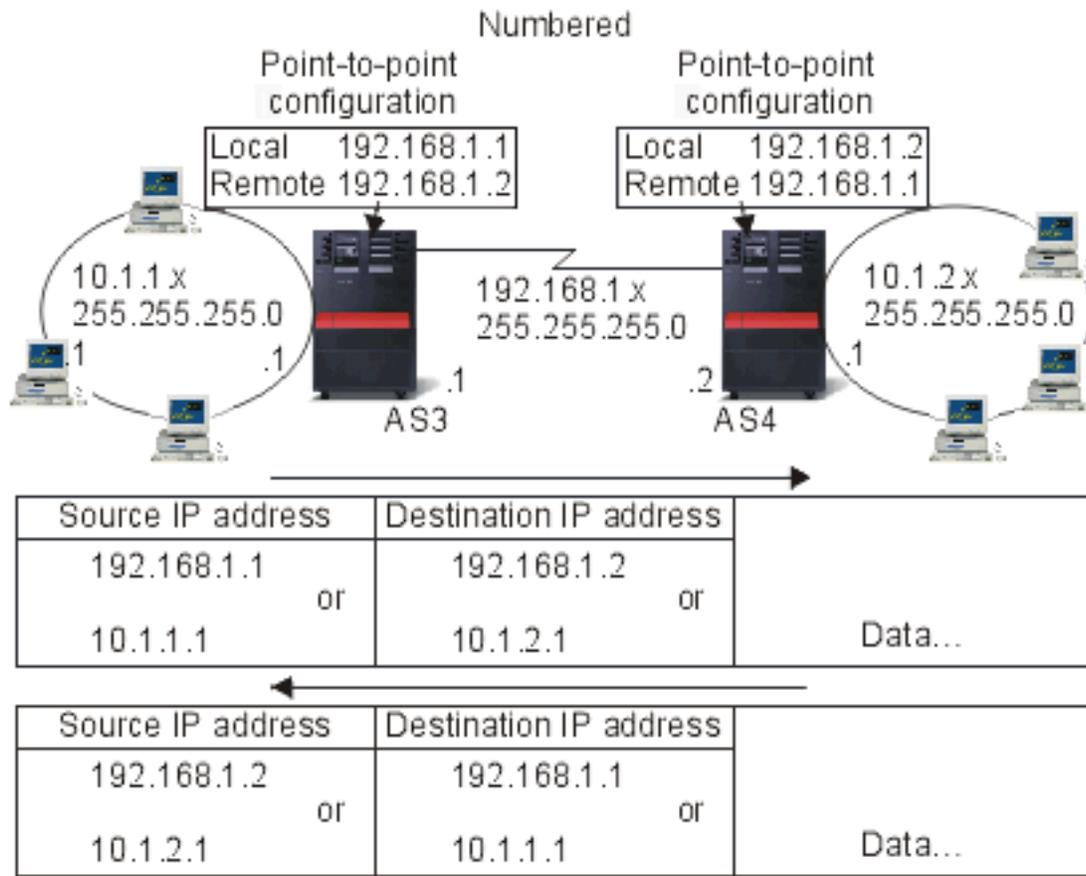
Also shown in the example is AS2. AS2 is connected to LAN network 10.1.4.x with an address of 10.1.4.1. This allows AS2 to communicate with any system on the 10.1.4.x network directly. Each system (AS1 and AS2) adds the remote address to its routing table as a local interface. The address is treated specially so that packets destined for that address will not be processed locally. The packets for the remote address will be placed on the interface and transported to the other end of the connection. When the packet arrives at the other end of the connection, normal packet processing is used.

Now you have a need to connect AS1 to the 10.1.4.x network and to connect AS2 to the 10.1.3.x network. If these two systems were in the same room, you can simply add a LAN adapter to each system and plug the new interface into the correct LAN. If you did this, AS1 and AS2 would not need any routing entries added. In this example, however, the systems are in different cities so you must use a point-to-point connection. Even though you are using a point-to-point connection, you might still want to avoid adding routing entries. By defining the Point-to-Point Protocol (PPP) connection as an unnumbered connection, you achieve the same results that you can get if you use LAN adapters without adding any routing entries to your system. To do this, each system borrows the IP address of the remote system for use with route resolution.

## Unnumbered versus numbered connection data flow

The following figure shows the addresses that will be used in a numbered and unnumbered point-to-point connection. The top half of the picture shows, that with a numbered connection, the remote

system address of 192.168.1.2 or 10.1.2.1 could be used to reach the remote system. This is because there is a routing entry in AS3 that directs packets for 10.1.2.1 to 192.168.1.2 as the next hop. The addresses used in the return packet are based on the received packet. The bottom of the figure shows the addresses used with an unnumbered connection. The outbound packet has a source of 10.1.3.1 and a destination of 10.1.4.1. No routing entries are needed on either system because the systems have a direct interface to the remote network by using the remote system address of the point-to-point connection.



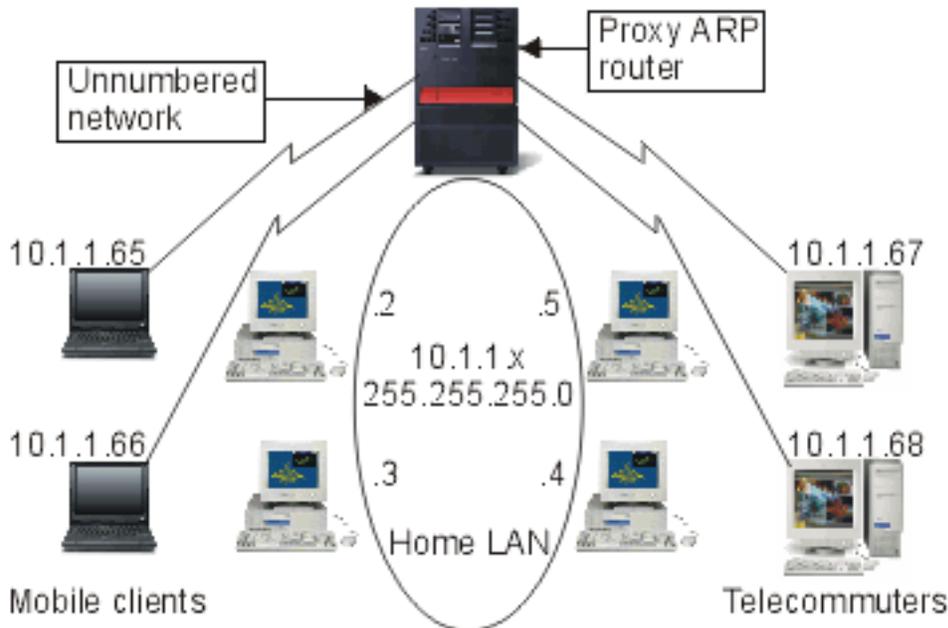
**Related concepts**

PPP connections

## Proxy Address Resolution Protocol routing

Proxy Address Resolution Protocol (ARP) provides connectivity between physically separate networks without creating any new logical networks and without updating any routing tables. This topic also contains a description of transparent subnets, which is an extension to the proxy ARP routing technique.

ARP routing allows physically distinct, separate networks to appear as if they were a single logical network. It allows systems that are not directly connected to a local area network (LAN) to appear to other systems on the LAN as though they are connected. This is useful in dial-up scenarios to provide connections to the entire network from a dial-in interface. The following figure shows a possible scenario. The 10.1.1.x is your home LAN and the 10.1.1.65 through 10.1.1.68 are your remote systems.

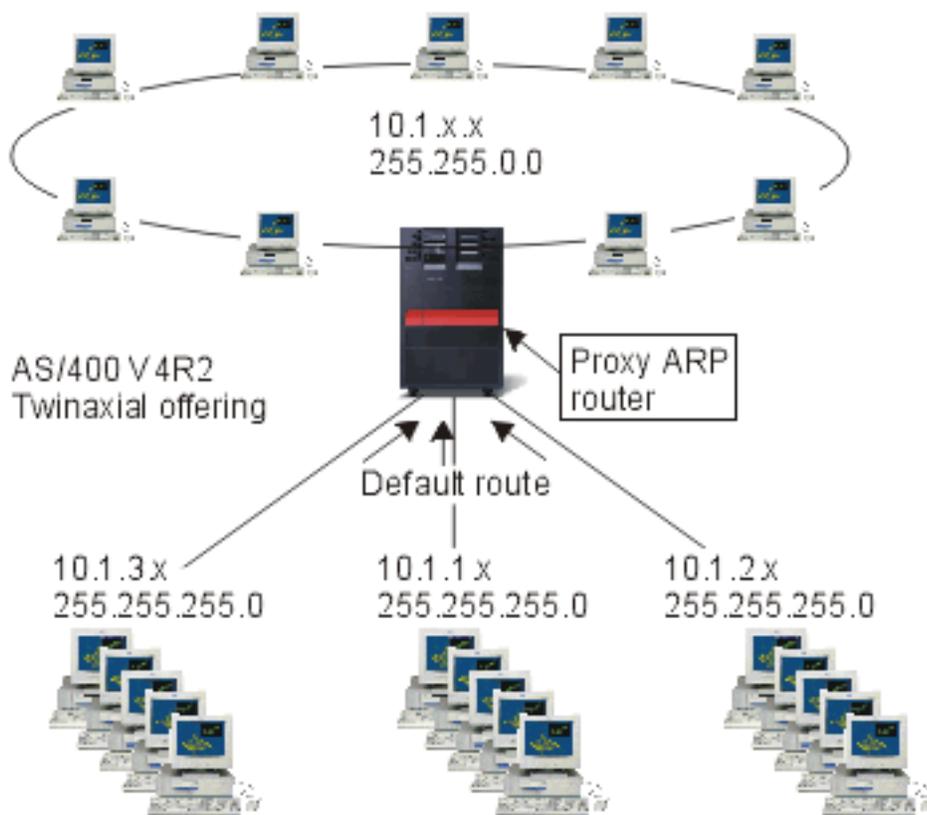


When a system on your home LAN (10.1.1.x) wants to send data to one of your remote systems, it will first do an ARP request. This is a broadcast that goes out to all your systems attached to the LAN segment to request the address of the target system, so a remotely connected system cannot see the broadcast. But with proxy ARP, your system knows which systems are connected remotely. If your system sees an ARP request for one of your remotely connected systems, your system replies to the ARP request with its address. Your system in turn receives the data and forwards it to the remote system. For this forwarding to take place, IP forwarding must be set to \*YES. If your remote system is not connected, your system cannot reply to the ARP request and the requesting system cannot send data.

