PRINCIPLES OF COMPUTER NETWORKS
COMP 3203

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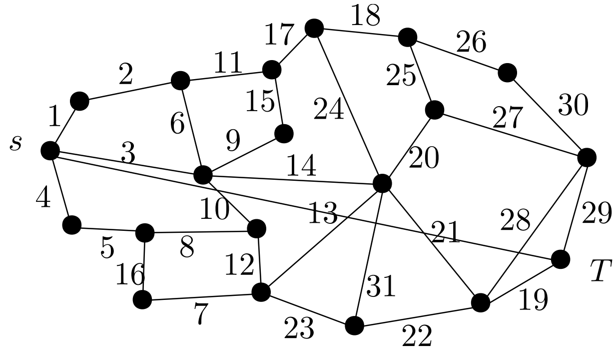
Solve the problems below. Your answers do not have to be long, but they should be complete, precise, concise and clear. Write the solutions on your own and acknowledge your sources in case you used library material. Look in the course web page on how to avoid plagiarism and for submission details (where/when/how). Exercises marked with ($\star$) are usually more challenging. Please type your work using your favourite package but submit only in pdf. Two excellent and free packages are LATEX (for typesetting mathematics) and Ipe (for drawing pictures). **Note: some of the exercises may require material that will be covered in forthcoming lectures.**

Assignment C

1 [15 pts]

The links of a wireless network are labeled as depicted in the Figure below. Moreover there is a source node S and a destination node T.



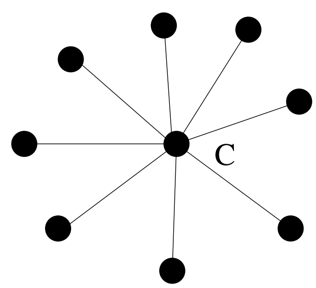
1. [**5 pts**] Apply compass routing to give a path from node S to node T.
2. [**5 pts**] Apply the left-hand rule in face routing algorithm to give a path from node S to node T.

3. **[5 pts]** Apply the right-hand rule in face routing algorithm to give a path from node S to node T.

If $e = (u, v)$ is the last edge you discover during the traversal of a face (i.e., the edge crossing the line ST) then start the traversal of the next face from the vertex u. In your answer you must list all the links being traversed including the last one crossed and the paths formed must use the corresponding face routing algorithm!

2 [10 pts]

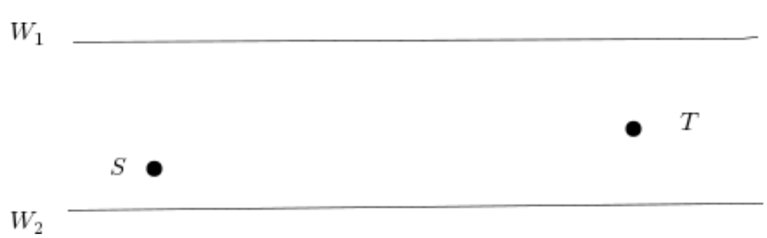
A wireless network consists of $k + 1$ omnidirectional sensors of identical range (radius). They form a hub (star graph) with one sensor at the center C



and the remaining set S of k other sensors around it and within range of the center C. Assume that the sensors in S are outside the range of each other. Show that if all the sensors have the same range then $k \leq 5$.

3 [10 pts] ($\star$)

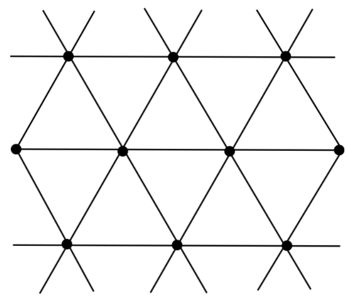
Consider two parallel mirrors, depicted as W_1, W_2, at distance $w = 5$ from each other. A source S and a target T are located between the mirrors at respective heights $s = 1$ and $t = 2$ from W_2.



Assume the horizontal distance between S and T is $d = 10$. At what angle, say ϕ, should a ray leave S so as to reach T after one reflection on W_1?

4 [10 pts]

We want to cover a large city by placing antennas at the vertices of a regular triangular network. Two neighboring antennas are at a distance a, the side length of the equilateral



triangles building up the network.

1. What point inside the triangle is the furthest away from all three corners and why?
2. What is the distance of this point from the corners of the triangle (as a function of the length a)?
3. If identical antennae are to be placed at the vertices of the triangles, what is the minimum radius that will ensure that every point in the plane is within the range of an antenna?

