CSC 478/678
Principles of Wireless Networks (Spring 2021)
Exam 2

Note:
• This is an open-book, open-note exam, though you must work on it yourself. Please do not request help from any others or experts from any website.
• There are seven (7) questions. Good luck!

1. True or False. Briefly explain if the statement is false. (3 points each)

(a) In ad hoc routing, RREP messages are broadcasted back the sender of the RREQ message.

FALSE, if a node has route to destination, then it sends RREP back to send neighbor, not direct necessarily direct to sender. If no route, then either forwards RREQ or ignores if duplicate.

(b) Spread spectrum helps with hiding wireless communication in the presence of eavesdroppers.

TRUE

(c) In information transmission of binary sequence, once we identify the locations of the bit errors, we can correct them by simply flipping them (0 to 1 and 1 to 0).

TRUE, if you knew the exact error bit, it could be corrected

2. Answer the following questions briefly: (21 points, 7 points each)

(a) Explain what spread spectrum is in wireless communication and list two of its major benefits.

Spectrum spread is modulating narrow bandwidth with a sequence of digits to wider bandwidth, before transmitting via carrier. One benefit is a natural signal hiding/encryption since only sender/receiver have the appropriate code to interpret (signal will be interpreted as noise by others). Another benefit is the ability of multiple users to communicate with the same wider bandwidth while experiencing limited interference.

(b) What is the biggest challenge in wireless sensor networks? Explain.

Power consumption. Sensor network lifespan is limited by the battery life of the sensors as it isn't feasible to replace individual units as they die. Communication consumes significantly more power than computation, so effective communication strategies must be put in place to ensure longevity of WSN by reducing power consumption.

(c) Explain what sensor fusion in wireless sensor networks.

Aggregation of data from multiple sensor sources to increase overall accuracy of data (combine or negate unreliable data readings), to limit power consumption with reduced transmissions, and to reduce noise.

3. (10 points) Use <u>XOR method</u> **OR** <u>polynomial method</u> to show whether $X^4 + 1$ is indivisible or not. Please show your work.

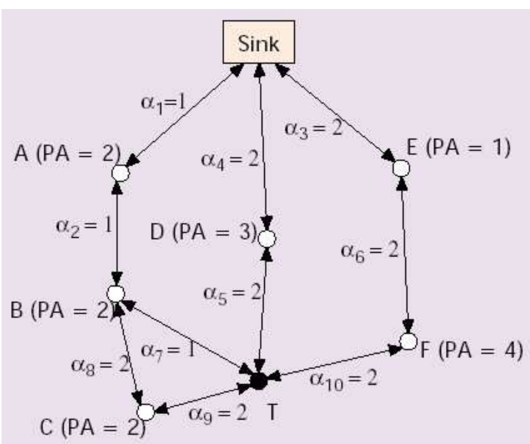
4[th] degree polynomial, so using ceil(D(f(x))/2), need to check at most X, $X+1$, X^2+1, $X^2 + X + 1$

Check X+1:

$$
\begin{array}{r|lllll}
 & X^3 & + X^2 & + X & + 1 & \\
\hline
X+1 & X^4 & & & & + 1 \\
 & \underline{X^4 + X^3} & & & & \\
 & & X^3 & & & \\
 & & \underline{X^3 + X^2} & & & \\
 & & & X^2 & & \\
 & & & \underline{X^2 + X} & & \\
 & & & & X & + 1 \\
 & & & & \underline{X} & \underline{+ 1}
\end{array}
$$

Since X+1 divides polynomial, it is NOT indivisible

4. (10 points) In the following wireless sensor network, PA represents Power that is Available on the sensor. α is cost of sending traffic over the link. Answer the following questions for route selection between T and Sink:



(a) Suppose a path with maximum minimum PA (i.e., among all routers, find the minimum PA, and then choose the path with maximum such minimum PA) should be chosen, which path should it be? Why?

Minimum minimum PA path should be sink-D-T. This path has the least power available (PA=3).

(b) Suppose a path with the lowest cost should be chosen, which path should it be? Why?

The path with the lowest cost is sink-A-B-T ($\alpha = 3$). Even though this path has more hops, it has less cost than the more direct path sink-D-T.