## Transparent subnets

Transparent subnets can be used as a way to extend the proxy ARP concept. You can use transparent subnets as a proxy for an entire subnet, or range of hosts. Transparent subnetting allows stub networks to be assigned addresses out of the primary network address space.

Transparent subnets work for a single host so that you can connect to an entire subnet or range of hosts. You can see in the following figure that the stub networks (10.1.1.x through 10.1.3.x) are assigned addresses out of the primary network address space (10.1.x.x).



- | The twinaxial LANs are defined in address ranges that are within the real LAN address range. This
- | allows two interfaces in different segments to have addresses that look like they are in the same segment.
- | When the system sees this happen, it automatically performs a proxy ARP for any systems that are
- | attached behind the twinaxial controller. This allows all the systems on the 10.1.x.x network to
- | communicate with all the subnet systems with no changes to the systems on the 10.1.x.x network.

### Transparent subnetting over WANs

The transparent subnet function can be further expanded to handle real LANs that are remotely located. Transparent subnetting over WANs makes remote networks appear to be connected to the home network. In the preceding figure, three networks are attached to the home 10.1.x.x network through the System i platform. These networks are all defined using a subnet mask that makes them transparent to the home network. Proxy ARP responds to any ARP request in the home network for systems in the 10.1.1.x, 10.1.2.x, and 10.1.3.x subnets. This causes the traffic for the home network to be routed automatically to the system in the home network. This system, in turn, routes the data to the correct remote system. The remote system either processes the data, or forwards it to the correct system within the remote LAN. The workstations in the remote LAN must have a default route that points to the remote system in their network as the first hop gateway. The workstations in the home LAN do not need any additional routing entries because no new logical networks are created.

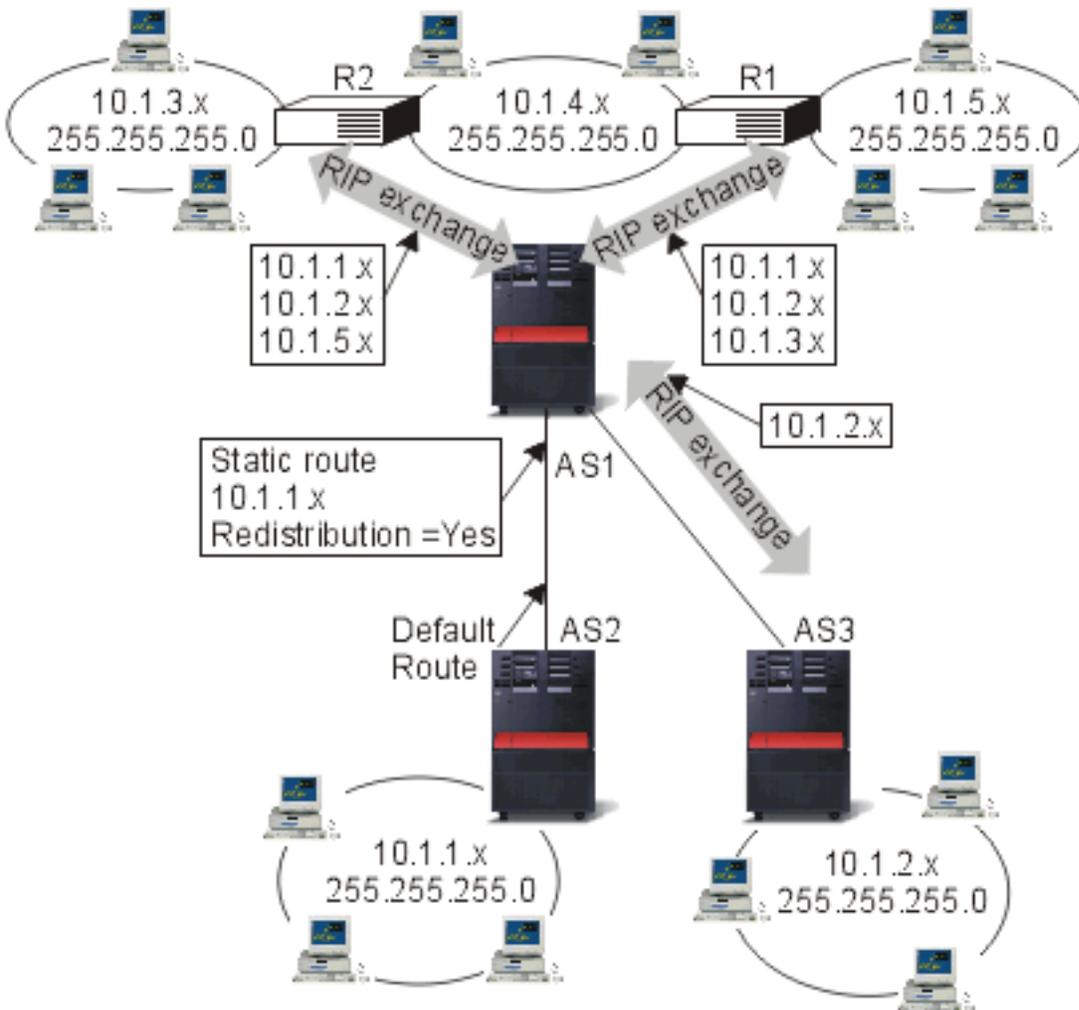
### Dynamic routing

Dynamic routing is a low-maintenance method that automatically reconfigures routing tables when your network changes.

Dynamic routing is provided by Interior Gateway Protocols (IGPs), such as Routing Information Protocol (RIP). RIP allows you to configure the hosts as part of a RIP network. This type of routing requires little

maintenance and also automatically reconfigures routing tables when your network changes or crashes. RIPv2 was added to the System i product so you can send and receive RIP packets to update routes throughout your network.

In the following figure, a static route is added to the central system (AS1) that describes the connection to the network 10.1.1.x via AS2. This is a static route (added by your network administrator) with route redistribution set to yes. This setting causes this route to be shared with other routers and systems so that when they have traffic for 10.1.1.x, they route the traffic to your central System i platform (AS1). AS2 has the routed system started so that it sends and receives RIP information. In this example, AS1 is sending the message that AS2 has a direct connection to 10.1.2.x.



This is a short description of what happens in the example:

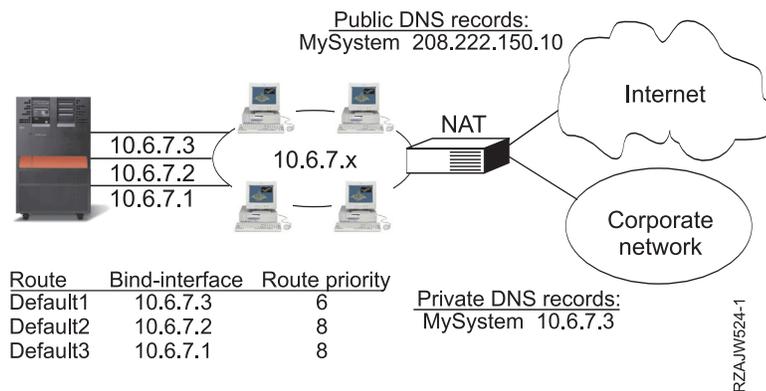
- AS1 receives this RIP packet from AS2 and processes it. If AS1 does not have a route to 10.1.2.x, it will store this route. If it does have a path to 10.1.2.x that is the same number of hops or fewer, it will discard this new route information. In this example, AS1 keeps the route data.
- AS1 receives information from R1 with route information to 10.1.5.x. AS1 keeps this route information.
- AS1 receives information from R2 with route information to 10.1.3.x. AS1 keeps this route information.
- The next time AS1 sends RIP messages, it will send information to R1 that describes all the connections AS1 knows about that R1 might not know about. AS1 sends route information about 10.1.1.x, 10.1.2.x, and 10.1.3.x. AS1 does not send information about 10.1.4.x to R1 because AS1 knows that R1 is connected to 10.1.4.x and does not need a route. Similar information is sent to R2 and AS3.

## Route binding

Route binding gives you control over which interface is used to send out response packets of information.

Before preferred route binding came along, you did not have complete control over which interface was used to send out response packets of information. The Preferred Route Binding Interface, added to the add route function, gives you more control over which interface is used to send out your packets by allowing you to explicitly bind routes to interfaces.

In the following figure, there are three interfaces connected to the same network. To guarantee that no matter which interface receives the inbound request, the reply can be sent back to the same interface, you must add the duplicate routes to each interface. In this example, three default routes are added; each one is explicitly bound to a different interface. This binding does not change regardless of the order in which interfaces are started or ended.



