1. (a) (6 pts) Integrated services(IS) and differentiated services(DS) are flow-based and class-based approaches to QoS, respectively. Describe the advantage and disadvantage of them each.

   (b) (6 pts) In the Internet, the design of explicit congestion notification (ECN) involves the use of two bits in the IP packet header and two 1-bit flags ECE and CWR in the TCP segment header. Describe how the full ECN mechanism works.

2. A private company has **two** public IP addresses, 198.60.42.12 and 198.60.42.13, in a **NAT** box (like the one shown in Fig. 1). Within the company, every computer gets a unique private IP address of the form $10.x.y.z$.

   (a) (3 pts) How many addresses does the company have for its internal hosts/machines?

   (b) (5 pts) How many internal machines at most can communicate simultaneously with the machines with public IP addresses outside of the company?

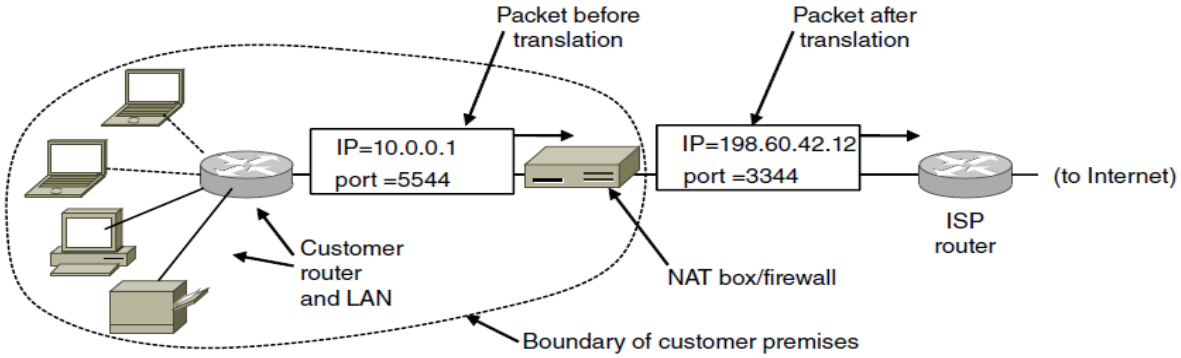

Figure 1: Placement and operation of a NAT box.

3. IPv4 header comprises such fields: *Version, IHL, Differentiated services, Total length, Identification , DF, MF, Fragment offset , Time to live, Protocol , Header checksum, Source address, Destination address, and Options.*

   (a) (6 pts) What fields are used to implement nontransparent fragmentation ? Also describe their functions;

   (b) (3 pts) Describe the method used by IPv6 to deal with fragmentation issues.

4. Suppose that the transport entity at source S is sending packets at the rate λ packets/sec across a network to destination transport entity D and that the network is capable of supporting the capacity of the SD connection at rate μ packets/sec.

   (a) (6 pts) View the network as an M/M/1 queueing system of a single node. Show the mean delay, denoted by T, from S to D.

   (b) (4 pts) Kleinrock (1970) proposed the metric of **power** for congestion. This metric is a function of load λ pkts/sec. Show the power, a function of T and λ.

   (c) (5 pts) The load with the highest power represents an efficient load for the transport entity D to place on the network. Find the load λ that maximizes the power.

5. (a) (4 pts) The timing **ack clock** is an essential part of TCP. Explain its meaning and use.

   (b) (6 pts) TCP adjusts the congestion window size according to the AIMD (Additive Increase Multiplicative Decrease) control law. However, the algorithm called **slow start** is still used for "increase" and there is also a **slow start threshold** involved. Describe why the slow start algorithm is chosen and how it works.

6. (6+7 pts) Suppose that the clock-driven scheme for generating initial sequence number is used with a 10-bit clock counter. The clock ticks once every 1000 *m*sec (i.e., 1 per second), and the maximum packet lifetime is 24 sec. How often need resynchronization take place?

   (a) in the worst case?

   (b) when the data consumes 40 sequence numbers/min?

7. Consider that a **weighted fair queueing algorithm** is chosen as the packet scheduling algorithm in a queueing system and that the algorithm simulates a byte-by-byte round-robin. Suppose that there are currently three flows of packets, with flow i having a weight of i, for $i = 1, 2, 3$. Listed in Table 1 are the flow number, packet arrival time, packet length (byte), some unresolved packet finish time, unresolved packet output order for each of packets A, B, $\cdots$, and H waiting in the queue.

Table 1: The flow number, arrival time, packet length (byte), virtual finish time, and packet output order for each of packets A, B, $\cdots$ and H arriving at input queues for service.

Packet	Flow No.	Arrival time	Length	Finish time	Output order
A	1	0	7	7	1
B	2	1	14	8	2
C	3	3	27	12	y_1
D	2	5	18	x_1	y_2
E	3	7	6	x_2	y_3
F	1	9	11	x_3	y_4
G	3	10	12	x_4	y_5
H	1	11	8	x_5	y_6

   (a) (10 pts) Compute virtual finish times $x_i, i = 1, 2, \cdots, 5$.

   (b) (6 pts) Show packet output order $y_i, i = 1, 2, \cdots, 6$, where $y_i \in \{3, 4, \cdots, 8\}$.

8. (a) (6 pts) Give the full name and main functionality of each term: ARP, ICMP, DNS.

   (b) (4 pts) What is the relevance of the **two army problem** to releasing connections?

   (c) (4 pts) A network on the Internet has a subnet mask of 255.255.224.0 What is the maximum number of hosts it can handle?

   (d) (3 pts) The Sequence number in a RTP header is just a counter that is incremented on each RTP packet sent. For what is the number used?