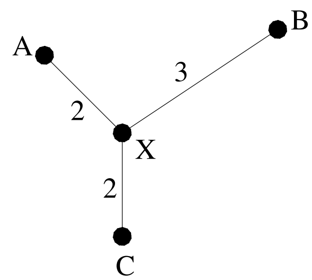
5 [10 pts]

In the questions below provide the formulas and explain your reasoning.

1. [**5 pts**] A wireless transmission system has bit-error rate p bits per sec $(0 < p < 1)$ and packet length of n bits. What is the probability that a packet has an error?
2. [**5 pts**] What is the maximum possible packet length so that the probability a packet has error is at most ϵ?

6 [10 pts]

Consider the wireless nodes $A = (a, a'), B = (b, b'), C = (c, c'), X$ depicted below. A, B, C know their coordinates but X does not.



Using radio location X knows that its distances from A, B, C are $2, 2, 3$ respectively. Give an algorithm (in pseudocode) so that X can determine its own coordinates. Provide the communication exchange required as well as the computation needed (but do not solve the resulting system of equations).

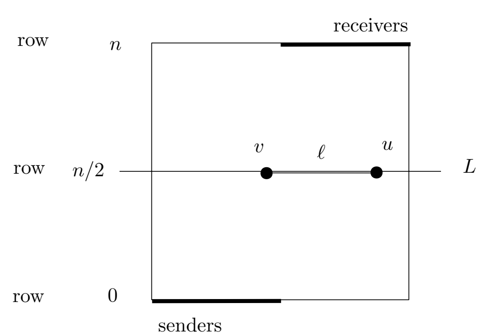
7 [10 pts]

A node keeps unsent TCP packets at a buffer whose capacity is C (in number of packets it can hold). Initially the buffer has C_0 packets, where $C_0 > 0$. Because of the current flow patterns at this node, the amount of packets at the buffer after departure of the old and arrival of the new packets increases at the rate of r, where $r > 0$ (arrival and departure happens at one time unit).

1. [**5 pts**] After how many time units (expressed as a function of C) does the *buffer overflow*?
2. [**5 pts**] An early warning system sends a *potential buffer overflow* message when the buffer reaches $p\%$ of its capacity. After how many time units (expressed as a function of C, p) will a *potential buffer overflow* message be sent?

8 [10 pts]

Consider an $(n+1) \times (n+1)$ square grid with $(n+1)^2$ nodes and assume n is even. Label by (i, j) the node in the i-th row and j-th column of the grid.



$(0,0), (1,0), \ldots, (n/2-1, 0)$

Suppose that each of the $n/2$ nodes $\cancel{(0,1),(1,1),\ldots,(n/2-1,1)}$ at the bottom left half of the grid routes packets (a different packet per destination node) to each of the nodes $(n/2+1, n), (n/2+2, n), \ldots, (n, n)$ at the top right half of the grid using a(ny) shortest path. Consider the horizontal line L from node $(n/2, 0)$ to $(n/2, n)$.

1. [**2 pts**] Show that in total at least $\Omega(n^2)$ packets have to pass through nodes of the line L.

2. [**4 pts**] ($\star$) Show that there is node in the line L so that at least $\Omega(n)$ packets have to pass through it.[1]

3. [**4 pts**] ($\star$) Now assume that all but the ℓ nodes between the nodes u, v on a subsegment of the horizontal line L are faulty and cannot route packets; so all packets have to be routed through non-faulty nodes berween u and v; the senders know of these nodes. Show that there is node in the line segment between u and v so that at least $\Omega(n^2/\ell)$ packets have to pass through it.?

9 [10 pts]

Application of each new protocol adds a header of length h bits to a packet.

1. [**5 pts**] If a packet is undergoing applications of n protocols what percenteage of the resulting packet length is occupied by protocol headers. (Assume each protocol header has length h bits.)

2. [**5 pts**] After how many protocol applications is the length of the resulting packet at least triple the length of the original packet?

10 [10 pts]

The congestion window is a number that directs the size of the sliding window to be used. TCP keeps track of the congestion window w at a host by constantly updating it, and the precise rules are as follows: 1) Every time a positive acknowledgment comes in, $w \leftarrow w + \frac{1}{w}$, and 2) every time a lost packet is detected, $w \leftarrow \frac{w}{2}$. Let p be the probability that a packet is lost.

1. [**5 pts**] What is the expected change of the congestion window?

2. [**5 pts**] Given p, what congestion window will keep the expected change equal to 0?

[1]The symbol $\Omega(f(n))$ means "at least $cf(n)$", where $c > 0$ is a constant independent of n.