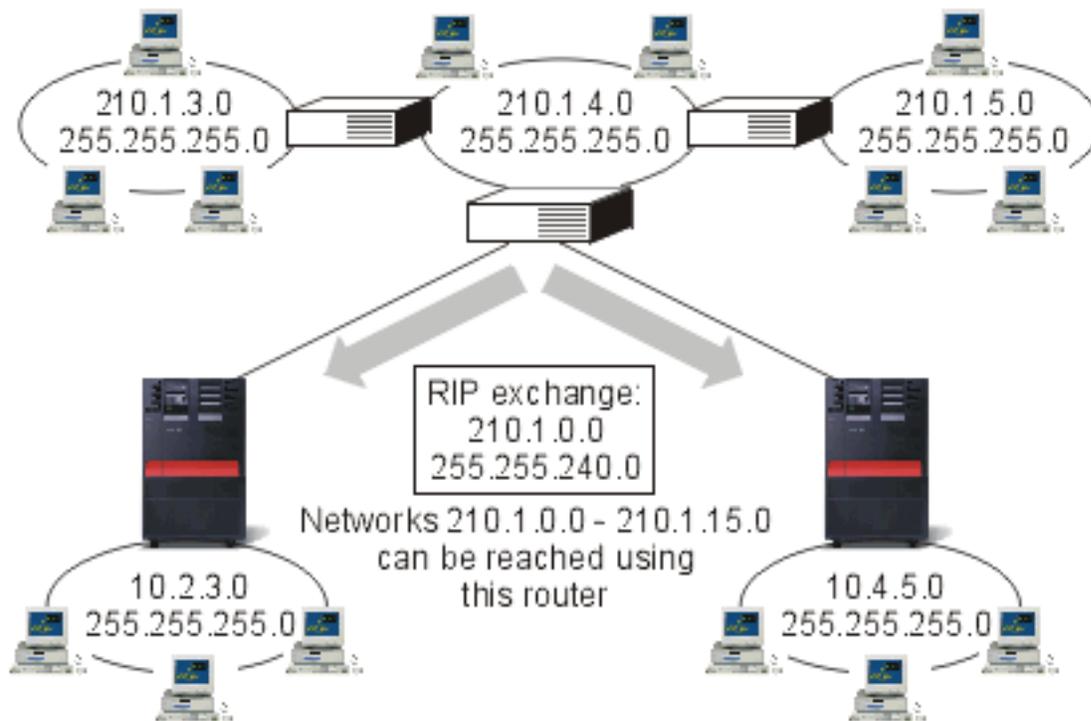
## Classless Inter-Domain Routing

Classless Inter-Domain Routing can reduce the size of your routing tables and make more IP addresses available within your business.

Classless Inter-Domain Routing (CIDR or supernetting) is a way to combine several class-C address ranges into a single network or route. This method of routing adds class-C Internet Protocol (IP) addresses. These addresses are given out by Internet service providers (ISPs) for use by their customers. CIDR addresses can reduce the size of your routing tables and make more IP addresses available within your business.

In the past, you were required to enter a subnet mask that was equal to or greater than the mask required for the network class. For class-C addresses, this meant a subnet of 255.255.255.0 was the largest (253 host) that could be specified. To conserve IP addresses, when companies needed more than 253 hosts in a network, the Internet was issuing several class-C addresses. This made the configuration of routes and other things difficult.

Now, CIDR allows these contiguous class-C addresses to be combined into a single network address range by using the subnet mask. For example, if you are giving out four class-C network addresses (208.222.148.0, 208.222.149.0, 208.222.150.0, and 208.222.151.0 with a subnet mask of 255.255.255.0), you can ask your ISP to make them a supernet by using the subnet mask 255.255.252.0. This mask combines the four networks into one for routing purposes. CIDR is beneficial because it reduces the number of assigned but unnecessary IP addresses.

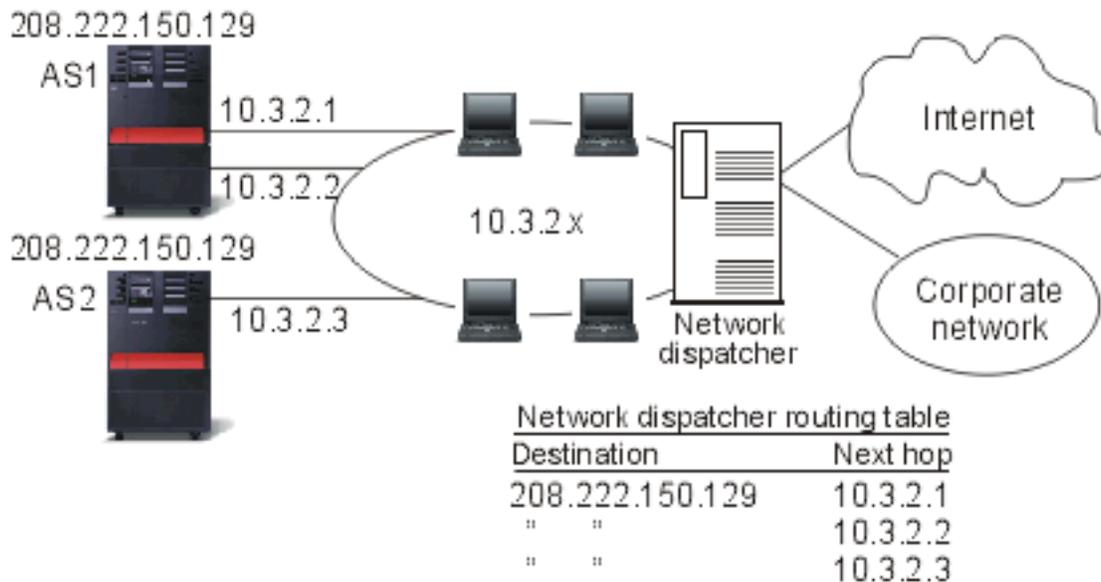


In this example, the router is set up to send one RIP message with the network address 210.1.0.0 and subnet mask 255.255.240.0. This tells your systems to receive the RIP messages for networks 210.1.0.0 through 210.1.15.0 through this router. This sends one message rather than the 16 that it would take to convey the same information if CIDR were not available.

## Routing with virtual IP

Virtual IP, also called a circuitless or loopback interface, is a powerful function that provides a way to assign one or more addresses to the system without the need of binding the address to a physical interface.

You can use this function when you want to run multiple occurrences of a system bound to different addresses, or if you want to run other services that need to bind to default ports. Most environments where you might want to use virtual IP are cases where you want to provide multiple paths between the local gateway and the System i platform; for example, load balancing and fault tolerance. In this context, each path implies an additional interface, and consequently, an additional, nonvirtual IP address on the system. The existence of these multiple interfaces should only be visible on the local network. You do not want the remote clients to be aware of the multiple IP addresses for the system. Ideally, you want them to view your system as a single IP address. How the inbound packet gets routed through the gateway, over the local network, and to the system should be invisible to a remote client. The way to accomplish this is by using virtual IP. Local clients should communicate with the system by any of the physical IP addresses while remote clients see only the virtual IP interface.



**Advantage:**  
- Load-based dispatching

**Disadvantage:**  
- Requires external dispatcher

The virtual IP environment is for the system that acts as the server for remotely connected clients. More importantly, the virtual IP address is on a different subnet than the physical interfaces. Moreover, the virtual IP address makes your system appear as a single host, not necessarily as one attached to a larger network or subnetwork. Therefore, the subnet mask for the virtual IP interface should usually be set to 255.255.255.255.

Because the virtual IP address is not bound to a single physical interface, the system never responds to an Address Resolution Protocol (ARP) request to the virtual IP address unless you enable proxy ARP for the virtual IP address. In other words, by enabling proxy ARP, a local interface can respond to the ARP requests on behalf of the virtual IP address. Otherwise, remote systems must have a route defined to reach the address.

In the preceding example, the workstations all point to one of the 10.3.2 interfaces on the system as their next hop gateway. When a packet arrives at the system, it goes through the packet processing. If the destination address matches any address defined on the system (including virtual IP addresses), the system processes the packet.

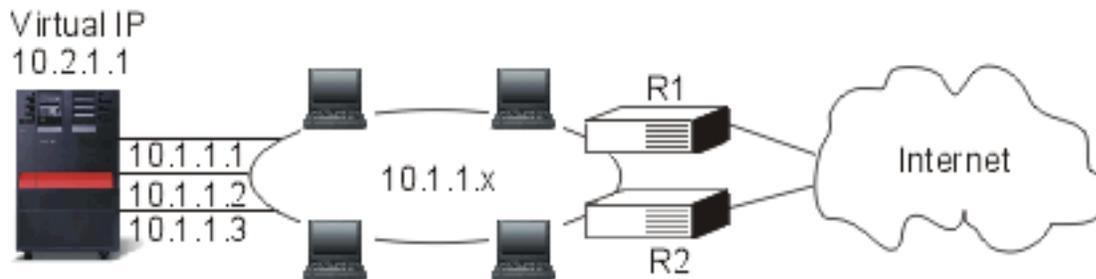
The Domain Name System (DNS) servers use the addresses of the requested system. In this case, all the addresses represent the same system. You can use the virtual IP function when consolidating multiple systems into one larger system.

## Fault tolerance

Another use for virtual IP addresses is to protect against router failures. Fault tolerance shows several different ways a route might be recovered after an outage.

This example shows several different ways a route can be recovered after an outage. The most reliable connection is when a virtual IP address is defined on the system. With virtual IP's support, even if an interface fails, the session can still communicate using different interfaces.

Network failure: Routes and connections are rebound to an alternate path, if one exists.



