ECEN 621 - HW#3: Please answer the following questions:

1) **Differentiate between LAN and WAN.**
   - Scope of a LAN is smaller
     - LAN interconnects devices within a single building or cluster of buildings
   - LAN usually owned by organization that owns the attached devices
     - For WANs, most of network assets are not owned by same organization
   - Internal data rate of LAN is much greater

2) **What’s the principal application that has driven the design of circuit-switching networks?**
   Real-time services

3) **Explain the differences between datagram-based and virtual-circuit based networks.**
   **Datagram-based:**
   - Each packet treated independently, without reference to previous packets
   - Each node chooses next node on packet’s path
   - Packets don’t necessarily follow same route and may arrive out of sequence
   - Exit node restores packets to original order
   - Responsibility of exit node or destination to detect loss of packet and how to recover
   **Virtual-circuit based**
   - Preplanned route established before packets sent
   - All packets between source and destination follow this route
   - Routing decision not required by nodes for each packet
   - Emulates a circuit in a circuit switching network but is not a dedicated path
   - Packets still buffered at each node and queued for output over a line

4) **What are the disadvantages of using a circuit-switching based network for data transmissions?**
   - Utilization not 100%
   - Delay prior to signal transfer for establishment

5) **Please categorize ATM services.**
   - Real-time service
     - Constant bit rate (CBR)
     - Real-time variable bit rate (rt-VBR)
   - Non-real-time service
     - Non-real-time variable bit rate (nrt-VBR)
6) Explain the flaw in the following reasoning: Packet switching requires control and address bits to be added to each packet. This introduces considerable overhead in packet switching. In circuit switching, a transparent circuit is established. No extra bits are needed. Thus, there is no overhead in circuit switching, and, because there is no overhead in circuit switching, line utilization must be more efficient than in packet switching networks.

The circuit switch still needs overhead to build the connections. Also, the bandwidth occupation will not change once the connections have been built, thus often leading to utilization of the assigned bandwidth not equal to 100%, especially for variable rate services. In addition, there is delay prior to signal transfer for establishment. All the above factors may cause inefficiency as compared to packet switching networks.

7) One key design decision for ATM network was whether to use fixed-or variable-length cells. Let us consider this decision from the point of view of efficiency. We can define transmission efficiency as:

\[ N = \frac{\text{Number of information bytes}}{\text{Number of information bytes + Number of overhead bytes}} \]

a). Consider the use of fixed length packets. In this case, the overhead consists of the header bytes. Define:

- \( L \) = Data field size of the cell in bytes
- \( H \) = Header size of the cell in bytes
- \( X \) = Number of information bytes to be transmitted as a single message

Derive an expression for \( N \). Hint: The expression will need to use the operator of \([X]\) which is taking the smallest integer greater than or equal to \( X \).

b) If cells have variable length, then overhead is determined by the header plus the flags to delimit the cells or an additional length field in the header. Let \( H_v \) = additional overhead bytes required to enable the use of variable-length cells. Derive an expression for \( N \) in terms of \( X \), \( H \), and \( H_v \).

c) Let \( L = 48 \), \( H = 5 \), and \( H_v = 2 \). Plot \( N \) versus message size for fixed and variable-length cells. Comment on the results.

Solutions: a.
We reason as follows. A total of $X$ octets are to be transmitted. This will require a total of $\left\lceil \frac{X}{L} \right\rceil$ cells. Each cell consists of $(L + H)$ octets, where $L$ is the number of data field octets and $H$ is the number of header octets. Thus

$$N = \frac{X}{\left\lceil \frac{X}{L} \right\rceil (L + H)}$$

The efficiency is optimal for all values of $X$ which are integer multiples of the cell information size. In the optimal case, the efficiency becomes

$$N_{\text{opt}} = \frac{X}{\left( \frac{X}{L} \right)(L + H)} = \frac{L}{L + H}$$

For the case of ATM, with $L = 48$ and $H = 5$, we have $N_{\text{opt}} = 0.91$

b.

Assume that the entire $X$ octets to be transmitted can fit into a single variable-length cell. Then

$$N = \frac{X}{X + H + H_{\text{cell}}}$$

c.
N for fixed-sized cells has a sawtooth shape. For long messages, the optimal achievable efficiency is approached. It is only for very short cells that efficiency is rather low. For variable-length cells, efficiency can be quite high, approaching 100% for large X. However, it does not provide significant gains over fixed-length cells for most values of X.