

Exercise 1. Router R_1 receives an IP Packet which Destination IP (IP_D) is 192.168.3.222. What is the next-hop selected by the router when forwarding that IP packet? You must apply the Longest Prefix Matching algorithm. Review the concepts and structures explained in the lecture about IP forwarding/LPM.

The IP forwarding algorithm is known as Longest Prefix Matching. This algorithm looks up the Destination IP (IP_D) of each received IP packet in the Forwarding Table and finishes when it has determined the longest of the prefixes from the Forwarding Table matching the given IP_D .

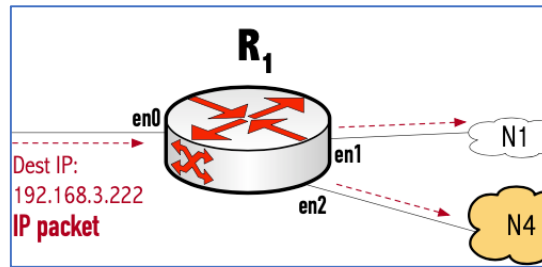


Figure 2. Router R_1 for exercise about LPM

Forwarding Table of Router R1

Net diagram label	Network Prefix Number	Next-Hop	Interface
N_1	192.168.4.0/24	Direct	en1
N_4	192.168.3.0/24	Direct	en2
default	0.0.0.0 ¹	192.168.4.2	en1

The IP_D matches a Forwarding Table (FT) entry if it belongs to the IP Block represented by the entry. Suppose an FT entry (An IP block) has a CIDR prefix /n, then if IP_D belongs to the IP block, then computing (IP_D & MASK) should yield the IP Block's Network number. In conclusion, we attain a match if the following predicate is true:

$$(IP_D \& \text{MASK of FT entry}) == \text{Network Number of FT entry}$$

Let's check whether IP_D matches the first entry from the FT. The first entry's CIDR prefix is /24, consequently its network mask is composed of a block of 24 bits 1 concatenated to a block of 8 bits 0:

CIDR Prefix contained in entry N_1 from FT = /24 \equiv netmask 255.255.255.0

Now, we apply that netmask to IP_D :

¹ Check the special significance of IP address 0.0.0.0 in RFC 4632. It may represent the *default route* in a FT.

$$\begin{array}{r} 192.168.003.222 \\ \& 255.255.255.000 \\ \hline 192.168.003.000 \end{array} \quad (i)$$

Normally, the FT entry should directly contain the IP Block's Network Prefix, nevertheless we should compute it:

$$\begin{array}{r} 192.168.004.000 \\ \& 255.255.255.000 \\ \hline 192.168.004.000 \end{array}$$

Since the results are not equal, we haven't obtained a match for entry #1.

We should proceed to entry N₄. The CIDR prefix to entry N₄ is equal to entry N₁'s which we obtained above in (i): /24, so we need not to calculate it again. The network prefix to entry N₄ is:

$$\begin{array}{r} 192.168.003.022 \\ \& 255.255.255.000 \\ \hline 192.168.003.000 \end{array}$$

In this case we have a **match** since the result of the last operation is equal to (i), the Network Prefix. The length of this match is the CIDR prefix, /24. In this simple case, we have finished since the FT contains no further entries, but the *default route*. The Longest Prefix Matching IP_D is 192.168.3.0/24, accordingly, R₁ forwards the IP onto the next-hop contained on the entry's next-hop column.

The next-hop column indicates *direct*, which means that the destination host is directly connected to network N₄. The packet forwarding should be done through interface en2. Since the FT indicates the route is *direct*, the router will encapsulate the IP packet into a new Ethernet frame sent to the *final receiving host*, which must be directly connected to network N₄, without any other IP router in between. The transmission of the reencapsulated IP packet happens per the processes and specifications that we developed in the lecture about IP and ARP.

The default router entry is used only when none of the remaining FT entries offers a match.

Exercise 2. Consider the same internetwork from Fig. 1. In this case, Router R₁ receives an IP Packet which Destination IP (IP_D) is 192.168.5.10. What is the next-hop selected by the router for forwarding that IP packet? Try to use Linux ipcalc utility for doing the calculations.