### What happens if router R1 fails

- Connections through R1 are rerouted through R2.
- The failed gateway will detect R1 recovery, but active connections will continue to run through R2.

### What happens if interface 10.1.1.1 fails

- Active connections to 10.1.1.1 are lost, but other connections to 10.1.1.2, 10.1.1.3, and 10.2.1.1 remain.
- Route rebinding:
  - Pre-V4R2: Indirect routes are rebound to 10.1.1.2 or 10.1.1.3.
  - V4R2: Routes are rebound only if Preferred Binding Interface is set to NONE.
  - V4R3 and higher: You need to define 10.2.1.1 as the virtual IP address and primary system address.
    - The primary IP address of the system remains active.
    - The system stays accessible as long as at least one physical interface remains active.

## Routing with network address translation

Routing with network address translation (NAT) allows you to access remote networks, such as the Internet, while protecting your private network by masking IP addresses that are used on the private network.

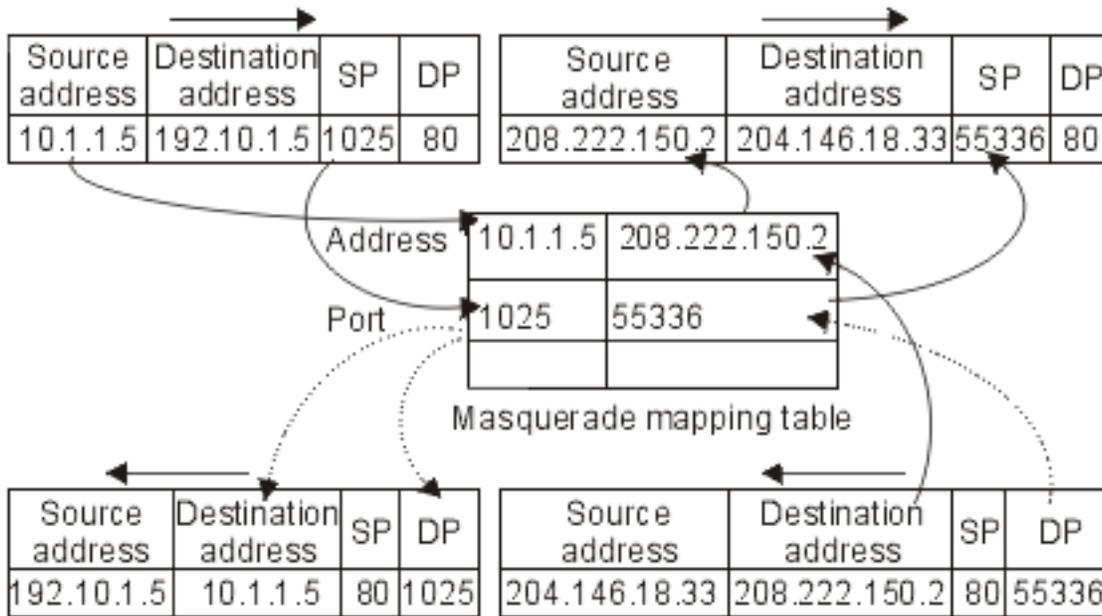
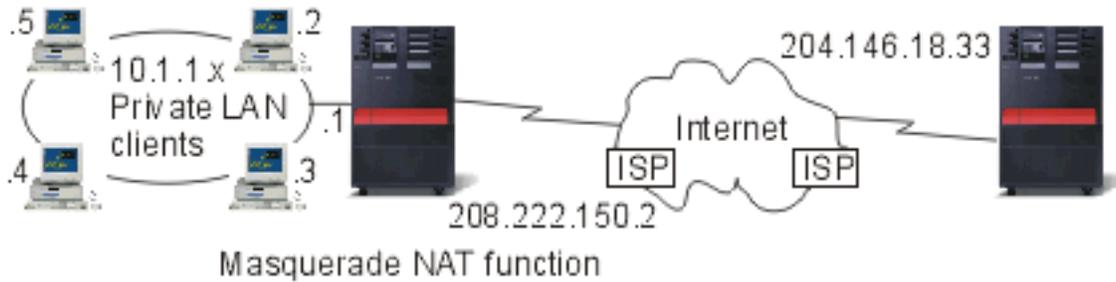
NAT provides access to a remote network, usually the Internet, while protecting the private network by masking the IP addresses that are used inside your firewall.

### Masquerade NAT

Masquerade NAT is used to allow your private network to hide behind, as well as be represented by, the address bound to the public interface.

In many situations, the address bound to the public interface is the address that has been assigned by an Internet service provider (ISP), and the address can be dynamic in the case of a Point-to-Point Protocol (PPP) connection. This type of translation can only be used for connections originating within the private network destined for the outside public network. Each outbound connection is maintained by using a different source IP port number.

Masquerade NAT allows workstations with private IP addresses to communicate with hosts on the Internet using the i5/OS operating system. i5/OS has an IP address assigned by the local ISP as its Internet gateway. The term *locally attached machine* refers to all systems on an internal network regardless of the method of attachment (local area network or wide area network) and regardless of the distance of the connection. The term *external machines* refers to systems located on the Internet. The following figure illustrates how masquerade NAT works.



To the Internet, all of your workstations appear to be contained within your system; that is, only one IP address is associated with both your system and your workstations. When a router receives a packet intended for your workstation, it attempts to determine what address on the internal LAN should receive the packet and sends it there.

Each workstation must be set up so that i5/OS is its gateway and also its default destination. The correspondence between a particular communication connection (port) and a workstation is set up when one of your workstations sends a packet to i5/OS to be sent to the Internet. The masquerade NAT function saves the port number so that when it receives responses to your workstation's packet over that connection, it can send the response to the correct workstation.

A record of active port connections and the last access time by either end of the connection is created and maintained by masquerade NAT. These records are periodically purged of all connections that are idle for a predetermined amount of time based on the assumption that an idle link is no longer in use.

All communication between your workstation and the Internet must be initiated by locally attached machines. This is an effective security firewall; the Internet knows nothing of the existence of your workstations, and it cannot broadcast those addresses to the Internet.

A key to masquerade NAT implementation is the use of logical ports, issued by masquerade NAT to distinguish between the various communication streams. TCP contains a source and a destination port number. To these designations, NAT adds a logical port number.

**Inbound masquerade NAT processing (response and other):**

This process, which is the partner of outbound masquerade NAT processing, unfolds the corresponding outbound message to get right source workstation information.

The inbound message in the previous figure is a packet from the Internet to your private LAN. For inbound datagrams, the destination port number is the local port number. (For inbound messages, the source port number is the external port number. For outbound messages, the destination port number is the external port number.)

Response messages returning from the Internet bound for a locally attached machine have a masquerade-assigned logical port number as the destination port number in the transport layer header. The masquerade NAT inbound processing steps are:

1. Masquerade NAT searches its database for this logical port number (source port). If it is not found, the packet is assumed to be an unsolicited packet, and the packet is returned to the caller unchanged. It is then handled as a normal unknown destination.
2. If a matching logical port number is found, a further check is made to determine that the source IP address matches the destination IP address of the existing logical port number table entry. If it matches, the original local machine's port number replaces the source port in the IP header. If the check fails, the packet is returned unchanged.
3. The local matching IP addresses are placed in the packet IP destination.
4. The packet is then processed, as usual by IP or TCP, and ends up at the correct locally attached machine. Because masquerade NAT requires a logical port number to determine the correct source and destination port addresses, masquerade NAT is incapable of handling unsolicited datagrams from the Internet.

### **Outbound masquerade NAT processing:**

This process replaces the source port of an outbound message with a unique logical port number when the message is sent from the private LAN to the Internet.

