

## EE3009 Data Communications and Networking

### Quiz 2 (Solution), Semester A, 2013/14

1. A sender can use an RTS packet to reserve the channel first. As this control message is short, the chance of collision with other packets is low. After receiving this RTS packet, the access point will broadcast a CTS packet, which notifies all terminals (which may be hidden from the sender). The sender can then transmit its data packet and collision is thus avoided.

2.

- Terminal C has the highest throughput. Its throughput is  $0.4 (1-0.2) (1-0.3) = 0.224$ .

- Total throughput = throughput of A + throughput of B + throughput of C

$$= 0.2 (1-0.3) (1-0.4) + 0.3 (1-0.2)(1-0.4) + 0.224$$

$$= 0.084 + 0.144 + 0.224$$

$$= 0.452$$

- The system becomes fair if all terminals transmit with the same probability  $p$ .

$$\text{Total throughput } f(p) = 3p(1-p)^2$$

To maximize the total throughput, we differentiate  $f(p)$  with respect to  $p$ .

$$\begin{aligned} f'(p) &= 3(1-p)^2 - 6(1-p) \\ &= 3(1-p)(1-3p) \end{aligned}$$

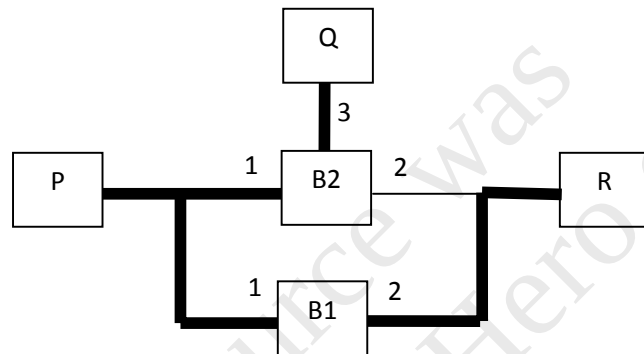
Set the derivative to zero, we get  $p = 1$  or  $1/3$ .  $p$  cannot be equal to 1, since the total throughput will become zero. By differentiating again, we can show that  $p = 1/3$  gives maximum throughput.

The maximum total throughput is

$$\begin{aligned} f\left(\frac{1}{3}\right) &= 3\left(\frac{1}{3}\right)\left(1-\frac{1}{3}\right)^2 \\ &= \frac{4}{9} \\ &\approx 0.444 \end{aligned}$$

3.

- Both B1 and B2 receive the frame. The entry (P, 1) will be added to both the forwarding tables for B1 and B2.
- After receiving the frame, B2 forwards it into its interfaces 2 and 3.
- Similarly, B1 forwards it into its interface 2.
- The result is that two packets are forwarded within the loop in opposite directions. R will receive the same frame an infinite number of times.



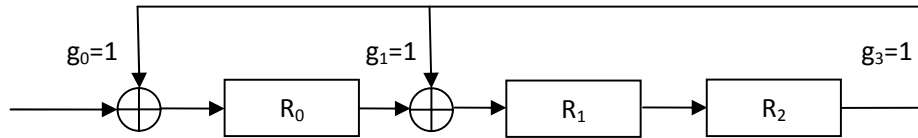
- The entry (P, 1) will be added to both the forwarding tables for B1 and B2.
- B1 will forward the frame using its interface 2, and R will receive it.
- B2 will forward the frame using its interface 3.

4.

$$\begin{aligned}
 \text{Average Throughput} &= \frac{300 \times 20}{(300 + 10) \times 20 + (10 + 10) \times 80} \\
 &= \frac{6000}{6200 + 1600} \\
 &= 76.92\%
 \end{aligned}$$

5.

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| Clock | Input | R <sub>0</sub> | R <sub>1</sub> | R <sub>2</sub> |
|-------|-------|----------------|----------------|----------------|
| 0     | ----  | 0              | 0              | 0              |
| 1     | 1     | 1              | 0              | 0              |
| 2     | 0     | 0              | 1              | 0              |
| 3     | 0     | 0              | 0              | 1              |
| 4     | 1     | 0              | 1              | 0              |
| 5     | 0     | 0              | 0              | 1              |
| 6     | 1     | 0              | 1              | 0              |
| 7     | 0     | 0              | 0              | 1              |
| 8     | 0     | 1              | 1              | 0              |
| 9     | 0     | 0              | 1              | 1              |

Therefore, the CRC bits are 110.

6.

- The  $4 \times 4$  Hadamard matrix is shown below:

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

- The two signature sequences are  $(-1, -1, -1, -1)$  and  $(-1, 1, -1, 1)$ . Their inner product is  $(-1)(-1) + (-1)(1) + (-1)(-1) + (-1)(1) = 1 - 1 + 1 - 1 = 0$ . Therefore, they are orthogonal.

7.

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| $d_1$ | $d_2$ | $d_3$ | $c_1$ | $c_2$ | $c_3$ |
|-------|-------|-------|-------|-------|-------|
| 0     | 0     | 0     | 0     | 0     | 0     |
| 0     | 0     | 1     | 0     | 1     | 1     |
| 0     | 1     | 0     | 1     | 0     | 1     |
| 0     | 1     | 1     | 1     | 1     | 0     |
| 1     | 0     | 0     | 1     | 1     | 0     |
| 1     | 0     | 1     | 1     | 0     | 1     |
| 1     | 1     | 0     | 0     | 1     | 1     |
| 1     | 1     | 1     | 0     | 0     | 0     |

- Minimum distance = 3
- This code is able to detect all double-bit errors. The probability of detection failure is roughly equal to

$$\begin{aligned}
 & 1 - \left[ (0.999)^6 + \binom{6}{1} (0.999)^5 (0.001) + \binom{6}{2} (0.999)^4 (0.001)^2 \right] \\
 &= 1 - [0.9940 + 0.00597 + 0.00001494] \\
 &= 1.506 \times 10^{-5}
 \end{aligned}$$

8.

- The sender has an encryption key.
- To encrypt the frame, an initialization vector is generated randomly.
- The encryption key and the initialization vector are used together as input to a pseudo-random generator.
- A keystream is then generated.
- Encryption is performed by performing XOR between the data and the keystream.

9.

