- **Problem 1** (5 points) **Due on Feb. 2 (Friday), by 17:00**.

  The diagram of the virtual networks is posted at the homepage of this course. There is a gateway (`cs-vnl`), a file server (`seasons`) and 20 client hosts. Four of the clients (`December, January, February, March`) are configured as routers. The client hosts are connected to five networks: `admin (192.168.0.0/24), net16 (172.16.0.0/16), net17 (172.17.0.0/16), net18 (172.18.0.0/16)` and `net19 (172.19.0.0/16)`. Write a shell script to test the reachability of **every network connection** of **every client host** from **one specific client host**. You can use `ping`, `tracepath` or `traceroute` command for your test. Please refer to the online manual (`man`) to find how to use these commands. You need to complete the following tests:

  – Use host names as destinations.

    For a host with name `aaaa`, `aaaa` is used for the network connection of the host to network `admin` (`192.168.0.0/24`), and `aaaa.net`xx, $xx = 16, 17, 18, 19$, is used for the network connection of the host to network `net`xx. For example, `April` is used for the connection `192.168.0.4` and `April.net16` is used for the connection `172.16.1.4`. Network connections specified by `aaaa` and `aaaa.net`xx are different and you need to test the reachability for every network connection of every host. You need to get some unreachable messages (e.g., use a non-existing name as the destination) as well.

  – Use IPv4 addresses as destinations.

    You need to test the reachability for every IPv4 address. You need to to get some unreachable messages (e.g., use a non-existing IPv4 address as the destination) as well.

  – Use IPv6 addresses as destinations.

    You can use `tracepath6` or `ping6` for the test. Not all hosts support IPv6. You can do your test only on those hosts (on `net17`, `net18` and `net19`) supporting IPv6. You can use `ifconfig` command on a host A to find the IPv6 addresses assigned to each network connection of A and then test the reachability of a network connection X of A from another host B using the IPv6 address assigned to X. For example, network connection `may.net18` of host `may` is assigned two IPv6 ULA (unique local address) addresses
    `fdd0:8184:d967:18:250:56ff:fe85:d1d8/64` and
    `fdd0:8184:d967:8018:250:56ff:fe85:d1d8/64`.
    You may test the reachability of network connection `may.net18` from host `august` using each of two IPv6 addresses above as the destination.

    Network `net18` is assigned two subnet addresses `18` and `8018` in the IPv6 ULA addresses. Use `tracepath6` to observe the routing path for each of two IPv6 addresses above as the destination and report your observation.

    You only need to test the IPv6 address reachabilities for **one** network connection.

  – Find the Ethernet addresses of network connections.

You can use `arp` command to find the Ethernet address of a network connection in the same network connected to the host where you run your script. You need to find the Ethernet address of every network connection on a same network (any network of `net16`,`net17`,`net18`,`net19` is fine).

For each network connection which is reachable from a host `aaaa` (`aaaa.net`xx) with IP address `a.b.c.d` (source) where you run your script, you are asked to provide the information like the network connection with name `bbbb` (`bbbb.net`xx) or IP address `w.x.y.z` is reachable from host `aaaa` (`aaaa.net`xx) or IP address `a.b.c.d`. You should also provide the information on the routing path to reach the network connection. For each network connection in a same network, you need to provide the Ethernet address `XX:XX:XX:XX:XX:XX` of the network connection. For a host or an IP address `w.x.y.z` which is not reachable (e.g., a host or an IP address not in the networks, or an IP address in the networks but its corresponding network connection is shut down), your output should like host `bbbb` (`bbbb.net`xx) or IP address `w.x.y.z` is not reachable from host `aaaa` (`aaaa.net`xx) or `a.b.c.d`. You can use a non-existing hostname or IP address to get the unreachable information.

You need to use `for` or `while` statement to make your scripts concise and efficient. You may use these statements to generate the machine names and IPv4 addresses to scan the network connections (a major goal of this assignment is to learn how to write scripts). You need to limit the scan range of the IP addresses to make your program efficient. Enumerating all IP addresses line-by-line or using IP addresses from `/etc/hosts` file are not encouraged (points will be reduced).

I suggest you **do not** run scans outside the Networking Lab. Scanning a range of IP addresses may bring you to the attention of network administrators in a manner you may not want.

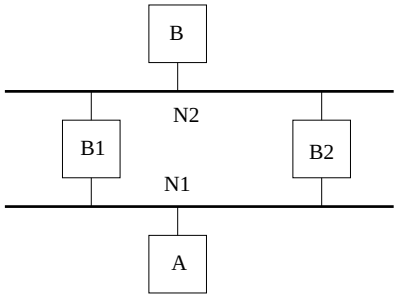
Your scripts must work in the virtual network. You need to submit your program to the directory `/assignment/1/yourid` in the gateway machine `cs-vnl` by the due time. Please have clear comments in your shell script to explain how it works.

- **Problem 2:** (0 points) Solving the following problems will help you to understand the materials we have discussed. You do not need to submit your answers. Answers for the questions will be provided and explained before the midterm test. Please ask if you have any question.

  1. What are the protocol layers in the TCP/IP model and what are these in the OSI model?
  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 as the destination address in the Ethernet data frame. The other approach is to use the Ethernet broadcast. In this approach, the Ethernet broadcast address $FF.FF.FF.FF.FF.FF$ is used as the

destination address in the data frame. Give the outlines of the two approaches. Compare the two approaches and give the pros and cons for each of them.

3. Two Ethernets N_1 and N_2 are connected by two bridges B_1 and B_2 as shown in Figure 3. 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).



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 this subnet? What is the IP address for the directed broadcast in this subnet?

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.

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`?

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?

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.

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.

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