5. (20 points) Suppose there are three pairs of senders/receivers using the direct sequence spread spectrum technique for wireless communication. All nodes are in range of each other. These are their codes (chips):

A and R_A:
+1 +1 +1 +1 -1 -1 -1 -1

B and R_B:
+1 +1 -1 -1 +1 +1 -1 -1

C and R_C:
+1 -1 +1 -1 +1 -1 +1 -1

Therefore, A and R_A will use the same code, B and R_B will use the same code, etc.

Suppose B sends "0" and C sends "1".

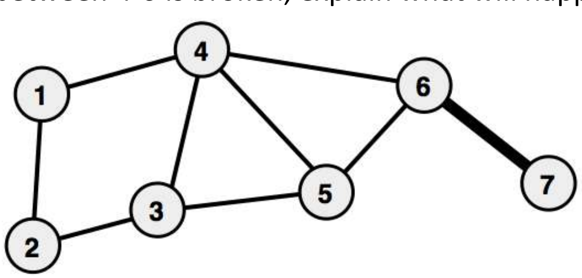
(a) Please show what chips (smaller bits) R_A receives and what it decodes.

B sends "0": -1 -1 +1 +1 -1 -1 +1 +1
C sends "1": +1 -1 +1 -1 +1 -1 +1 -1
R_A receives: +0 -2 +2 +0 +0 -2 +2 +0
R_A code: +1 +1 +1 +1 -1 -1 -1 -1
Multiply: +0 -2 +2 +0 +0 +2 -2 +0
Sum = 0, decode as "noise"

(b) Please show what chips (smaller bits) R_C receives and what it decodes.

B sends "0": -1 -1 +1 +1 -1 -1 +1 +1
C sends "1": +1 -1 +1 -1 +1 -1 +1 -1
R_C receives: +0 -2 +2 +0 +0 -2 +2 +0
R_C code: +1 -1 +1 -1 +1 -1 +1 -1
Multiply: +0 +2 +2 +0 +0 +2 +2 +0
Sum = 8, decode as "1"

6. (10 points) In ad hoc routing, routes may fail/change at any time. In the figure below, suppose AODV is used and the route 1-4-6-7 has been established for node 1 towards node 7. If the link between 4-6 is broken, explain what will happen in AODV.



Node4 sends RERR packet out indicating that it has lost path connectivity
RERR packet makes to back to Node1 (direct connection here)
Node1 or Node4 can send a new RREQ to rebuild new path to Node7
Eventually Node5 receives RREQ and forwards to Node6
Node6 sends RREP on reverse path indicating connectivity to Node7
All nodes on return path update routing table info and hop count
Node1 resends packet to Node4
Node4 forwards packet to Node5 via updated routing table
Node5 forward packet to Node6 and to Node7

7. (20 points) Suppose the following data sequence is to be transmitted 1110,0110 with CRC using a pattern of "110101". Please find out the frame check sequence and show that with it, the resulted transmission is divisible by "110101". Please show your work in details. [Hint: the transmitted sequence should be 8+5=13 bits.]

D = 11100110, |D| = 8
P = 110101, |P| = 6
|F| = |P| - 1 = 5 bits
|T| = |D| + |F| = 8 + 5 = 13 bits
$T = 2^{n-k} D + R$
$T/P = 2^{n-k} D/P + R/P$

$2^{n-k} D$ = 11100110 00000

```
                                 [Q]
 [P]                 1 0 1 0 0 1 0 1
         _________________________
110101 | 1 1 1 0 0 1 1 0 0 0 0 0 0   [2^(n-k) D]
         1 1 0 1 0 1
         -----------
             1 1 0 0 1 0
             1 1 0 1 0 1
             -----------
                   1 1 1 0 0 0
                   1 1 0 1 0 1
                   -----------
                       1 1 0 1 0 0
                       1 1 0 1 0 1   [R]
                       -----------
                                 1
```

R (FRC) must be 5 bits long -> **00001**
T = 1110 0110 00001

Verify:

```
                                  Q
         P
                     1 0 1 0 0 1 0 1
          ___________________________
 110101 | 1 1 1 0 0 1 1 0 0 0 0 0 1   T
          1 1 0 1 0 1
          -----------
              1 1 0 0 1 0
              1 1 0 1 0 1
              -----------
                    1 1 1 0 0 0
                    1 1 0 1 0 1
                    -----------
                        1 1 0 1 0 1
                        1 1 0 1 0 1
                        -----------
                                  0   <- divisible
```

100/100
Great Job!