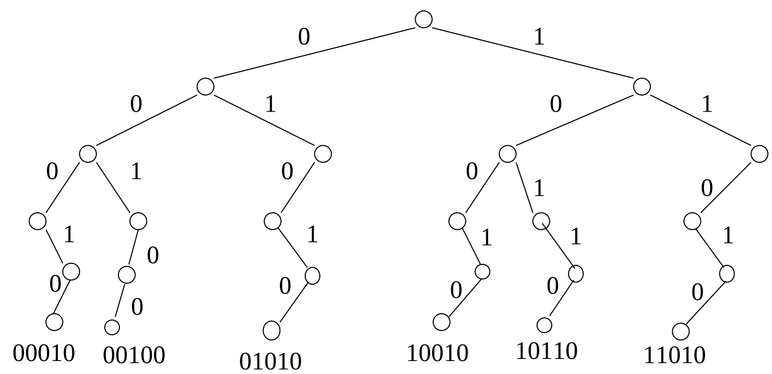
Problem 2:

1. 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: See Figure 1.



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

3. 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.

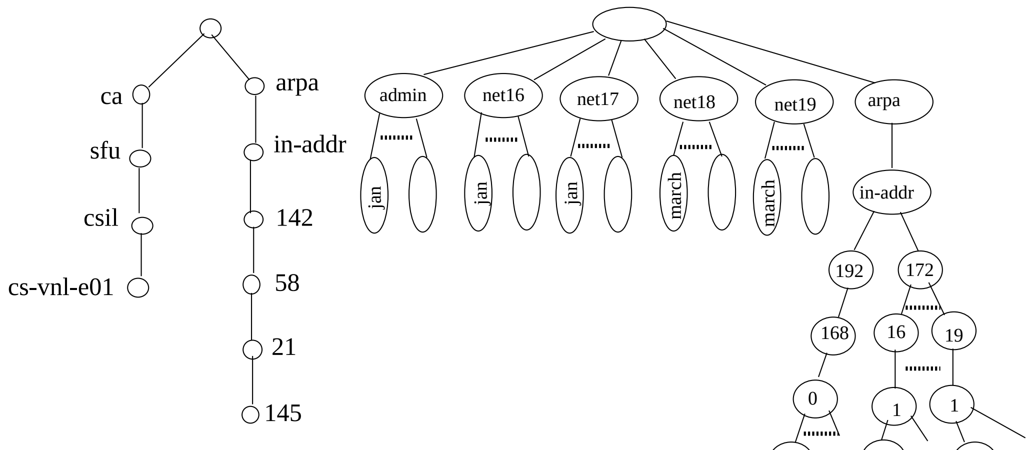
4. Assume that networks N_1 and N_2 are connected by router R which performs Proxy ARP to allow N_1 and N_2 to use a same network address. Describe how a host A connected to network N_1 sends a datagram to a host B connected to network N_2 via Proxy ARP.

   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.

5. In the domain name space, the names of machines are defined in a tree structure with the `root` at the top. Each node in the tree is assigned a label called domain name. A machine's full domain name is a sequence of domain names from a leaf node to a child of the `root` deparated by dot. 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.

   Answer:

   See Figure 5 (a).



(a) (b)

6. 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 `net16, net17, net18, net19`.

   Does the DNS server provides name to IPv6 address service? Verify your answer by a test in the vertual networks.

   Answer: No, the DNS server does not provide name to IPv6 address service. If you use a machine name as the destination in an IPv6 command such as ping6, you will get an error message "unknown host".

   Figure 5 (b) gives the domain space.

7. 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 $x - 1$.

8. 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.

9. 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.

10. 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: