Problem 2:

1. Find the IPv6 ULA address and the link local address assigned to interface `eth0` of machine `may` in the VNL. Each of the IPv6 addresses can be partitioned into two parts: part I for identifying network `admin` and part II for identifying interface `eth0`. Give the uncompressed hexadecimal notations for part I and part II of the ULA address and link local address.

   Answer: ULA address: `fdd0:8184:d967::c0a8:5/64`; part I, `fdd0:8184:d967:0000`; part II, `0000:0000:c0a8:0005`.

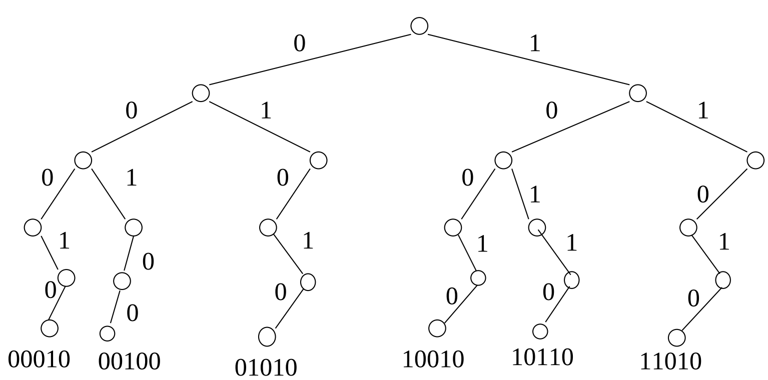
   Link local address: `fe80::250:56ff:fe85:4264/64`; part I, `fe80:0000:0000:0000`; part II, `0250:56ff:fe85:4264`.

2. Find the Ethernet address assigned to `eth0` of machine `may`. Is the Ethernet address embedded in part II of the IPv6 ULA address for `eth0` of `may`? Is the Ethernet address embedded in part II of the IPv6 link local address for `eth0` of `may`? If your answer is yes for one of the above questions, explain how the Ethernet address is embedded.

   Answer: Ethernet address: `00:50:56:85:42:64`. The Ethernet address is not embedded in part II of the ULA address but is embedded in part II of the link local address. Let $c_1c_2c_3c_4c_5c_6$ be the 6 bytes of an Ethernet address and $d_1d_2d_3d_4d_5d_6d_7d_8$ be the 8 bytes for a host id (part II) of an IPv6 address. The Ethernet address is embedded in part II as follows: $c_1c_2c_3$ are maped to $d_1d_2d_3$ with the global/local bit (the 2nd least significant bit in c_1) set to 1, d_4 is set to `1111 1111` (`ff`), d_5 is set to `1111 1110` (`fe`) and $c_4c_5c_6$ are mapped to $d_6d_7d_8$. So Ethernet address `00:50:56:85:42:64` are embedded as `02:50:56:ff:fe:85:42:64` (`0250:56ff:fe85:4246` in hexadecimal for IPv6).

3. Binary trie is a data structure used for efficient address lookup at a routing table. Assume that a routing table has the following network addresses: `00010`, `10010`, `00100`, `01010`, `11010`, and `10110`. Draw a binary trie for looking up the network addresses in this routing table.

   Answer:



4. Assume that an IPv4 datagram D with 1120 bytes of data is fragmented at a router into two datagrams, D_1 with the 1st 640 bytes of the data in D and D_2 with the rest data. Let M_1 and M_2 be the *the more fragment bits* in the IP headers of D_1 and D_2, respectively. Let Off_1 and Off_2 be *the fragmentation offsets* in the IP headers of D_1 and D_2, respectively. Give the values of M_1, M_2, Off_1, Off_2.

   Answer: $M_1 = 1$, $M_2 = 0$, $Off_1 = 0$, $Off_2 = 80$.

5. Describe briefly how ARP works and give the ARP message format.

   Answer: To find the hardware address for an IP address IP_A, ARP first checks ARP cache. If the hardware address can not be found from the cache, ARP sends an ARP request with IP_A as the destination address to the physical network by broadcast. All hosts in the network will receive this request and the host with IP address IP_A will send an ARP reply message with its hardware address to the requester by unicast. Other hosts will ignore the ARP request.

6. Assume that networks N_1 and N_2 are connected by router R which performs Proxy ARP to allow N_1 and N_2 to use a same network address. Describe how a host A connected to network N_1 sends a datagram to a host B connected to network N_2 via Proxy ARP.

   Answer: Let D be an IP datagram with B's IP address IP_B as the destination address. Because the `netid` of IP_B is the same as that of the IP address for N_1, A uses the direct forwarding to deliver D: sending an ARP request with IP_B as the destination address to N_1 to find the hardware address for IP_B; router R receives the ARP request and replies A with the hardware address of R; A sends a network data frame with R's hardware address as the destination to N_1; R receives this data frame and forwards the data frame to B in N_2.

