

5. Network Layer

5.1 Use of IP addresses

IP addresses and subnet masks are necessary to identify if the destination of a packet is within the own network or not.

5.2 IPv4 address

The IP address is a 32-bit number, thus there can be $4.294.967.296 = 2^{32}$ different IPv4-addresses. IPv4 = Internet Protocol version 4.

The IPv6-addresses are about to be implemented. IPv6 addresses are 128 bit numbers.

IPv4-addresses are usually written in 4 octets separated by dots. Each octet is often converted to a decimal number between 0 and 255.

Example:

1 octet = 8 bits = 1 byte

10101100	.	00010000	.	11111110	.	00000001
↓		↓		↓		↓
172	.	16	.	254	.	1

5.3 Subnet Mask

The IPv4-address is divided in two portions, the *network portion* and the *host portion*.

All hosts with the same network portion are forming one network which is the condition that the hosts can directly communicate between each other via hubs, switches or cross link cables. In one network no IP-address is allowed to appear twice.

For communications between two networks with different network portions a router (often also called gateway) is needed.

The *subnet mask* indicates which part of the IPv4-address forms the network portion and which part forms the host portion.

A subnet mask is a 32 bit number starting with a series of 1 followed by a series of 0.

Example:

	network portion	host portion
IPv4-address	10101100 . 00010000 . 10111	110 . 00000001
subnet mask	11111111 . 11111111 . 11111	000 . 00000000

5.4 CIDR syntax

The CIDR syntax (deut.: Schreibweise, franc.: notation) of an IPv4 address and its subnet mask is as follows:

192.168.0.34 / 24

The "/24" says that the first 24 bits of the IP address are forming the network portion. As a consequence the last 32-24=8 bits are forming the host portion.

5.5 Describing a network

There is a slight but important difference between the terms network portion and network address. *The network address* is the IP address of a network where all the bits of the host portion are 0. So the network address is the lowest possible IPv4 address in a network.

Example:

	network portion	host portion
a host address	10101100 . 00010000 . 10111	110 . 00000001
the subnet mask	11111111 . 11111111 . 11111	000 . 00000000
the network address	10101100 . 00010000 . 10111	000 . 00000000

network address = host address _____ subnet mask

To *describe a complete network* you write the network address and the subnet mask in CIDR syntax.

Example:

192.168.0.0 / 24 is describing the whole network with
the IP addresses 192.168.0.0 till 192.168.0.255

The first and the last IP-address in a network are always reserved and cannot be allocated to a host. The first IP-address (host portion=0) cannot be used as it corresponds to the network address. The last one is used for broadcast message. A broadcast message is a message addressed to all hosts on a network.

The default gateway is the router in the network that is responsible to treat all traffic to and from IP addresses that do not belong to the network of the host. So the default gateway needs to have an IP address of each network it belongs to.

Exercise 1:

Are the following host couples part of the same network? Justify your answer.

- a) 153.160.12.3/24 and 153.160.13.4/24
- b) 153.160.12.3/16 and 153.160.13.4/16
- c) 10.0.0.5/30 and 10.0.0.4/30
- d) 10.194.0.3 and 10.200.0.5 with subnet mask 255.192.0.0

Exercise 2:

How many hosts can be part of the following networks?

- a) 153.160.12.0/24
- b) 153.160.0.0/16
- c) 10.0.0.0/30
- d) 10.192.0.0/10

Exercise 3:

A host (172.16.50.53/16) wants to send a request for a web-page to the IP address 172.16.35.4. Does the request need to be forwarded to the default gateway? Justify your answer.

Exercise 4:

What is the logical condition that has to be checked between the 32 bits of the hosts IPv4 address IP-HOST, the 32 bits of the subnet mask MASK and the 32 bits of the destination IPv4 address IP-DEST in order to determine if the packet needs to be forwarded to the default gateway or not?

Exercise 5:

Suggest a network to which you can connect at least 1000 hosts without wasting unnecessarily IP addresses.

5.6 Private IP-addresses and NAT

No IP-address is allowed to appear twice in the Internet. That's why every IP-address has to be reserved at the IANA (Internet Assigned Numbers Authority). For local networks this approach is not practical. In addition the number of available IPv4-addresses is insufficient for all the hosts in use today.

The solution for both problems is "private IP-addresses". These are ranges of addresses that can be freely used within private networks and that are not allowed to be used in the public internet.

Three ranges of private IPv4-addresses have been defined. These ranges can of course be split into subnets.

