LABORATORY WORK NO. 4
STATIC ROUTING

1. Objectives

The aims of this laboratory are: understanding the concept of static routing, learning the elements of a routing table, understanding the concept of gateway and default route and learn to configure routing tables.

2. Theoretical considerations

2.1 Using static routing

An important element of routing strategy is the decision to use static or dynamic routing on your network. Static routing protocols are hardly protocols at all. They work well in environments where network traffic is predictable and network design is simple. With static routing, network administrators must manually create and modify the routing table entries before the routing begins. Dynamic routing uses specialized protocols that enable routers to communicate with each other and share their routing table information.

Static routing is advantageous in small networks for which configuring a few static routes is simpler than configuring a dynamic routing protocol. Besides this ease of deployment, another advantage of static routing is that static routes are less resource-intensive (no overhead on the router CPU) than are dynamic routing protocols. They do not require communication among routers, and this feature makes static routes preferable to dynamic routing protocols for low-bandwidth WAN links. A final advantage of static routing is that, unlike dynamic routing protocols, static routes provide support for unnumbered connections: connections in which one or both of the connecting logical interfaces (usually in a demand-dial connection) fail to obtain an IP address.

The main disadvantage of static routing is that it is a feasible means of maintaining only small routed networks. The administrator must really understand the internetwork and how each router is connected to configure the routes correctly. As a network grows, the administrative cost of maintaining static routes quickly outweighs the cost of implementing and maintaining a dynamic routing protocol. A second disadvantage of static routing is the lack of fault tolerance. If a route is improperly configured, connectivity is disrupted until the problem is diagnosed and fixed.

2.2 Understanding the IP routing table

2.2.1 Important elements of IP routing table

Routers use routing tables to determine where to send packets. When IP packets are sent to an IP router, the router reads the destination address of the packet and compares that destination address to the entries in the routing table. One of these entries is used to determine which interface to use to send the packet and to which hop (gateway) the packet will be sent next.

To assist in this process, each routing table entry includes:

- network destination: this column provides entries that the router compares to the destination address of every received IP packet. A few of these entries are common to most routing tables. For example, the entry 0.0.0.0 represents the default route, used when no other matches are found in the routing table. The entry 127.0.0.0 points to the loopback address of 127.0.0.1, which corresponds to the local machine. Each entry of 224.0.0.0, furthermore, refers to a separate multicast route. Finally, entries with a final octet value of 255 represent a broadcast address. Broadcast addresses include specific subnet broadcast addresses, and the limited broadcast address 255.255.255.255, which is general for all networks and routers;
- netmask: the value in this column determines which part of the IP packet’s destination address is compared to the entries in the network destination column. This information is important because the largest match determines the route or table entry that is applied to the packet;
- gateway: when a particular route or table entry is applied to a packet, the gateway value determines the next address or hop for which that packet is destined. A basic concept to understand for the gateway value is that this address should be distinct from that of the network destination listed in the same routing table entry,

even when the network destination itself is within broadcast range of the router;

- interface: when a particular route (table entry) is applied to a packet, the interface value specified in that route determines which local network interface is used to forward the packet to the next hop;
- metric: this column indicates the cost of using a route. If separate routes (entries) match an IP packet's destination address equally, the metric is used to determine which route is applied. Lower metrics have precedence over higher metrics. However, you can use any algorithm to determine the metric if you are configuring a route manually.

2.2.2 Default route

Default routes are used to direct packets addressed to networks not explicitly listed in the routing table. Default routes are invaluable in topologies where learning all the more specific networks is not desirable or not feasible due to limited system resources such as memory and processing power.

If your network has only one gateway, use a default route to direct all traffic bound for remote networks through that gateway. The network address associated with the default route is 0.0.0.0.

2.2.3 Gateway

The gateway address the IP address of the external gateway through which data is sent to the destination address. The address must be the address of a gateway on a directly connected network. TCP/IP routes specify the next-hop in the path to a remote destination. That next-hop must be directly accessible to the local host; therefore, it must be on a directly connected network.

2.3 Static routing in Linux and IOS

Most hosts use static routing to configure their default route. Keeping static routing tables entries consistent on routers is tedious, even in networks with a small number of routers. Therefore, most routers run a routing protocol that automatically updates routing tables to reflect changes of the network topology. Static routing entries can be added, even if a router runs a routing protocol, however, static routes may interfere with the path calculation determined by a routing protocol.

When static routing entries are entered manually at a command line interface, they remain valid only until the operating system is rebooted. To ensure that static routing table entries remain valid after the operating system is rebooted, commands to add static routes must be written in a configuration file, such as the startup configuration file in IOS.

Certain routing table entries are automatically configured. For example, whenever a network interface is configured with an IP address, most operating systems automatically add a routing table entry for the IP network to which the interface is directly connected.

