1. (a) In many transmission control mechanisms retransmissions are controlled by acknowledge messages. For practical reasons the amount of unacknowledged octets is limited. What is the maximum transmission speed that can be reached on 1000 km optical link if the window size, i.e., the number of unacknowledged octets, is 8 kB and it takes 1 μs to process acknowledgement message at each end-point? How large window size is required fill a 1 Gbit/s link? Use $2 \cdot 10^8$ m/s as a propagation speed of optical signal.

   (b) Strict priorities in packet scheduling can be used to provide better quality of service for high priority packets. However, high priority packet cannot interrupt transmission of a low priority packet but it must wait. How large delay variations this can cause on links that operate at speeds 64 kbit/s, 256 kbit/s, 1 Mbit/s, and 1 Gbit/s when using Ethernet framing? Compare these values with a case where ATM is used instead of Ethernet.

2. (a) Calculate the true throughput (payload bit/baud) of 1 Gbit/s Ethernet and Classical IP over ATM (ClIP) on 155 Mbit/s SDH link when the average datagram size is 250 octets. In ClIP datagram is encapsulated into LLC/SNAP frame (8 octet header) which is encapsulated into AAL5 frame (8 octet trailer).

   (b) What bit-rate is required to transport 100 Mbit/s Ethernet over LAN Emulation (LANE) if the average datagram size is the same 250 octets? LANE is ATM based and LANE frames are transported over AAL5. The LANE header is 2 octets long. The preamble, start-of-frame, and CRC fields are stripped from Ethernet frame before encapsulation into LANE frame.

3. When voice (and other delay sensitive data) is sent over packet networks the delay to fill a packet has to be taken account for. Consider uncompressed voice, i.e., 64 kbit/s and compressed voice, 16 kbit/s and 8 kbit/s in the following cases:

   (a) In Voice over IP systems (VoIP) packets has to be sent at short intervals to avoid too long delays. What is the ratio between actual voice data and the whole frame length if IP packets are sent over Ethernet at rate of 20 and 50 packets per second? Use 40 octets for total overhead caused IPv4, UDP and RTP headers.

   (b) How long it takes to fill AAL1 payload (AAL1 overhead is one octet per cell)? Compare AAL1 efficiency with VoIP over Ethernet.

4. In ATM networks two different kinds of adaptation layers, AAL3/4 or AAL5, can be used to send data. The overhead per datagram of both AAL3/4 and AAL5 is 8 octets. In AAL3/4 4 octets per cell are used various fields, e.g., check sum and sequence number, leaving only 44 octets for the data. In AAL5 the whole cell payload can be used to transport data. If transport errors occur, AAL3/4 can detect errored cells and sequence number can be used to request retransmission of a single cell. However, with AAL5 a single bit error causes invalidation and retransmission of the whole datagram. What is the "goodput", i.e., amount data that has been successfully received, relative to bit error rate probability p_{BER} when average datagram length is 250 octets? At which p_{BER} AAL3/4 and AAL5 are equally efficient?