General guidelines

- The Project work assignment has two parts. First part is worth $p_1 = 25$ points, second part is worth $p_2 = 25$ points.
  Final points for the project are $p_1 + 2 \cdot p_2$

- The assignment must be solved in groups of two, with same groups for parts 1 and 2.

- All answers must be the students' own and original contribution. If the answers consist of copy pasted material from the book, lecture slides, Internet or other students' answers, the student group will not pass the project work and other measures may also be taken.

- There are exercise classes on Thursday at 14-16 in hall **S4** where you can ask questions concerning the problems.

- An FAQ page will be created on the web page concerning the problems

- Answers can be written in English or Finnish.

- Answers are to be returned into the box under the notice board in G-wing, 2nd floor.

- **Deadline for returning first part is 6.2.2006 at 20:00**

Project Work, Part 1

1. **The NORDUnet link between Helsinki and Stockholm is a 10 Gbps link. The distance between Helsinki and Stockholm is 400 km, and the propagation speed of the signal is approximately** $2 \cdot 10^8 \frac{m}{s}$ [worth 2 points]

   a) [1p] What is the minimum round trip time (RTT) of the link?

   b) [0.5p] How "wide" (in units of time) is one bit on this link?

   Hint: If the link carries 10 Gigabits in second, how many seconds does it take to transmit one bit?

   c) [0.5p] How long (in units of length) is the bit?

2. **For a 100km long, 2 Gbps link** [worth 2 points]

   a) [1p] Calculate the bandwidth delay product (BDP) of the link.

   hint: *BDP = bandwidth * delay*, where delay means one way propagation delay, and bandwidth in this case refers to the bit rate of the link.

   b) [1p] What is the significance of the BDP value?

3. **Use the Unix utilities `ping` and `traceroute`.** [worth 3 points]

Before collecting measurements read the man pages for `ping` and `traceroute`. Choose at least 10 hosts, for which you do the measurements, including at least one host from each continent. Also, before collecting measurements check that the RTTs and hops can be measured for your choices of hosts. For traceroute, try the `-I` argument if having trouble reaching the host, or just select another host.

In the UNIX machines of the university, you may have to give the command `use ping` and `use traceroute` to load the application to your path.

a) Use `ping` to find the RTTs to various Internet hosts.
- Measure the RTT *at least at two*, preferably more than two, different times of the day.
- Justify your choice of measurement times.
- For each measurement do at least 20 repetitions and calculate the average RTT and the standard deviation of the RTT at that time of day.
- How much does the time of the day affect the results?

b) Use `traceroute` to find the number of hops on the path from your site to the sites for which you calculated the RTTs using the `ping` utility.

4. **Using the results of exercise 3, find out** [worth 3 points]

a) how well does RTT correlate with the number of hops.

b) how well does RTT correlate with geographical distance.

- In both cases draw a picture to illustrate possible correlations.
- You are also encouraged to use statistical tools to find the functional relationship between the variables. For instance, calculating correlation coefficient and using regression analysis.

5. **Consider hosts A and B, connected by a link with bit rate B bps, with length m meters. The propagation speed along the link is s m/s.**
Host A sends a packet of size L bits to host B.[worth 5 points]

a) [0.5p] What is the propagation delay d_{prop}.

b) [0.5p] Determine the transmission time of the packet d_{trans}.

c) [0.5p] Ignoring processing and queueing delays, obtain an expression for the end-to-end delay.

d) [0.5p] Host A begins submitting at time $t = 0$. At time $t = d_{trans}$ where is the last bit of the packet.

e) [0.5p] Suppose d_{prop} is greater than d_{trans}. At time $t = d_{trans}$ where is the first bit of the packet?

f) [0.5p] Suppose d_{prop} is less than d_{trans}. At time $t = d_{trans}$ where is the first bit of the packet?