2.3.1 Enabling IP forwarding in Linux and IOS

On a Linux system, IP forwarding is enabled when the file */proc/sys/net/ipv4/ip_forward* contains a 1 and disabled when it contains a 0. Hence, enabling IP forwarding is done by writing a 1 in the file, for example, with the command:

```
PC1% echo “1” > /proc/sys/net/ipv4/ip_forward
```

IP forwarding is disabled with the command:

```
PC1% echo “0” > /proc/sys/net/ipv4/ip_forward
```

The command has an immediate effect, however, changes are not permanent, and are lost when the system is rebooted, the change is lost.

Modifying the IP forwarding state permanently requires changes to the configuration file */etc/sysctl.conf*. IP forwarding is enabled if the file contains a line *net.ipv4.ip_forward* = 1, and IP forwarding is disabled when the line does not exist or the file contains the line *net.ipv4.ip_forward = 0.* Changes to the configuration file */etc/sysctl.conf* take effect the next time when Linux is rebooted.

In IOS, IP forwarding is enabled/disabled with the global configuration command:

```
Router1(config)# ip routing
Router1(config)# no ip routing
```

Disabling IP forwarding also deletes IP related information, such as the routing tables.

2.3.2 Routing tables and static routing in Linux

Linux has a routing table and a routing cache. The routing table stores permanent routing entries, which are inserted through static or dynamic routing methods. The routing cache contains recently used routing entries. The purpose of the routing cache is to increase the efficiency of the routing table lookup. The Linux route cache is located in main memory. Before a router looks up the routing table it checks if the route can be found in the cache. If the entry is found no routing table lookup is necessary. If the entry is not found, then a routing table lookup occurs, and the result of the lookup is stored in the routing cache.

2.3.2.1 Linux routing tables

The routing table in Linux is displayed with `netstat –rn`. The output of the command is as follows:

```
% netstat –rn
```

Table 4.1 *Kernel IP routing table*

Dest.	Gateway	Genmask	Flags	MSS	Win	Irtt	If
10.0.1.4	0.0.0.0	255.255.255.255	UH	40	0	0	eth0
10.0.3.0	0.0.0.0	255.255.255.0	U	40	0	0	eth1
20.0.2.0	0.0.0.0	255.255.255.0	U	40	0	0	eth0
10.0.5.0	10.0.2.1	255.255.255.0	UG	40	0	0	eth0
127.0.0.0	0.0.0.0	255.0.0.0	UH	40	0	0	lo
0.0.0.0	10.0.3.1	0.0.0.0	UG	40	0	0	eth1

Each row shows a routing table entry. The first column contains the destination, which can be a network address or a host address. The third column (Genmask) provides the netmask for the destination address. Therefore, the destination addresses in this routing table are 10.0.1.4/32, 10.0.1.0/24, 10.0.2.0/24, 127.0.0.0/8, and 0.0.0.0/0. Destination 127.0.0.0/24 is the entry for the loopback, and 0.0.0.0 indicates the default route (the default route can be interpreted as prefix of length 0 with IP address 0.0.0.0/0.).

The second column (Gateway) identifies the next hop router, and the last column (Iface) identifies the network interface where packets with matching entries are sent. Entries that are set to 0.0.0.0 or * in the second column indicate that the destination address is directly reachable. In the shown table, there are two IP directly connected networks: 10.0.2.0/24 via interface eth0, and 10.0.3.0/24 via interface eth1.

The Flags qualify the type of route: G indicates that the next hop is a gateway, H indicates a host route, U indicates that the interface to be used is enabled. The columns MSS, Window, and irtt are parameters used by TCP, and indicate respectively, the maximum segment size, the advertised window, and initial round-trip time for TCP connections over this link. A value of 0 in these columns means that the default values are used.

When a Linux system performs a routing table lookup, it first inspects the routing cache. If no matching entry is found in the cache, Linux performs a lookup in the routing table. After each routing table lookup, an entry is added to the routing cache. The routing cache does not aggregate table entries, and there is a separate entry for each destination IP address. As a consequence, a lookup in the routing cache does not require a longest prefix match. An entry in the routing cache is deleted if it has not been used for some time, usually after 10 minutes. When an ICMP redirect message arrives, an entry is added to the routing cache, but no update is performed to the routing table.

The entries in the routing cache can be viewed by issuing the command:

```
route –Cn
```

Note that the entries of the routing cache do not use prefixes or netmasks. There is one entry for each destination IP address. In addition to the destination and gateway columns, the route cache has entries for the source address. In the column with name Flags, the letter "*i*" indicates that the source IP address is directly reachable from this system and the letter "*l*" indicates that the destination address is that of the local system. The column Metric displays link metric which can be used as a cost measure for a routing protocol. The metric value for a directly connected network is 0. The column Ref refers to the number of references made to the route. The column Use indicates the number of packets using the path and Iface identifies the network interface where a packet with a matching entry is sent.

