CSL 861: Special topics in hardware
Dependable Computing and Networking Systems

Major Assignment
Assigned: April 22, 2011
Due: April 25, 2011 (8AM)

Directions:

1. **No books, notes, collaboration, or cheating are allowed.**
2. **No questions will be answered. So make any assumption you need to make to answer the question. Any mistakes/inconsistencies/assumptions will be considered in grading.**
3. **Each part of the problem is worth the points indicated along with the problem.**
4. **You should spend less time writing and more time in thinking of the solution. Do not write more than what is required. Stay to the point.**
5. **The paper may appear to be long. However, it is not.**
6. **There are no tricks involved.**

P1. (10 points) A multicore system consists of N = n x n cores arranged in a 2-dimension n x n mesh torus for n being 5 or more. Up to t of these cores can be permanently faulty. In addition, sometimes up to k cores may have transient faults. Others are fault-free. We want to use a core-testing-core approach to diagnose faulty cores. A fault-free core always tests a permanently faulty or fault-free processor correctly. However, it may or may not be able to test a transient fault properly. Faulty (permanent or transient) cores may behave in an arbitrary fashion.

a. What is the relationship between N, t, and k?
b. Using the above model, show possible test outcomes you can expect depending on the actual status (fault-free, faulty, or transient) of a tester and a tested core.
c. Suppose the tests are possible from a neighboring unit only. The value of t can vary from 1 to 6. For each value of t, how many different fault set are possible? How many different faults sets are uniquely diagnosable with respect to any other fault set of size up to 6.
d. Assuming that probability of a unit being faulty is p, compute the probability of occurrence of each possible fault set?
e. What is the probability that a correct and complete diagnosis is possible for a fault set of size t with assuming that no fault set of size more than 6 is present in the system?

P2. (10 points) The following problem is based on folklore from the puzzle world. In the remote country of Mamajorca, which is ruled by women, there is a problem of infidelity. The queen (Queen Henrietta I, unmarried) wants to eliminate the problem by killing all husbands who are unfaithful. The following facts are common knowledge among all married women. (Such a problem appears in the diagnosis of distributed systems with reliable broadcasting and synchronized clocks.)

- Every married woman knows the fidelity or infidelity of every married man except her own husband (each processor can test all others).

- Every statement that the queen makes is true (one good central controller).
- If the queen gives an order, all subjects obey (central controller has full control).
- Every married woman will hear any gunshot (broadcast of all messages).
- All women can make all possible deductions from their knowledge (Smart processors).
- All married women can see the same clock, which is perfect and never fails (clocks are synchronized).
- The women do not talk to each other (No direct communication).

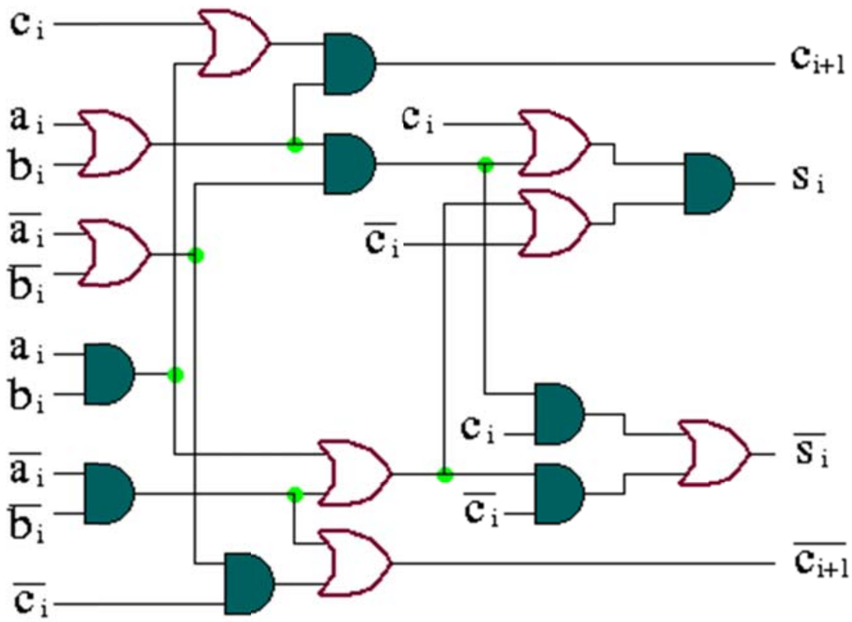
The queen gathers all of the married women together, and makes the following statement. ``All of the married women in my kingdom are gathered here. If you discover that your own husband is unfaithful, then you are ordered to shoot him at midnight on the day that you discover that fact. There is at least one unfaithful husband."

a. Suppose there are n >0 unfaithful husbands. Are any unfaithful husbands shot at midnight on the first day? Why or why not? Does the answer depend on n?
b. Is it possible that a faithful husband gets killed? Why or why not?
c. Let n_k be the number of unfaithful husbands killed at midnight on the k^{th} day. Determine n_k as a function of n.
d. What happens to your solutions in parts (a), (b), and (c) if each woman sees a different clock and the clocks are not synchronized exactly? What tolerance, which is known to all women, is tolerable?

P3. (10 points) In certain situations, order of failures of components has an impact on the reconfiguration, and therefore, failure of the system. Suppose in a system there are two components, A and B. Let their failure rates be λ_A and λ_B, respectively. Suppose the system fails if A fails before B, but not if B fails before A. Such a situation cannot be handled by fault tree modeling.

a. Give an example of a system where this scenario applies.
b. How many different states the system can be? Draw the states as circles and show possible transitions from each state to other states.
c. Compute the probability of system failing.

P4. (10 points) Consider the following circuit. It implements a one bit full adder using two rail signals. Demonstrate that this self-checking binary adder circuit produces a non-code word output for a primary input (a, b, or c, or their complements) fault or a single fault in the circuit (note that you can exploit symmetry to prove this argument).



P5. (20 point) Let us try to extend the DIVA paradigm by assuming that two cores are used to check one core. What should be the design decisions, software, and hardware architecture of the system in this case?

P6. (20 points) Let us try to make DIVA or Paceline power efficient. A system is made power efficient by eliminating some amount of useless work, or by reducing the frequency. Outline an approach to make architectures like DIVA, Paceline and Slipstream power efficient.