1. 10.0.0.0/8
2. 172.16.0.0/12
3. 192.168.0.0/16

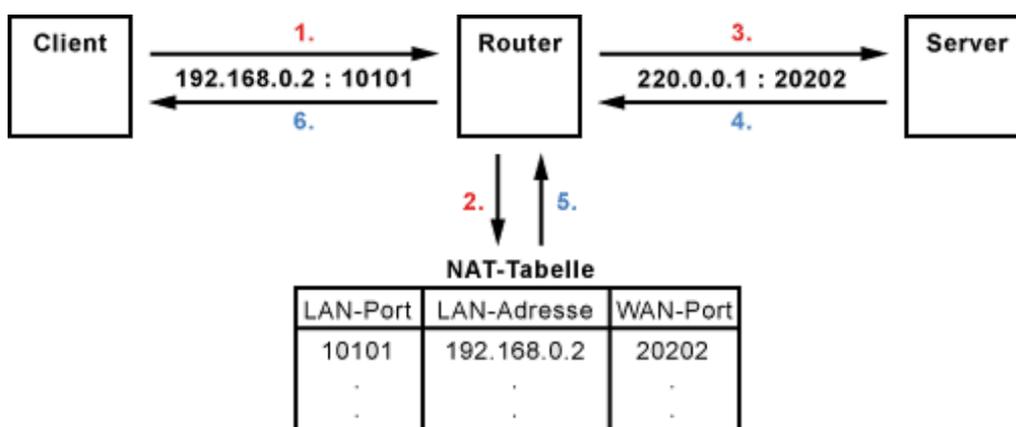
Exercise 6:

Determine the lowest and highest IPv4-address of every private IPv4-address range as well as the total number of IPv4-addresses in every range.

Exercise 7:

- How many /24 networks can be formed within the 3rd range of private IPv4-addresses?
- How many /16 networks can be formed within the 3rd range of private IPv4-addresses?
- How many /16 networks can be formed within the 2cd range of private IPv4-addresses?
- How many /24 networks can be formed within the 2cd range of private IPv4-addresses?
- How many /8 networks can be formed within the 1st range of private IPv4-addresses?
- How many /16 networks can be formed within the 1st range of private IPv4-addresses?
- How many /24 networks can be formed within the 1st range of private IPv4-addresses?

As private IP-addresses are not allowed to appear in the header of whatever packet in the public Internet, a special technique has to be applied to exchange the private "in house" IP-addresses by the unique public IP-address of the default gateway once the packet is leaving the private network. This technique is called NAT (network address translation) or PAT (port address translation).

How NAT works:

5.8 Socket & netstat-command

The combination of a port number and an IP address is called a socket. A socket uniquely identifies a particular process running on a specific host.

Example:

192.168.0.23:80 identifies the webserver software on the host with the IPv4 address 192.168.0.23.

When an application wants to communicate with another host over the network it first has to ask the operating system to open a socket. This causes the operating system to assign a port number to the application and to register the socket-pair into the so called netstat table. The netstat table can be displayed with the netstat command.

Example:

```
C:\> netstat

TCP    192.168.99.5:59813    snt-re3-10d:http      ESTABLISHED
TCP    192.168.99.5:59940    db3wns2010710:https   ESTABLISHED
TCP    192.168.99.5:60936    design27:imap         ESTABLISHED
```

5.9 ipconfig command

With the ipconfig command you can question a host for its IP-addresses, subnet-masks and default gateway IP addresses of every network it is connected to.

Example:

```
C:\> ipconfig

Ethernet adapter Ethernet:

Connection-specific DNS Suffix:

Link-local IPv6 Address :    fe80::e000:727:696c:8bfb%17
IPv4 Address :              192.168.99.5
Subnet Mask :               255.255.255.0
Default Gateway :           192.168.99.19
```

If in addition to the IP addresses also the MAC addresses of the network cards are needed, then type `ipconfig /all`.

Example:

```
C:\> ipconfig /all
```

```
Ethernet adapter Ethernet:
```

```
Connection-specific DNS Suffix . :
```

```
Description : Realtek PCIe GBE Family Controller
```

```
Physical Address : 74-D4-35-B3-8E-E1
```

```
DHCP Enabled : No
```

```
Autoconfiguration Enabled : Yes
```

```
Link-local IPv6 Address fe80::e000:727:696c:8bfb%17 (Preferred)
```

```
IPv4 Address : 192.168.99.5 (Preferred)
```

```
Subnet : 255.255.255.0
```

```
Default : 192.168.99.19
```

```
DHCPv6 : 292869173
```

```
DHCPv6 Client DUID : 00-01-00-01-1B-CA-DD-C2-74-D4-35-B3-8E-E1
```

```
DNS Servers : 192.168.99.19
```

```
NetBIOS over Tcpiip : Enabled
```