2.3.2.2 Configuring static routing in Linux

Configuring static routing in Linux can be done with the command route, which has numerous options for viewing, adding, deleting or modifying routing entries. The various uses of the route command are summarized below. Then, static routes are set each time Linux is booted up.

Commands for configuring static routing

`route –e =` displays the current routing table with extended fields. The command is identical to the *netstat -r* command

`route –Cn =` displays the routing table cache

`route add –net` *`netaddr`* `netmask` *`mask`* `gw g`*`w_address`* `=` adds a routing table entry for the network prefix identified by IP address *netaddr* and netmask *mas*k. The next hop is identified by IP address *gw_address* or by interface *ifac*e

`route add –net` *`netaddr`* `netmask` *`mask`* `dev` *`iface`* `=` adds a host route entry for IP address *hostaddr* with next hop identified by IP address *gw_addr* or by interface *ifac*e

`route add default gw` *`gw_add`* `=` sets the default route to IP address *gw_addr*

`route del –net` *`netaddr`* `netmask` *`mask`* `gw` *`gw_addr`*
`route del –host` *`hostaddr`* `gw` *`gw_addr`*
`route del default gw` *`gw_addr`* `=` deletes an existing route from the routing table. It is not necessary to type all arguments. If enough arguments are provided so that it can be matched with an existing routing entry, the first entry that matches the given arguments is deleted.

There is no simple way to delete all entries in the routing table. One method to flush the routing table is to disable the interface and then enable the interface, as in: `PC1% ifconfig eth0 down up.`

Note: when the commands are issued interactively in a Linux Shell, the added entries are valid until Linux is rebooted. To make static routes permanent, the routes need to be entered in the configuration file */etc/sysconfig/static-route*s, which is read each time Linux is started.

2.3.3 Routing Tables and Static Routing in IOS

2.3.3.1 IOS Routing Tables

The command to display the routing table in IOS is *show ip route*.

```
router1#show ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M -
mobile, B – BGP
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter
area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type
2
E1 - OSPF external type 1, E2 - OSPF external type 2, E – EGP
i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS
inter area
* - candidate default, U - per-user static route, o – ODR
P - periodic downloaded static route
Gateway of last resort is 10.0.2.2 to network 0.0.0.0
10.0.0.0/24 is subnetted, 2 subnets
C 10.0.1.0 is directly connected, FastEthernet0/1
C 10.0.2.0 is directly connected, FastEthernet0/0
S* 0.0.0.0/0 [1/0] via 10.0.2.2
```

The first lines explain the abbreviations that indicate how a routing table entry was created. The abbreviations are printed in the first column of the routing table. The routing table has entries for two subnets, 10.0.1.0/24 and 10.0.2.0/24. As indicated by the letter *C* in the first column, both entries are for a directly connected network. For directly connected networks, IOS displays the name of the interface as next hop information. The last entry is labeled as a default route *(S)* and as the default route *(*)*. As in Linux, the default route is listed with a network prefix of 0.0.0.0/0. The next hop of the entry is the IP address 10.0.2.2. In IOS the default gateway is called gateway of last resort.

The values [1/0] in the last routing table entry are the administrative distance and the metric of the entry. The administrative distance plays a role when a router runs multiple routing protocols. Since it may happen that there are multiple routing table entries for the same destination, the administrative distance determines the preference of the routing table selection. A lower distance indicates a higher priority. The administrative distance is a configurable parameter. The second value in the tuple [1/0] is the metric. Routing protocols use the metric for shortest path calculations.

For static routes, the metric has no meaning, and IOS assigns static routes the metric 0.

The routing cache on the route processor is displayed with the following command:

```
router#1 show ip cache
```

Note that, different from the route cache in Linux, IOS stores network prefixes in the cache.

2.3.3.2 Configuring Static Routing in IOS

The command used to add a static route to a routing table is:

```
ip route [destination_network ][mask ][next_hop_address or
exitinterface ] [administrative_distance ][permanent ]
```

Table 4.1 *Commands to add a static route to a routing table*

Command	Explanation
ip route	the command used to create the static route
mask	indicates the subnet mask being used on the network
destination network	the network you are placing in the routing table
next hop address	the address of the next hop router that will receive the packet and forward it to the remote network. This is a router interface that is on a directly connected network. You must be able to ping the router interface before you add the route
`exit interface`	used in place of the next hop address if desired. Must be on a point-to-point link, such as a WAN. This command does not work on a LAN; for example, Ethernet
`administrative distance`	by default, static routes have an administrative distance of 1. You can change the default value by adding an administrative weight at the end of the command
`permanent`	if the interface is shut down or the router cannot communicate to the next hop router, the route is automatically discarded from the routing table

After the router is configured, you can type `show running-config` and `show ip route` to see the static routes.