- Assume that $s = 2 \cdot 10^8 \frac{m}{s}$, $m = 400km$, $L = 1000b$, $B = 10Gbps$ and RTT $\approx 2 \cdot d_{prop}$.

g) [1p] Calculate the total time required to send a file of 80 KB, if packets can be sent continuously, and an initial handshake of 2 RTTs is required.

h) [1p] Calculate the total time required to send a file of 80 KB, if packets are sent using the stop and wait algorithm, and an initial handshake of 2 RTTs is required.

6. **Using Dijkstra's algorithm, calculate routing table for node A in the network of Figure 1**[worth 3 points]

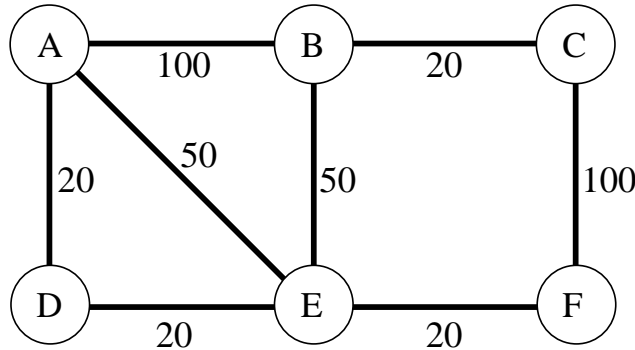   **NOTE:** Your answer to this questions should show the calculations step by step, not just the final routing table.

Figure 1: Network for exercise 6

7. **Change routing by changing the link costs.** [worth 3 points]

   a) **[1p**] In the network of figure 2 Node A sends 1 Mb of data to each of the four other nodes in the network (B,C,D,E), and node B sends 1 Mb of data to each of the four other nodes in the network (A,C,D,E).
      - Determine the least-cost paths for the eight traffic flows when the link costs are $X = 15$
      - How much traffic does each link in the network carry?

   b) **[2p**] If you have calculated correctly in the previous question, the maximum link load is on link BA, which has 3 Mb of traffic, while no other link has more than 2 Mb.
      In a situation like this it sometimes might be a good idea to balance the load more evenly over all links.
      - Can you reduce the maximum link load by changing the link cost X?
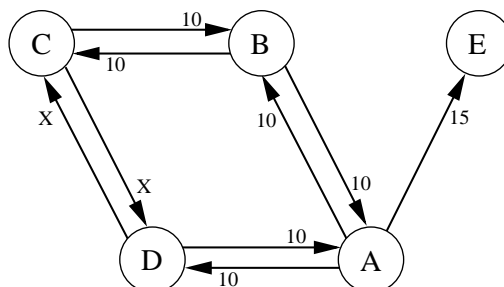   - Which value gives the most balanced load?

Figure 2: Network for exercise 7

8. **Consider an Autonomous System (AS) with 600 hosts** [worth 4 points]

a) [1p] If this AS is assigned a class B IP address, what is the efficiency of the address assignment? (what percentage of the address space is used)

• Instead of assigning a class B IP address, Classless InterDomain Routing (CIDR) is used and the AS is assigned four class C IP addresses. What is the efficiency of this new address assignment?

b) [1p] The four class C addresses are 130.233.152.0-130.233.155.0 or in hexadecimals 82.E9.98.0-82.E9.9B.0. CIDR addresses are often expressed in the form "address/length", where "length" denotes the length of the network part of the address, that is the leading bits that are the same for all hosts under the AS.

• What is the length of the network part of the address for the AS in question?

c) [2p] Assume that the hosts can be hierarchically divided into three separate subnets.

A	82.E9.99.0/24
B	82.E9.9A.0/24
C	82.E9.9B.0/24

We concentrate on the following networks inside these subnets.

A1	82.E9.99.10/28
A2	82.E9.99.20/27
A3	82.E9.99.40/26

Assume that A is connected to B and B is connected to C. A1, A2 and A3 are connected to A, and in addition A3 is connected to C.

• Sketch the network.

• How does C route packets heading to A1, A2 and A3? (For the case of multiple possible routes that have the same minimum hop count, choose the next hop that uses the core links A-B and B-C.)

• Form the routing table for C. (Routing tables consist of the network number and the next hop)