1. Hardware based IP address lookup can be realised using two level multibit stride. Consider a system where 1st level stride is 24-bit and 2nd level is 8-bit (slide 10-65).

   (a) Suppose that we are using DRAM devices having 85 ns random access time to implement the address lookup system. The system is pipelined and thus one lookup operation is completed at each memory cycle on the average. What is the throughput of a router using this system in worst case conditions? (Hint: under which conditions the arrival rate of IP datagrams is highest for an arbitrary bitrate?)

   (b) The performance requirements are relaxed so that the average IP datagram length of 200 octets can be used to derive the performance requirements. How many 1 Gbit/s Ethernet interfaces can supported? (NB: GbE ports operate in full-duplex mode, so neither carrier extension nor burst mode is used).

2. Consider the same system as in previous task.

   (a) How many memory accesses are required to 1st level memory to update 8, 16, and 24 bit IP address prefixes?

   (b) Let's suppose that an average prefix update mix contains 10% 8-bit, 30% 16-bit, and 60% 24-bit prefix updates. At what prexif update rates the number of memory accessess caused by updates exceeds that of normal address lookups?

   (c) At which update rate the system saturates, i.e., consumes all resources for prefix updates?

3. Consider a two node FT-FR broadcast and select network that uses fixed-frame scheduling to allocate the network capasity. The traffic matrix is

$$\Gamma = \begin{bmatrix} 1 & \pi \\ 1 & 1 \end{bmatrix}$$

   where $\gamma_{i,j}$ denotes the traffic intensty from i to j. Minimum number of time slots neccessary to create a collisionless schedule is

$$L_{min} = \max_{ij} \left(\left\lceil \frac{\bar{T}}{C} \right\rceil, \left\lceil \frac{\mathcal{T}_i'}{\alpha_i} \right\rceil, \left\lceil \frac{\mathcal{R}_j'}{\beta_i} \right\rceil \right),$$

   where $\bar{T}$ is the total amount of traffic, C the number of channels, $\mathcal{T}_i'$ traffic send by node i, α_i the number of transmitters in node i, $\mathcal{R}_j'$ traffic received by node j and β_j the number of receivers in node j.

   The number of required time-slots for each traffic flow can be found out by decomposing Γ to a scalar part and to a matrix where elements are relative prime numbers. If any $\gamma_{i,j}$ is not a rational number, such element has to be approximated by a suitable rational number $\gamma_{i,j}' > \gamma_{i,j}$

   Approximate π by 22/7 and determine the minimum frame length L_{min} for perfect scheduling. How much capasity is wasted?

4. Consider an optical network using fixed-frame scheduling for packet traffic. The traffic load from station i to j is 0.5, the frame length $L = 100$, frame time $F = 125\,\mu$s and there is one time slot allocated for $i \rightarrow j$ traffic. Determine the fiber distance at which the propagation delay in fiber equals the average system delay $\bar{D}$. Take the speed of light in the fiber to be $2 \cdot 10^8$ m/s.

   You may assume that the arrival process is a Poisson process and that the average waiting time in the queue is given by

$$\left(\frac{\rho}{2\mu}\right)\left(\frac{1}{1-\rho}\right)$$

   where ρ is traffic intensity and μ is service rate.

5. In broadcast and select network (i.e., broadcast star) capacity can be allocated dynamically. The efficiency of channel allocations depends on the structure of the nodes and the allocation scheme that is used. Consider a 4-node FT-TT network with fixed frame length. The queue in each node contain 4 frames which are:

   - Node 1 – $[1,2]_1, [1,3]_1, [1,2]_2, [1,3]_2$
   - Node 2 – $[2,4]_1, [2,3]_1, [2,4]_2, [2,4]_3$
   - Node 3 – $[3,1]_1, [3,4]_1, [3,1]_2, [3,3]_1$
   - Node 4 – $[4,1]_1, [4,2]_1, [4,1]_2, [4,3]_1$

   (in the shown order). Find out the schedules for

   (a) Tell-and-go capacity allocation; when a node has something to send, i.e., queue is non-empty, it first send a message (through a separate signalling channel) to all destination stations and then, without waiting a reply, it sends the frame in first free slot. If there is more than one frame destined to a particular destination station at the same time slot, it can tune only to a single wavelenght and receive a single frame. How many frames are lost?

   (b) Lossless scheduling; conflicts are avoided by using reservations, i.e., only one source can send a frame to a particular destination in each time slot. The First Come First Served (FCFS) queue dicipiline is maintained, i.e., the frames have to be sent in order.

   (c) Perfect scheduling; FCFS is not maintained but there is one queue for each destination in each source station and the frames can be sent out of order.