3. Lab activity

You will learn how to configure static routing. For this, we will use the configuration in figure 4.1.

3.1 Configure the computers with the IPs provided.
3.2 Configure the routers' interfaces using the computers as consoles. Do not forget the clock rate.
3.3 Configure a static route between Router1 and Router2.
3.4. Verify that the `ping` works between Computer1 and Computer2. Also, execute `traceroute –d ip_adress` to visualize the route.

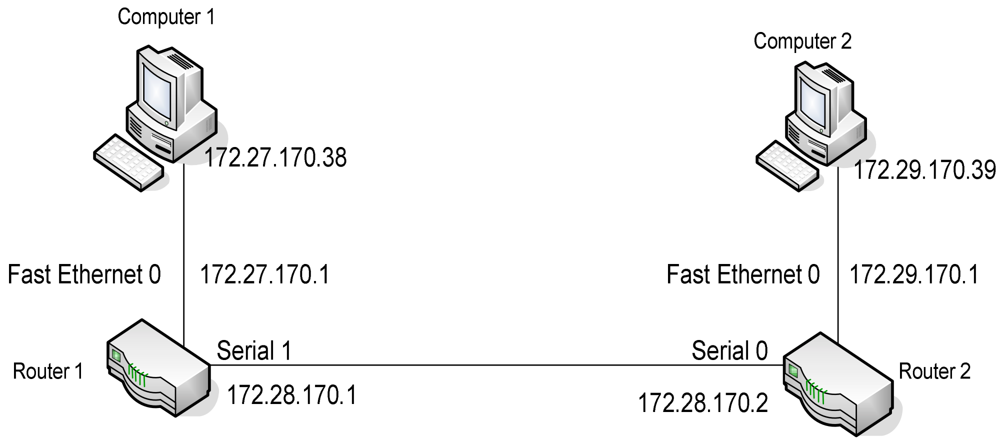

Figure 4.1 *Lab configuration*

Instead of two routers you can use two Linux machines (Figure 4.2).
3.5 Configure the interfaces with the addresses provided.
3.6 Configure the IP forwarding on the machines that are acting as routers.
3.7 Verify that `ping` works between eth0 of Computer1 and eth0 of Computer3. Interfaces on different subnets cannot be reached. Why?
3.8 Inspect the routing table from Computer1 and Computer3. What do you observe?

3.9 Configure the routing table on Computer1 in order to solve the problem from 3.7
3.10 Verify that the `ping` works between eth0 of Computer1 and eth1 of Computer3.
3.11 Verify if the `ping` works between eth0 of Computer1 and eth1 of Computer4. Interfaces on Computer4 are reachable? Can you say why?
3.12 Inspect the routing table on Computer4. What do you observe?
3.13 Do the proper static routes on Computer4 so that we can reach Computer2 from Computer1.
3.14 Verify that `ping` works between Computer1 and Computer2. Also, execute `traceroute –d ip_adress` to visualize the route.

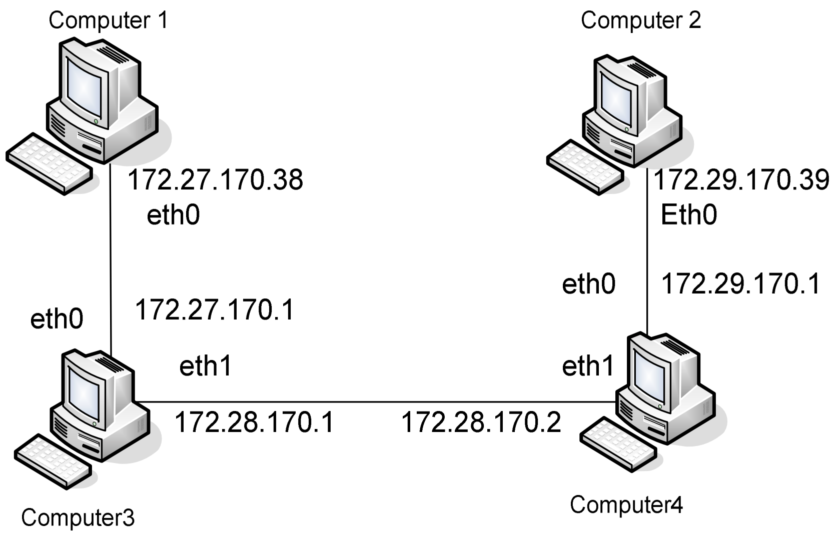

Figure 4.2 *Lab configuration*

Notes