- **Problem 2:**

  1. What are the protocol layers in the TCP/IP model and what are these in the OSI model?

     Answer: There are five layers in the TCP/IP model. The five layers from bottom to top are: physical layer, network access layer, internet layer, tranport layer and application layer.

     There are seven layers in the OSI model. The seven layers from bottom to top are: physical layer, data link layer, network layer, transport layer, session layer, presentation layer and application layer.

  2. To deliver an IP datagram from host A to host B connected in the same Ethernet, two approaches can be used. One approach is to use the Ethernet unicast. In this approach, the hardware address of B is used in the Ethernet data frame to deliver the message. The other approach is to use the Ethernet broadcast. In this approach, the Ethernet broadcast address $FF.FF.FF.FF.FF.FF_{16}$ is used in the data frame to deliver the message. Give the outlines of the two approaches. Compare the two approaches and give the pros and cons for each of them.

     Answer: In the unicast approach, A finds the hardware address of B based on B's IP address, encapsulates the datagram in an Ethernet data frame with B's hardware address as the destination address, and sends the data frame to the Ethernet. The data frame is broadcasted in the Ethernet. The network interface card (NIC) of B will pick up the data frame and forward it to IP at B. NIC at hosts other than B will ignore the data frame.

     In the broadcast approach, A encapsulates the datagram in an Ethernet data frame with the broadcast address as the destination address. The data frame is broadcasted in the Ethernet. NIC of every host will pick up the data frame and forward it to the host's IP.

     Pros of unicast approach: the data frame will be forwarded to IP only at the destination, hosts other than the destination are not bothered. Cons of unicast approach: need to find the hardware address of the destination, may cause extra traffic.

     Pros of broadcast approach: the hardware address of the destination is not ndded. Cons of the broadcast approach: the data frame will be forwarded to IP at every host, causing extra workload at every host.

  3. Two Ethernets N_1 and N_2 are connected by two bridges B_1 and B_2 as shown in Figure 1. Host A connected to N_1 sends a data frame to Host B connected to N_2. What problem can happen when the data frame is forwarded to B? How to solve this problem? (Hint: spanning tree topology for LANs connected by bridges).

     Answer: Disconnect one connection of a bridge to a network, for example the connection of B_2 to network N_2, to make the network topology a spanning tree.

  4. The IPv4 address of a subnet is defined as `145.180.3.0/24`. How many IP addresses in this subnet can be used for hosts? What is the IP address for the

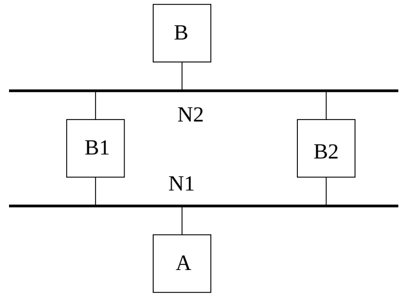

Figure 1: Ethernets connected by bridges.

directed broadcast in this subnet?

Answer: There are $2^{32-24} = 256$ IP addresses in the subnet defined by `145.180.3.0/24`. Excluding all 0 and all 1 in the hostid, 254 addresses can be used for hosts. The IP address for the directed broadcast in this subnet is `145.180.3.255`.

5. An organization is granted a block of IPv4 addresses specified by `172.16.0.0/21`. Design a scheme for using this block of addresses for 5 networks, each of them has 200 hosts, and 5 small networks, each of them has 25 hosts.

   Hint: You need to design multiple network masks to partition the entire block into sub-blocks of different sizes.

   Answer: The net mask for the given block is `255.255.248.0` and has length $n = 21$. The first subnet mask partitions the block into $2^k = 8$, $k = 3$, sub-blocks, each has $2^{32-(n+k)} = 2^8 = 256$ IP addresses. This subnet mask is `255.255.255.0` and has length $n + k = 24$. Five sub-blocks (e.g., the sub-blocks defined by `172.16.1.0/24`, `172.16.2.0/24`, `172.16.3.0/24`, `172.16.4.0/24`, `172.16.5.0/24`) can be used for the five physical networks with 200 hosts. The second subnet mask `255.255.255.224` has length $24 + 3 = 27$ and partitions one of the rest sub-blocks (e.g., the sub-block defined by `172.16.6.0/24` into 8 sub-sub-blocks, each has $2^{32-27} = 2^5 = 32$ IP addresses. Five sub-sub-blocks (e.g., the sub-sub-blocks defined by `172.16.6.32/27`, `172.16.6.64/27`, `172.16.6.96/27`, `172.16.6.128/27`,`172.16.6.160/27`) can be used to for the five networks with 25 hosts.

6. There are four networks N_1, N_2, N_3, and N_4, with network addresses `215.10.1.0/24`, `144.10.0.0/16`, `125.0.0.0/20`, and `220.10.1.0/24`, respectively. Networks N_1 and N_2 are connected by Router R_1 with IP address `215.10.1.5` in N_1 and IP address `144.10.0.5` in N_2. Networks N_1 and N_3 are connected by Router R_2 with IP address `215.10.1.6` in N_1 and IP address `125.0.0.6` in N_3. Networks N_3 and N_4 are connected by Router R_3 with IP address `125.0.0.7` in N_3 and IP address `220.10.1.7` in N_4. Give a routing table (including the subnet mask) for Router R_1 and one for a host H in N_1.