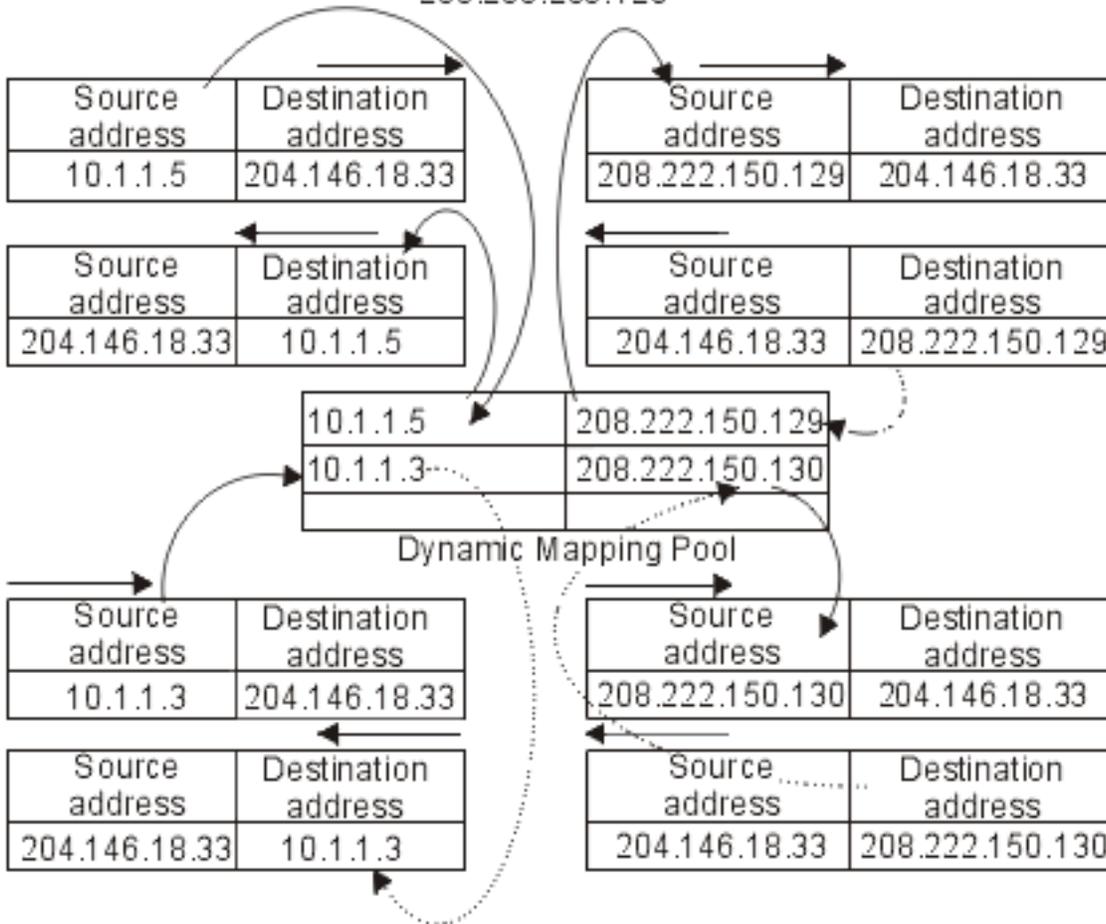
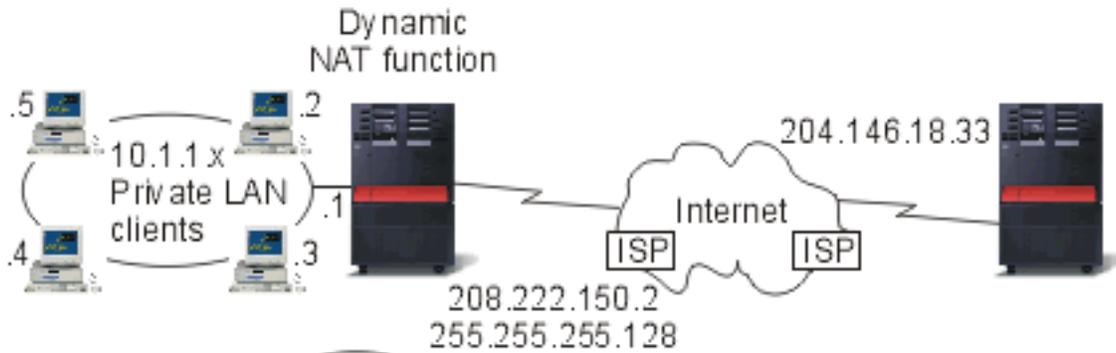
The outbound message in the previous figure is a packet from the private LAN to the Internet. An outbound message (local to external) contains the source port used by the originating workstation. NAT saves this number and replaces it in the transport header with a unique logical port number. For outbound datagrams, the source port number is the local port number. The masquerade NAT outbound processing steps are:

1. Outbound masquerade NAT processing assumes that all IP packets it receives are bound for external IP addresses, and therefore does not check to determine whether a packet should be routed locally.
2. The set of logical port numbers searches for a match on the transport layer as well as a source IP address and source port. If found, the corresponding logical port number is substituted for the source port. If no matching port number is found, a new one is created, and a new logical port number is selected and substituted for the source port.
3. The source IP address is translated.
4. The packet is then processed as usual by IP and is sent to the correct external system.

### **Dynamic NAT**

Dynamic NAT can only be used to establish connections from within the private network out to the public network.

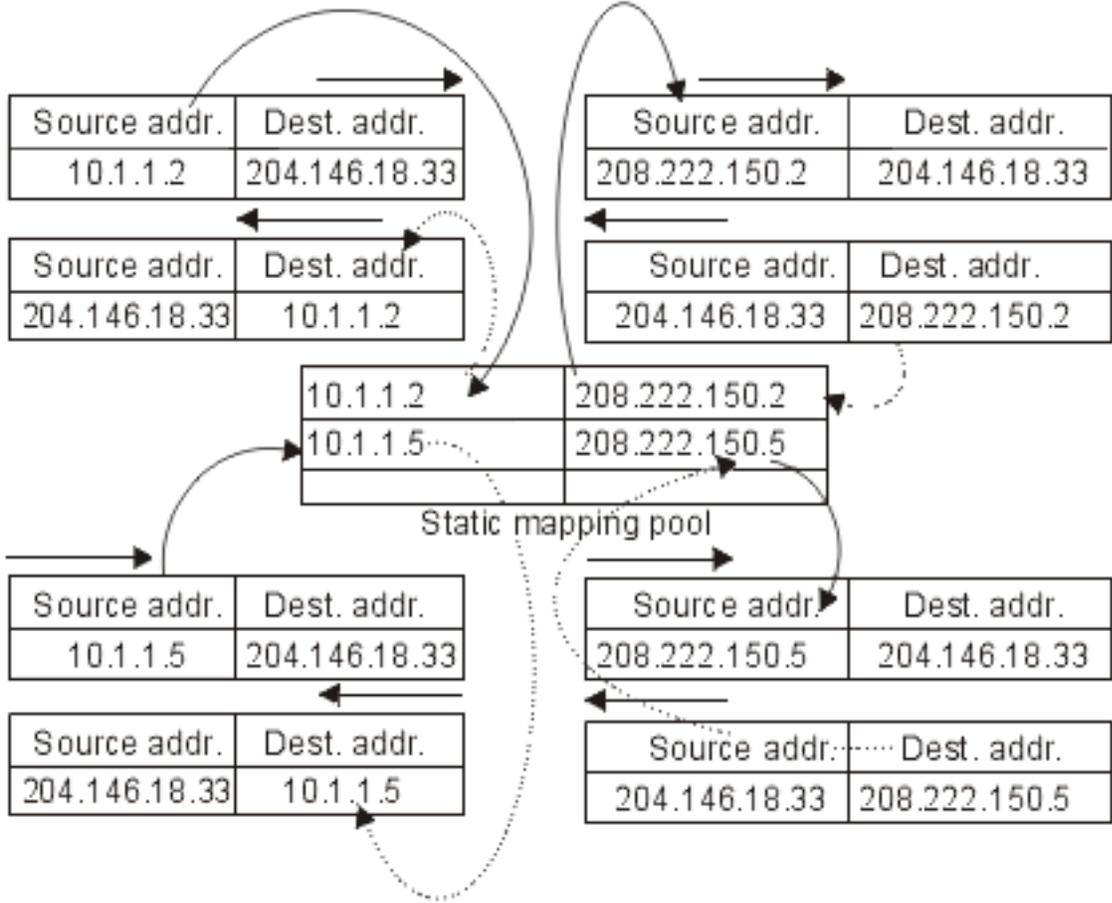
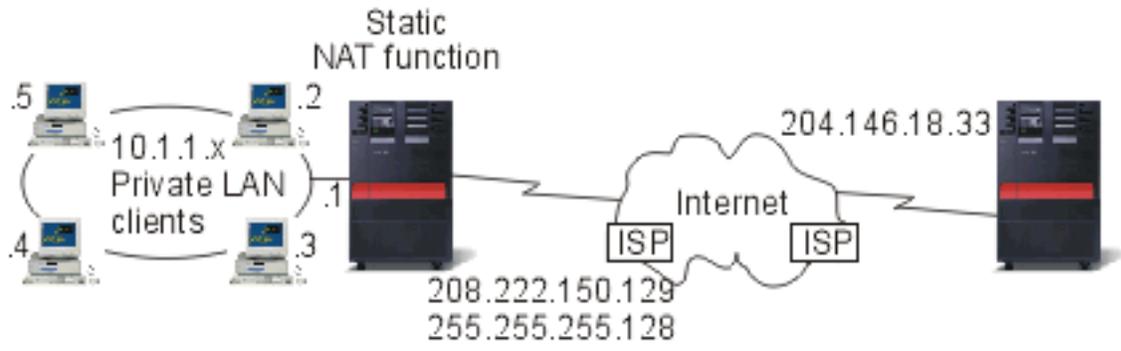
A pool of network addresses is maintained and used when an outbound connection is made. Each connection is assigned a unique public address. The maximum number of simultaneous connections is equal to the number of public addresses in the pool. This is similar to a one-to-one correspondence between addresses. Dynamic NAT allows you to communicate with the Internet through a dynamic NAT address. The following figure illustrates dynamic NAT.



### Static NAT

Static NAT can use inbound connections from a public network into a private network.

Static NAT is a simple one-to-one mapping of private and public addresses. This is required to support inbound connections from your public network into your private network. For each local address defined, there has to be an associated globally unique address.



**Related concepts**

“DNS-based load balancing” on page 22

You can use DNS-based load balancing for your inbound workload. If load balancing is needed for local clients, use DNS load balancing.

**Routing with OptiConnect and logical partitions**

OptiConnect can connect multiple System i platforms by using a high-speed, fiber-optic bus. This information covers using OptiConnect with logical partitions and the advantages of using them.

OptiConnect and logical partitions provide other environments for you to use the routing basics of proxy ARP, point-to-point, and virtual IP interfaces. Here are a few different methods of these basics.

