Foundations of Information Systems

Final Exam

February 20, 2024

1. Are the following identities true or false? If true, give a proof. If false, give a counterexample.

   (a) $(a \wedge b)' \wedge c = (a \vee b) \vee c'$

   (b) $((a \vee b) \wedge c)' = (a \wedge c)' \wedge (b \wedge c)'$

   (5+5)

2. (a) Convert the decimal number 433 to hexadecimal.

   (b) Add the 4-bit two's complement binary numbers 1110 and 1011.

   (c) Confirm your result by converting all three numbers from (b) to decimal.

   (d) How do you detect overflow when adding two's complement binary numbers?

   (5+5+5+5)

3. (a) Draw a finite state machine that can recognize whether a 3-bit binary string is a palindrome, i.e., reads the same backwards as forwards.

   (b) State a regular expression that is equivalent to the machine from part (a).

   (c) Is it possible to design a finite state machine that recognizes palindromes of arbitrary length? Explain!

   (5+5+5)

4. The following bit strings of a Hamming-(8,4) encoded message are received. Correct single-bit errors or detect double-bit errors as appropriate.

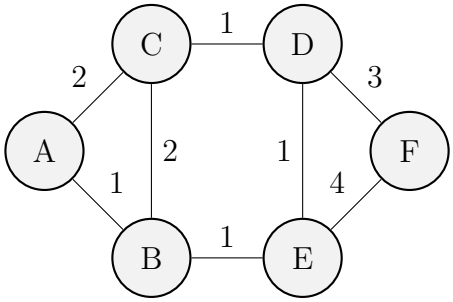
   (a) 11001011

   (b) 00010100

   (5+5)

5. Suppose you have a file `data_A`. You create a hard link `data_B` and a soft link `data_C` to it. Now you delete `data_A`. Is the data lost? Can you still access it via `data_B`? Via `data_C`? (5)

6. Consider the following router network which uses distance vector routing.



(a) State the optimal distance vector and routing table for router C. You do not need to compute anything as the network is simple enough to spot the answer directly.

(b) Now suppose that router C is malicious and wants to cut router F off the network. Can it do this? If so, what distance vector does it need to broadcast to its neighbors to attract all traffic destined for F?

(5+5)

7. Suppose you have three identical disks. The most natural way to create redundant storage from these three disks is a RAID-5 array. Your remember from class that RAID-5 with large capacity drives has a high probability of hitting an unrecoverable error during rebuild after a single-drive failure, so you ponder if it's worth investing in a fourth disk and using RAID-10 ("stripe of mirrors") instead. To help making this decision, rate the performance of the four-disk RAID-10 *relative* to the three-disk RAID-5, with a brief explanation, in each of the following categories:

   (a) Usable capacity (*not* raw capacity!)

   (b) Read speed when sequentially reading a large file

   (c) Write speed when sequentially writing a large file

   (d) Write speed when writing random blocks

   (e) Probability of hitting an error during rebuild after a single-drive failure

   Extra credit: Based on these numbers, write a recommendation whether or not to purchase the extra drive and use it in RAID-10 configuration. (2+2+2+2+2*+5*)