7. Company A has a naming hierarchy `xxxx.A.com` and Company B has a naming hierarchy `yyyy.B.com`. The names `xxxx` and `yyyy` are given independently (i.e., a popular name can be used in both `xxxx` and `yyyy`. Now B becomes part of A. Give a naming hierachy for all machines in A and B without changing `xxxx` nor `yyyy`.

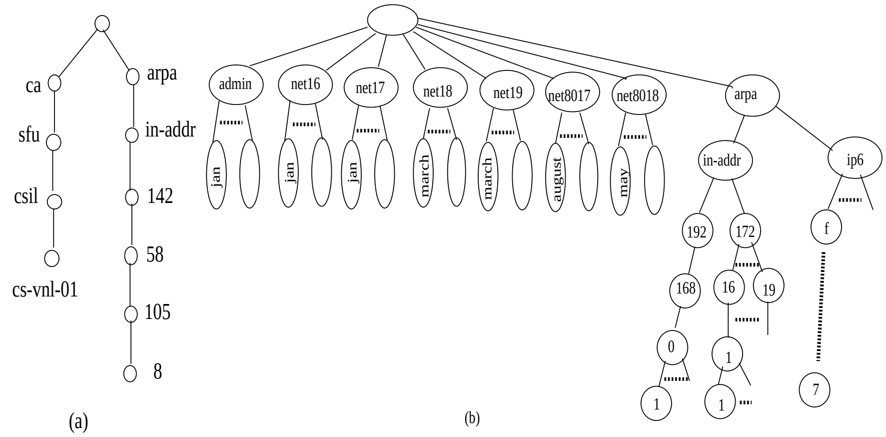
   Answer: One solution for the problem is to give each machine with name `yyyy.B.com` a new name `yyyy.B.A.com`.

8. Find the global IP address of a gateway to the virtual network lab. Draw the subtrees of the tree that define the full domain name and the inverse domain name for the gateway.

   In the virtual networks, `seasons` is the only machine that runs DNS server. The DNS server related files can be found at `/etc/bind/` at `seasons`. Study these files and give the tree which defines the hierarchical domain space and machine names connected to networks `admin, net16, net17, net18, net19`.

   Answer:

9. TCP uses positive acknowledgment and retransmission for reliable transmissions. Does a lost data segment always cause a retransmission? Does a lost ACK message always cause a retransmission? Explain briefly your answers.



Answer: A lost data segment always cause retransmission.

A lost ACK message may and may not cause re-transmission. TCP uses accumulative ACK. In the following example, a source does not perform retransmission: The destination sends ACK(x) with ACK number x and ACK(y) with ACK number y, $x < y$. ACK(x) gets lost but the source receives ACK(y) before the retransmission timer for the segment containing the byte with sequence number $x - 1$.

10. TCP uses 32 bits for data stream sequence numbers. How does this allow a stream of arbitrary length transmitted? How many bytes can a stream have if each byte in the stream must be assigned a distinct sequence number?

    Answer: Use the sequence numbers in a cyclic way: $0, 1, ..., 2^{32} - 1, 0, 1, ...$

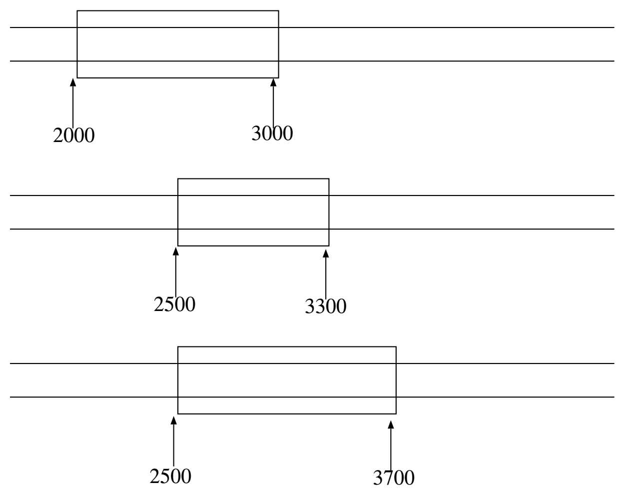
    2^{32} bytes.

11. Assume that both the sender and the receiver in a TCP connection has a window size of k bytes. What is the minimum number of distinct sequence numbers for the stream in the TCP connection such that every byte in the stream can be uniquely identified at both sides?

    Answer: k bytes.

12. The sender in a TCP connection is using a window size of 1000 and the previous ACK number is 2000. Now the sender receives a segment with ACK number 2500 and window size 800. Show the changes of the sender's window by figures. Show the changes of the window if the window size in the received ACK segment is 1200.

    Answer: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