## TCP/IP and OptiConnect

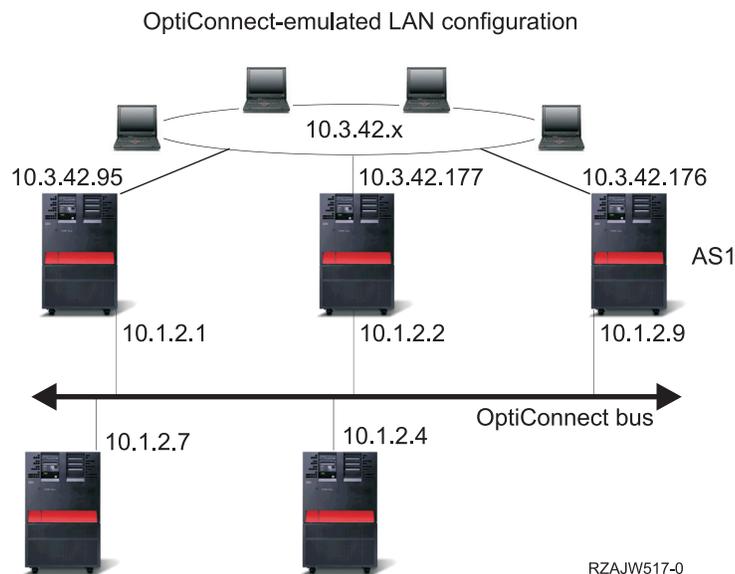
OptiConnect can give you the ability to define TCP/IP connections over an OptiConnect bus. This topic describes this feature and how it might be used.

TCP/IP over OptiConnect provides another method for the routing building blocks such as proxy ARP, unnumbered point-to-point networks, and virtual IP interfaces. You can configure this with an OptiConnect-emulated LAN configuration and an OptiConnect point-to-point configuration.

With an **OptiConnect-emulated LAN configuration**, the OptiConnect bus appears as a LAN to TCP/IP. This is simple to configure, but the LAN OptiConnect connectivity is not automatic because it requires Routing Information Protocol (RIP) or static routes.

The **OptiConnect point-to-point configuration** uses point-to-point unnumbered interfaces that are configured for each pair of OptiConnect hosts. No new networks are created and so the LAN OptiConnect connectivity is automatic. One advantage to this configuration is that no additional route definitions are required. Connectivity between a host on one network to hosts on another network is automatic. Another advantage is that if both networks are active, data sent between the systems flows over the OptiConnect bus because these routes have the most specific subnet mask. If the OptiConnect bus goes down, traffic is automatically switched to the token-ring LAN.

**OptiConnect point-to-point configuration using virtual IP** is a variation on the unnumbered point-to-point configuration. Remember that whenever you use unnumbered, point-to-point interfaces, each interface must have an associated local interface specified. This is the IP address by which the system on the remote end of the point-to-point link will know the local system. This associated local interface might be the system's primary LAN interface, as shown in the following figure. Or you can use a virtual IP interface as the associated local interface. In this configuration, you use the OptiConnect bus as a collection of point-to-point connections. You define an unnumbered connection for each pair of hosts. Like the previous configuration, no additional route definitions are required, and connectivity between a host on one network to hosts on the other network are automatic. An advantage of this configuration is that if either network is active, a path will exist to reach any system running on the i5/OS operating system.



## Routing with virtual OptiConnect and logical partitions

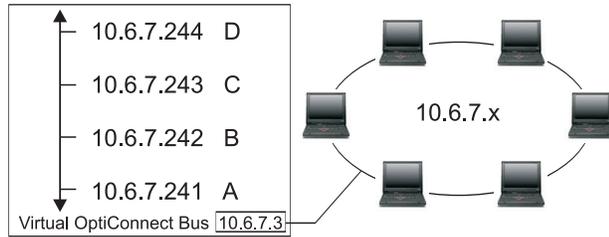
Virtual OptiConnect TCP/IP interfaces are used as interpartition communication paths.

A single System i platform is logically partitioned in multiple virtual machines. Each partition has its own address space. To TCP/IP, each partition appears as a distinct system.

With logical partitions, a single system is logically partitioned into multiple virtual machines. Virtual OptiConnect TCP/IP interfaces are used as interpartition communication paths. Each partition has its own address space, its own instance of TCP/IP, and might have its own dedicated I/O adapters. To TCP/IP, each partition appears as a distinct system. TCP/IP communication between the different partitions is done using a virtual OptiConnect bus. The TCP/IP routing code uses the path to another partition no differently than the path to another system connected by a physical OptiConnect bus.

Logical partitions: Virtual OptiConnect TCP/IP interfaces are used as inter partition communication paths.

Virtual OptiConnect network = 10.6.7.241 - 10.6.7.254  
This provides addresses for up to 14 partitions



Partition	Interface	Line	Subnet mask	MTU
D	10.6.7.244	*OPC	255.255.255.240	4096
C	10.6.7.243	*OPC	255.255.255.240	4096
B	10.6.7.242	*OPC	255.255.255.240	4096
A	10.6.7.241	*OPC	255.255.255.240	4096
A	10.6.7.3	TRNLNE	255.255.255.0	4096

(Associated local interface = 10.6.7.3)

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In these examples, only one LAN adapter is installed in the system. It is allocated to partition A. The clients in the LAN need to communicate with the other partitions defined on the system. To do this, you define a transparent subnet on the virtual OptiConnect bus. The LAN has a network address of 10.6.7.x. You want to plan for additional partitions, so IP addresses are then needed. To get 12 addresses, you must use a subnet mask of 255.255.255.240. This gives you addresses 10.6.7.241 through 10.6.7.254, a total of 14 usable addresses. You must ensure that these addresses are not already in use on the LAN. After you get the addresses, you assign one to each partition. You add an interface to each partition and define the address on the virtual OptiConnect bus.

*OPC	Partition	*Virtual IP	Partition	Interface	Line	Subnet Mask	MTU	Assoc. LCL IFC
10.6.7.3	D	10.6.7.4	D	10.6.7.4	*VIRTUALIP	255.255.255.255	4096	*NONE
10.6.7.2			D	10.6.7.1	*OPC	255.255.255.255	4096	10.6.7.4
10.6.7.1			D	10.6.7.2	*OPC	255.255.255.255	4096	10.6.7.4
			D	10.6.7.1	*OPC	255.255.255.255	4096	10.6.7.4
10.6.7.4	C	10.6.7.3	C	10.6.7.3	*VIRTUALIP	255.255.255.255	4096	*NONE
10.6.7.2			C	10.6.7.1	*OPC	255.255.255.255	4096	10.6.7.3
10.6.7.1			C	10.6.7.2	*OPC	255.255.255.255	4096	10.6.7.3
			C	10.6.7.4	*OPC	255.255.255.255	4096	10.6.7.3
10.6.7.4	B	10.6.7.2	B	10.6.7.2	*VIRTUALIP	255.255.255.255	4096	*NONE
10.6.7.3			B	10.6.7.1	*OPC	255.255.255.255	4096	10.6.7.2
10.6.7.1			B	10.6.7.3	*OPC	255.255.255.255	4096	10.6.7.2
			B	10.6.7.4	*OPC	255.255.255.255	4096	10.6.7.2
10.6.7.3	A	10.6.7.1	A	10.6.7.1	*TRNLNE	255.255.255.0	4096	*NONE
10.6.7.3			A	10.6.7.2	*OPC	255.255.255.255	4096	10.6.7.1
10.6.7.2			A	10.6.7.3	*OPC	255.255.255.255	4096	10.6.7.1
			A	10.6.7.4	*OPC	255.255.255.255	4096	10.6.7.1

Virtual OC Bus

→ To 10.6.7.x external LAN

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Transparent subnetting is automatically enabled when the following statements are true. First, the virtual OptiConnect bus is less than or equal to the size of the MTU on the real LAN interface. Second, the OptiConnect bus subnet is a subnet of the LAN network address. If both statements are true, then transparent subnetting is automatically enabled. The interface 10.6.7.3 performs a proxy for all the interfaces defined in the partitions. This allows clients on the LAN to connect to the partitions.

## TCP/IP workload balancing methods

*Workload balancing* is redistributing network traffic and workload of heavily accessed machines across multiple processors, multiple interface adapters, or multiple host systems.

If you want to get the best performance possible from the i5/OS operating system, you should put the communications workload on multiple parts of your system.

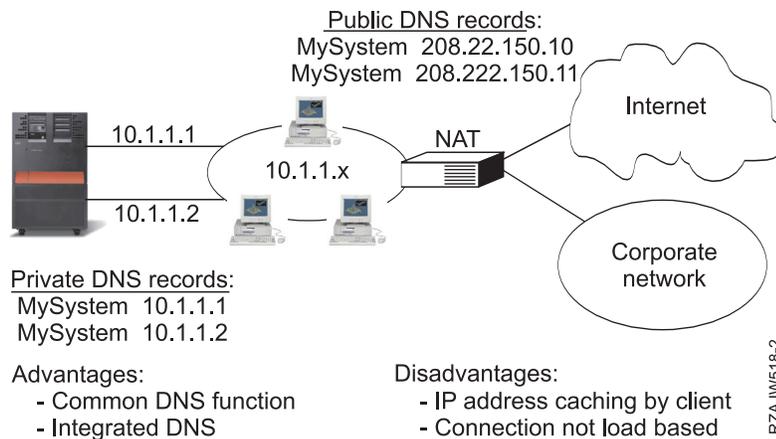
Several different TCP/IP routing methods can be used to balance the workload of your system.

## DNS-based load balancing

You can use DNS-based load balancing for your inbound workload. If load balancing is needed for local clients, use DNS load balancing.

DNS-based load balancing is used for inbound load balancing. Multiple host IP addresses are configured in DNS for a single host system name. DNS alternates the host IP address returned to a successive client host name resolution request. An advantage to this type of load balancing is that it is a common DNS function. Disadvantages to this solution are that IP addresses can be cached by a client and it is a connection-based solution, not a load-based solution.