   Assume that H sends a message to `144.10.0.9`. Which forwarding, directed or indirected, is used by R_1? Which forwarding is used by R_2 if H sends a message to 220.10.1.200?

Answer: Routing table for R_1:

Dest Address	Subnet Mask	Next Hop
215.10.1.0	255.255.255.0	*
144.10.0.0	255.255.0.0	*
125.0.0.0	255.255.240.0	215.10.1.6 (or R2)
220.10.1.0	225.225.225.0	215.10.1.6 (or R2)

or

Dest Address	Subnet Mask	Next Hop
215.10.1.0	255.255.255.0	*
144.10.0.0	255.255.0.0	*
default	0.0.0.0	215.10.1.6 (or R2)

Routing table for H

Dest Address	Subnet Mask	Next Hop
215.10.1.0	255.255.255.0	*
144.10.0.0	255.255.0.0	215.10.1.5 (or R1)
125.0.0.0	255.255.240.0	215.10.1.6 (or R2)
220.10.1.0	225.225.225.0	215.10.1.6 (or R2)

or

Dest Address	Subnet Mask	Next Hop
215.10.1.0	255.255.255.0	*
144.10.0.0	255.255.0.0	215.10.1.5 (or R1)
default	0.0.0.0	215.10.1.6 (or R2)

Direct forwarding by R_1 to 144.10.0.9.

Indirect forwarding by R_2 to 220.10.1.200.

7. Give a routing table for every router in Figure 8.2 of the text book. At which router a default route would reduce the routing table size?

   Answer:

   Routing table at router Q:

Dest Address	Network Mask	Next Hop Router
10.0.0.0/8	255.0.0.0	direct forwarding
20.0.0.0/8	255.0.0.0	direct forwarding
30.0.0.0/8	255.0.0.0	20.0.0.6 (or router R)
40.0.0.0/8	255.0.0.0	20.0.0.6 (or router R)

Routing table at router R:

Dest Address	Network Mask	Next Hop Router
10.0.0.0/8	255.0.0.0	20.0.0.5 (or router Q)

`20.0.0.0/8`	`255.0.0.0`	`direct forwarding`
`30.0.0.0/8`	`255.0.0.0`	`direct forwarding`
`40.0.0.0/8`	`255.0.0.0`	`30.0.0.7 (or router S)`

Routing table at router S:

Dest Address	Network Mask	Next Hop Router
`10.0.0.0/8`	`255.0.0.0`	`30.0.0.6 (or router R)`
`20.0.0.0/8`	`255.0.0.0`	`30.0.0.6 (or router R)`
`30.0.0.0/8`	`255.0.0.0`	`direct forwarding`
`40.0.0.0/8`	`255.0.0.0`	`direct forwarding`

At Routers Q and S, a default route will reduce the routing table size.

8. How many bits are used for an IPv6 address? Give the address format for the global unicast. Describe briefly how IPv6 supports autoconfiguration which allows a host to assign an IP address by itself.

   Answer: There are 128bits in an IPv6 address. An IPv6 global unicast address has the type prefix `001`, followed by a global site ID used to identified a site in the Internet, a subnet ID used to identify a subnet in the site and the low-order 64 bits host ID to identify an network connection in the subnet.

   A host can assign an IPv6 link local address by itself for communication within a same network. An IPv6 link local address for a network connection of a host has the type prefix `1111 1110 10` and the hardware address of the network connection in the low-order 64 bits.

9. Give the colon hex for the following IPv6 address without any zero compression:

```
0010 1000   1110 0110   0000 0000   0000 0000
0000 0000   0000 0000   0000 0000   0000 1011
0000 0000   0000 0000   0000 0000   0000 0000
0000 0000   0000 0000   0000 1100   0000 1111
```

   Applying the zero compression rules to simplify the colon hex address obtained above to a concise form.

   Answer: Colon hex address without zero compression,
   `24E6:0000:0000:000B:0000:0000:0000:0C0F`.

   Colon hex address after zero compression, `24E6:0:0:B::C0F`.

10. Give the IPv6 address in binary form for the following colon hex IPv6 address: `fdd0:8184:d967::c0a8:5`.

    Answer:

```
1111 1101   1101 0000   1000 0001   1000 0100
1101 1001   0110 0111   0000 0000   0000 0000
0000 0000   0000 0000   0000 0000   0000 0000
1100 0000   1010 1000   0000 0000   0000 0101
```

11. An IPv6 packet consists of the base header and a TCP segment. The length of the IPv6 data is 320 bytes. Draw the base header and and enter a value in the payload field and one in the next header field.
12. In the past, computer/communication networks were scaled proportional to the number of people who may use the networks. Now, this principle does not meet many new applications in computer/communication networks anymore. Assume that there are 7 billion people in the world now. How many IPv6 global unicast addresses each people can have in average? Would IPv6 allow us to scale computer/communication networks much larger than the population in the world?