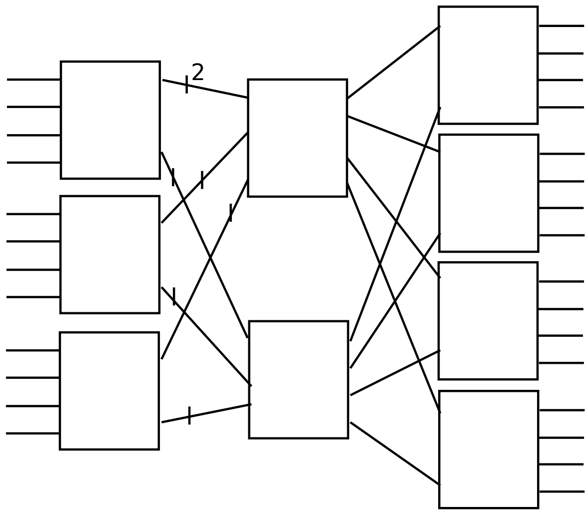
June 21th, 2019

Exam of Switching technologies for data centers (2018/19)

Rules for the exam. It is **forbidden** to use notes, books or calculators. Use only draft paper provided by the professor. When needed, use approximations. The answers must be provided in correct English. Any notation must be defined. **Time available: 70 minutes**.

Problem A

Consider a 12×16 interconnection network for circuit switching, composed by 9 switches interconnected as a 3 stage network, with double links between each pair of switches in the 1st and 2nd stage, as shown in the following figure.



1. Using the Lee method, compute the blocking probability in function of the normalized offered load h, with $h \in [0, 1]$, at each input port. Draw the original graph and show all the steps for its reduction.
2. What are the traffic admissibility conditions for the considered network? Provide an intuitive explanation for them.
3. Assume that the total offered traffic is 3 Erlang. Write the formula for the corresponding blocking probability.
4. Which routing algorithm can be adopted for each new incoming circuit?

Problem B

Consider the new network paradigm denoted as “Software Defined Networking” (SDN).

1. What is the main difference with the traditional Internet architecture?
2. What is a SDN controller? How can its API interfaces be classified?
3. What is Openflow?
4. How is a flow table defined in Openflow?
5. What are the main messages defined in Openflow and what are their purposes?
6. What are the main consequences of Openflow on the design of the switching architectures?

Problem C

Consider a $N \times M$ input queued switch with Virtual Output Queueing and supporting Strict Priority Queueing based on C classes. For each (input-i,output-j) pair there exist C queues: $[VOQ_{ij}^c]_{c=1}^C$, with decreasing priority level, where $c = 1$ refers to the highest priority traffic and $c = C$ refers to the lowest priority traffic (i.e., best effort traffic). Therefore, $C \times N \times M$ queues are present in total. We assume that an input traffic classifier sends the incoming packets to the correct queue.

1. Write in pseudocode a greedy algorithm to schedule the transmissions across the switching fabric, to be maximal and to maximize the number of higher priority packets that are selected at each timeslot. Define all the data structures adopted in your code.

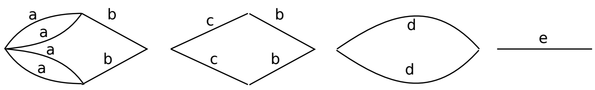
2. Does the scheduler obtain always the maximum throughput under admissible Bernoulli i.i.d. traffic? Motivate your answer.

3. Is it possible that low priority traffic will be starved indefinitely by high priority traffic? Motivate your answer with an example.

Hints for the solution

Problem A

1. By applying the Lee method we have the following graph reduction steps



with

$$c = a^2$$
$$d = 1 - (1-c)(1-b) = 1 - (1-a^2)(1-b)$$
$$P_b = e = d^2 = (1-(1-a^2)(1-b))^2$$

Given the offered load h at each input:

$$a = 12h/12 = h \qquad b = 12h/8 = 3h/2$$

and thus the blocking probability becomes:

$$P_b = (1-(1-h^2)(1-3h/2))^2 = (3h/2 + h^2 - 3h^3/2)^2$$

2. The admissibility conditions are

$$a \leq 1, b \leq 1 \qquad \Rightarrow \qquad h \leq 2/3$$

The final condition assures that the links between the 2nd and the 3rd stages are not overloaded, being the "bottleneck" in the architecture.
For any $h > 2/3$, $P_b = 1$.
3. If the total traffic is 3 Erlang, then $h = 3/12 = 1/4$, then

$$P_b = (3/8 + 1/16 - 3/128)^2$$

4. To compute the routing, a simple graph traversal algorithm would work (e.g., depth-first search, breadth-first search) on the graph in which only the available links are considered.

Problem B

Problem C