The first way to achieve load balancing is to use a DNS function to pass out multiple addresses for the same system name. The DNS will serve a different IP address each time a request is made for the address record for your system name. In the following example, each address corresponds to a different system. This allows you to provide load balancing across two separate systems. In the case of clients on the private networks, they receive a different address for each request. This is a common DNS function. Notice that the public DNS also has two address entries. These addresses are translated using static NAT so that if you are on the Internet, you can reach the two systems.



If your programs depend on getting to a specific system or depend on returning to the same system after the initial connection, the Web pages and sites should be coded to send a different system name after the first contact is made. Additional DNS entries can be added for MyServer1 208.22.150.10 and MyServer2 208.22.150.11. By doing this, the Web sites, for example, can point to MyServer2 after the first contact. This type of load balancing provides balancing by the connection request. In most cases, after you have resolved the address the client caches the address and will not ask again. This type of load balancing does not consider the amount of traffic going to each system. Note that this type of load balancing only considers inbound traffic and also that you can have two adapters on one system rather than one adapter on two systems.

### Related concepts

“Static NAT” on page 18

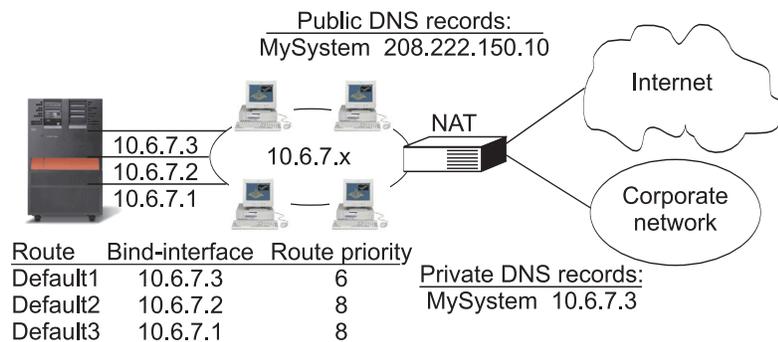
Static NAT can use inbound connections from a public network into a private network.

## Duplicate route-based load balancing

Duplicate route-based load balancing allows you to balance outbound workload across multiple interfaces.

This is a connection-based solution that has more flexibility than DNS-based load balancing, but it is not active for local clients. The advantages of using this type of load balancing are that it is a total i5/OS solution, it has more flexibility than DNS, and it is good for applications where most of the traffic is outbound, like HTTP and Telnet. The disadvantages to it are that it is a connection-based solution (not a load-based solution), it is not active for local clients, and it has no effect on inbound requests.

In the following example, three adapters on your system are all connected to the same LAN segment. You have set up one of the adapters as an inbound line only and set up the other two adapters as outbound. Local clients continue to work the same way as in the past. That is to say the outbound interface is the same as the inbound interface. Remember that a local client is any system that does not require a router to reach it. This can be a very large network if switches were used rather than routers.



**Duplicate, indirect routes, with priority >(5) default will be selected according to route priority**

Advantages:

- More flexibility than DNS
- Good for HTTP, Telnet

Disadvantages:

- Connection based, not load based
- Not active for local clients
- No effect on inbound requests

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You can configure duplicate route-based load balancing with the Add TCP/IP Route command or with the iSeries™ Navigator interface. It is accomplished by setting either the duplicate route priority or the preferred binding interface. If the value for duplicate route priority is left at the default value of 5, nothing happens. If a value greater than 5 is set, then connections are distributed between routes at the same priority. The preferred binding interface is used to bind a route to a specific interface by IP address rather than the first one the system sees.

In the preceding example, there is an "inbound" adapter (10.6.7.3) with a duplicate route priority of 6. The other two adapters are configured with a duplicate route priority of 8. Because the duplicate route priority on one adapter is 6, it will not be selected for an outbound connection unless all the single route priority interfaces of 8 are down.

You should put all the outbound interfaces at the same priority. If you put some at one value and some at another value, only the highest value interfaces will be used.

Notice that the DNS is pointing to the 10.6.7.3 interface, making it the inbound interface. Even if you decide not to use duplicate route priority, you should always define a default route out of the system on each interface by using the preferred binding interface parameter.

## Scenario: Adapter failover using virtual IP and proxy ARP

Virtual IP addresses allow you to assign an address to the system rather than to a specific interface. You can define the same address to multiple systems, which allows many new options for load balancing.

**Note:** This failover scenario is referring to a single LAN adapter rather than a major type of system outage like clustering would cover. This solution requires you to have an external load balancing system.

### Situation

Your production system handles data entry from both remote and LAN clients. It has the company's critical application on it. As the company has grown, so has its demand on the System i hardware and the network. Because of the growth, it has become imperative that this system be available on the network without an unscheduled down time. If, for any reason, a network adapter becomes unavailable, other network adapters on the system should take over and the network clients should be unaware of any failures.

### Objectives

The concept of availability has many different aspects of redundancy and backup for failing components. In this scenario, the goal is to provide network availability to the system for its clients in the event of an adapter failure.

### Details

One way to handle the preceding situation is to have multiple physical connections to the LAN from the System i platform. Consider the following figure.

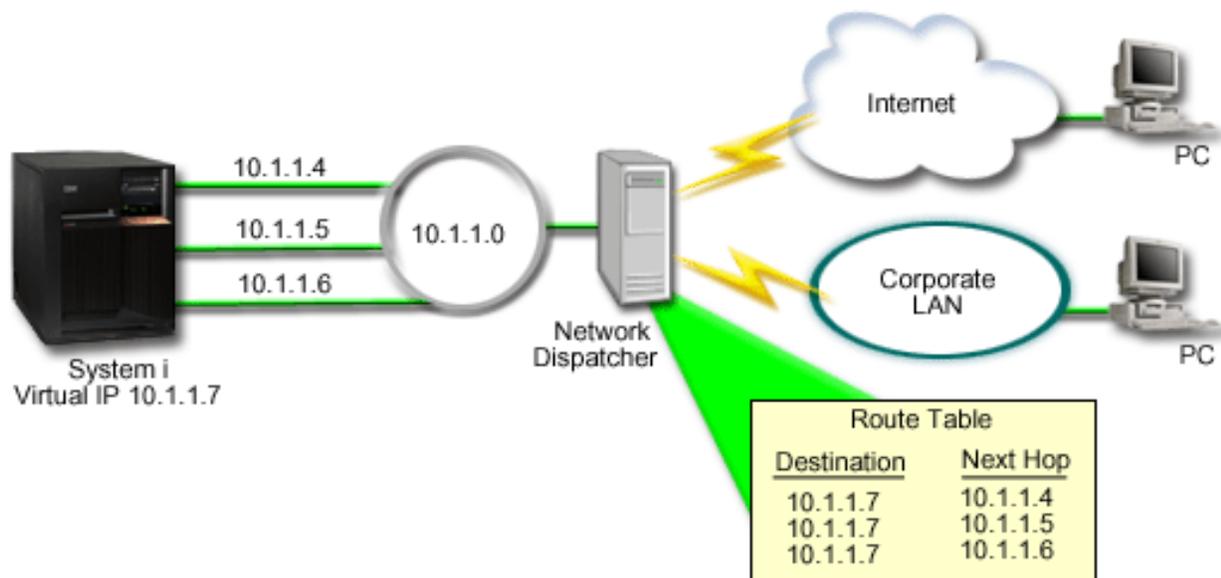


Figure 1. Adapter failover without local clients

Each physical connection has a different IP address. Then you can assign a virtual IP address to the system. This virtual IP address is the IP address by which all of its clients recognize it. All remote clients (clients that are not physically attached to the same LAN as the System i platform) communicate with the

system through an external load balancing server such as a network dispatcher. When IP requests from remote clients go through the network dispatcher, the network dispatcher routes the virtual IP addresses to one of the network adapters on the system.

If the LAN that the system is connected to has clients, these clients will not use the network dispatcher to direct their locally bound traffic because that unnecessarily overloads the network dispatcher. You can create route entries on each client that are similar to the route tables in the network dispatcher. However, this is impractical if the LAN has a large number of local clients. This situation is described in the following figure.

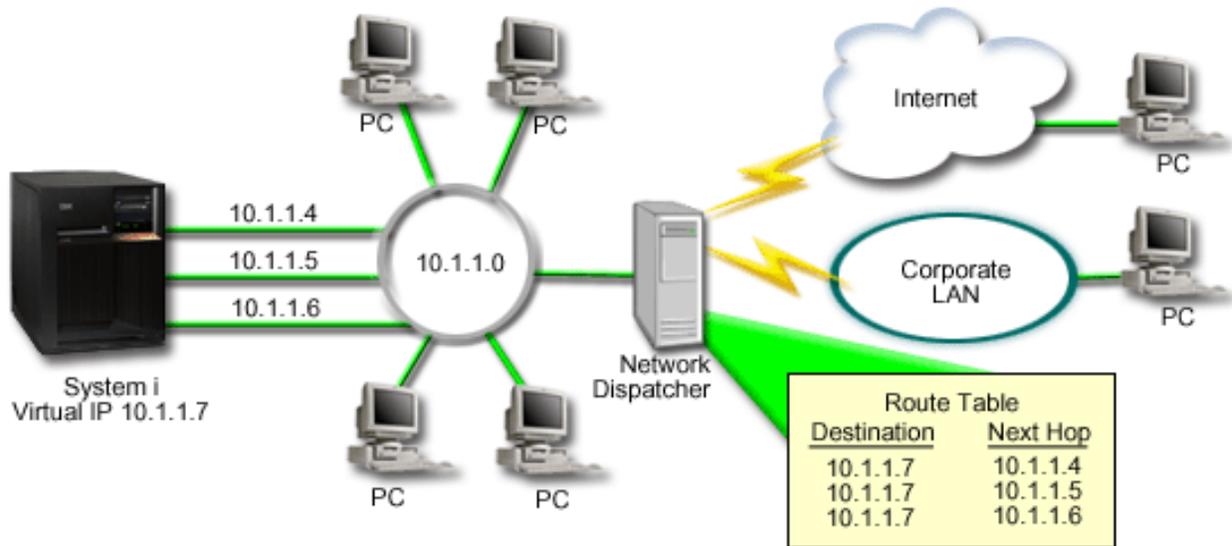


Figure 2. Adapter failover with local clients

- | Local clients (clients that are attached to the same LAN as the system) can connect to the virtual IP address of the system through ARP. This allows local clients to have an adapter failover solution as well.
- | In each case, neither local clients nor remote clients are aware of the failover when it occurs. The system chooses which adapters and IP addresses are the preferred interface for virtual IP address (VIP) Proxy Address Resolution Protocol (ARP) agent selection.
- | Starting with i5/OS V5R4, you can manually select which adapters and IP addresses are to be the preferred interface for VIP proxy ARP agent selection. You can select which interface to use by creating a preferred interface list if an adapter failure occurs. A preferred interface list is an ordered list of the interface addresses that take over for the failed adapters. You can use either iSeries Navigator or the Change TCP/IP IPv4 Interface (QTOCC4IF) application programming interface (API) to configure a preferred interface list. The preferred interface list is also configurable for both virtual Ethernet and virtual IP address interfaces.
- | Using Figure 2 as an example, remote clients are communicating with the local system using virtual IP address 10.1.1.7. Suppose 10.1.1.4 is the initial local adapter being used for this communication, and you want 10.1.1.5 to take over if 10.1.1.4 fails. You also want interface 10.1.1.6 to take over if both adapters for 10.1.1.4 and 10.1.1.5 fail. To control the order in which these interfaces are used in a failover situation, you can define a preferred interface list for virtual IP address 10.1.1.7. In this case, it is an ordered list of interface addresses that consists of 10.1.1.4, 10.1.1.5, and 10.1.1.6.

The solution can also involve using two or more System i platforms to support each other. If one of the systems becomes unavailable, then the second system can serve as a failover. The following figure shows

the same setup using two systems.

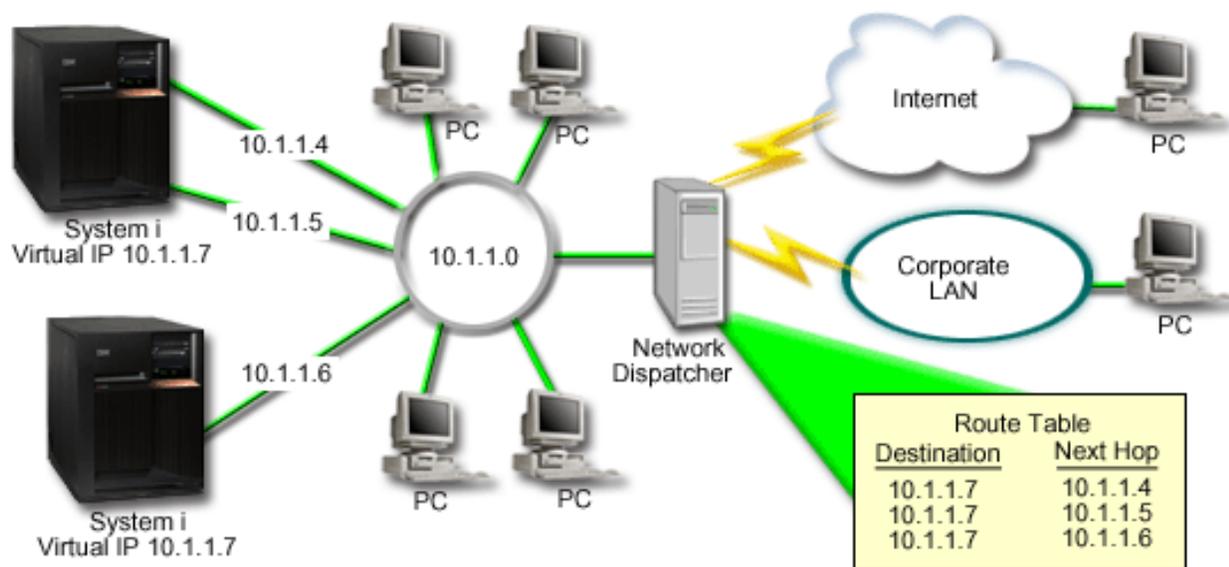


Figure 3. Adapter failover with multiple System i platforms and local clients

The packet routing is the same as routing for a single system and its remote clients; however, there is a distinct difference for the local clients. If you have multiple systems using the same virtual IP address, you can only use proxy for one of the systems. In this case, you will have the system with the two LAN connections serve as the proxy.

## Configuration steps

- | The configuration for load balancing using virtual IP and proxy ARP is similar to standard TCP/IP configurations with the addition of a virtual TCP/IP interface.

## Failover using automatic interface selection

Use these steps to configure virtual IP and proxy ARP for adapter failover situations in this scenario.

Using Figure 2 as an example, the general configuration steps would be:

1. Configure a virtual TCP/IP interface

Using iSeries Navigator, create a virtual TCP/IP interface. The new Virtual IP interface wizard can be found at: **Network** → **TCP/IP Configuration** → **IPv4** → **Interfaces**. Then right-click **Interfaces** and choose **New Interface** → **Virtual IP**.

For our example, you will enter an IP address of 10.1.1.7 with a subnet mask of 255.255.255.255. After you have created the Virtual interface, right-click the interface and select **Properties**. Click the **Advanced** tab and select the **Enable proxy ARP** check box.

2. Create TCP/IP interfaces for all of your physical LAN connections

Use the Create TCP/IP interface wizard to create your TCP/IP interfaces. The wizard is in iSeries Navigator and can be found at: **Network** → **TCP/IP Configuration** → **IPv4** → **Interfaces**. Then right-click **Interfaces** and choose **New Interface** → **Local Area Network**. Complete the wizard for each of your LAN connections.

For our example, you will run the wizard three times entering the IP addresses of 10.1.1.4, 10.1.1.5, and 10.1.1.6 with a subnet mask of 255.255.255.0. After you have completed each interface, right-click

the interface and choose **Properties**. On the **Advanced** tab, associate the interface with the Virtual IP interface you created in step 1 on page 26. You can associate the interfaces with the **Associated local interface** select box.

## Failover using a preferred interface list

You can create a preferred interface list to control the order in which the local interfaces are used when an adapter failure occurs.

To create a preferred interface list, follow these steps:

1. In iSeries Navigator, expand **Network** → **TCP/IP Configuration** → **IPv4**.
2. Click **Interfaces**.
3. From the lists of interfaces that are displayed, select an interface for the virtual IP address or virtual Ethernet for which you want to create the preferred interface list.  
Using Figure 2 as an example, select the virtual IP address 10.1.1.7.
4. Right-click the interface, and then select **Properties**.
5. Click the **Advanced** tab.
6. In the panel, select the interface addresses from the Available interface list, and click **Add**.  
Using Figure 2 as an example, select interfaces 10.1.1.4, 10.1.1.5, and 10.1.1.6, and add them to the preferred interface list one by one.  
You can also remove an interface from the preferred interface list in the right pane by using the **Remove** button, or move an interface up and down the list to change the order by using the **Move up** and **Move down** buttons.
7. Select the **Enable proxy ARP** check box above the Available interfaces list to enable the list.
8. Click **OK** to save the preferred interface list that you have just created.

### Notes:

- a. You can only include 10 interfaces in the preferred interface list. If you configure more than 10, the list is truncated to the first 10.
- b. The interface for which you want to create the preferred interface list must be inactive for the list to be configured. Interfaces listed in the preferred interface list do not need to be inactive at the time the list is configured.

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## Related information for TCP/IP routing and workload balancing

Listed here are the product manuals and IBM® Redbooks™ (in PDF format), Web sites, and information center topics that relate to the TCP/IP routing and workload balancing topic. You can view or print any of the PDFs.

### Other information

- Domain Name System DNS is an advanced system for managing the host names that are associated with Internet Protocol (IP) addresses on TCP/IP networks. Here you will find basic concepts and procedures that you need to know to configure and administer DNS.
- Logical partitions This topic provides you with more background information and detail.
- IP filtering and network address translation Information in this topic helps you manage your filter rules. Some of the functions include adding comments, editing, and viewing.
- OptiConnect This topic provides you with information about OptiConnect routing.
- Point-to-Point Protocol This protocol is commonly used to connect a computer to the Internet. PPP is an Internet standard and is the most widely used connection protocol among Internet service providers (ISPs).

## **Saving PDF files**

To save a PDF on your workstation for viewing or printing:

1. Right-click the PDF in your browser (right-click the link above).
2. Click the option that saves the PDF locally.
3. Navigate to the directory in which you want to save the PDF.
4. Click **Save**.

## **Downloading Adobe Reader**

- 1 You need Adobe Reader installed on your system to view or print these PDFs. You can download a free copy from the Adobe Web site ([www.adobe.com/products/acrobat/readstep.html](http://www.adobe.com/products/acrobat/readstep.html))  .

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## Appendix. Notices

This information was developed for products and services offered in the U.S.A.

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This TCP/IP routing and workload balancing publication documents intended Programming Interfaces that allow the customer to write programs to obtain the services of IBM i5/OS.

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