Error Control Codes

Course Code: COE 3206 Course Title: Computer Networks

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Lecture Outline

1. Cyclic redundancy check

Cyclic Redundancy Check

Introduction

- What if the transmitted bits get altered on the way?
  - Is there any technique to detect the error?

Yes, using Cyclic Redundancy Check (CRC)

- CRC
  - In CRC, some redundant bits are sent in addition to the message bits.
  - The purpose of the redundant bits is to facilitate detecting error.
  - *The redundant bits are called frame check sequence (FCS)*

How is FCS generated?

Cyclic Redundancy Check….

Introduction….

- Strength of the CRC depends on the number of redundant bits (that is, FCS length)
- Longer FCS length results in better accuracy in detecting error

❑ Required two sequence

- *Message sequence, M*
  - ➢ The desired data to be sent
  - ➢ Can be of any length
- *Pattern sequence, P*
  - ➢ Known to both sender and receiver
  - ➢ If we want to use *K* bits FCS, we need a pattern bit sequence, *P,* of length *K+1* bits.

Cyclic Redundancy Check….

Generation of FCS

1. Decide how many FCS bits, *K*, you are going to use.
2. Append K zeros at the end of the message bits to generate *M+K* bits long sequence *S*.
3. Select a *K+1* bits long pattern sequence, *P*.
4. Divide the sequence *S* by the pattern sequence *P* to find the *K* bits of the remainder, R.
5. Remove the appended zeros from S and append the calculated remainder *R* Thus, the *N* bits message bits and *K* bits remainder constitutes the transmitting sequence, *T*.

Cyclic Redundancy Check….

Error detection at the receiver

1. At the destination, the received sequence, T', is divided by the same patter sequence, P.
2. If at this step there is no remainder, the data unit is assumed to be correct and is therefore accepted.
3. A remainder indicates that the data unit has been damaged on the way and therefore must be rejected.

Cyclic Redundancy Check….

Example 1

- Generate FCS if the message polynomial and generator polynomial are $X^3 + X^2 + 1$ And $X^3 + X + 1$, respectively.

Let M(x) be the **message polynomial**

Let P(x) be the **generator polynomial/Pattern sequence**

Let P(x) = $X^3 + X + 1$ ⟶ **1 0 1 1**

Let M(x) = $X^3 + X^2 + 1$ ⟶ **1 1 0 1**

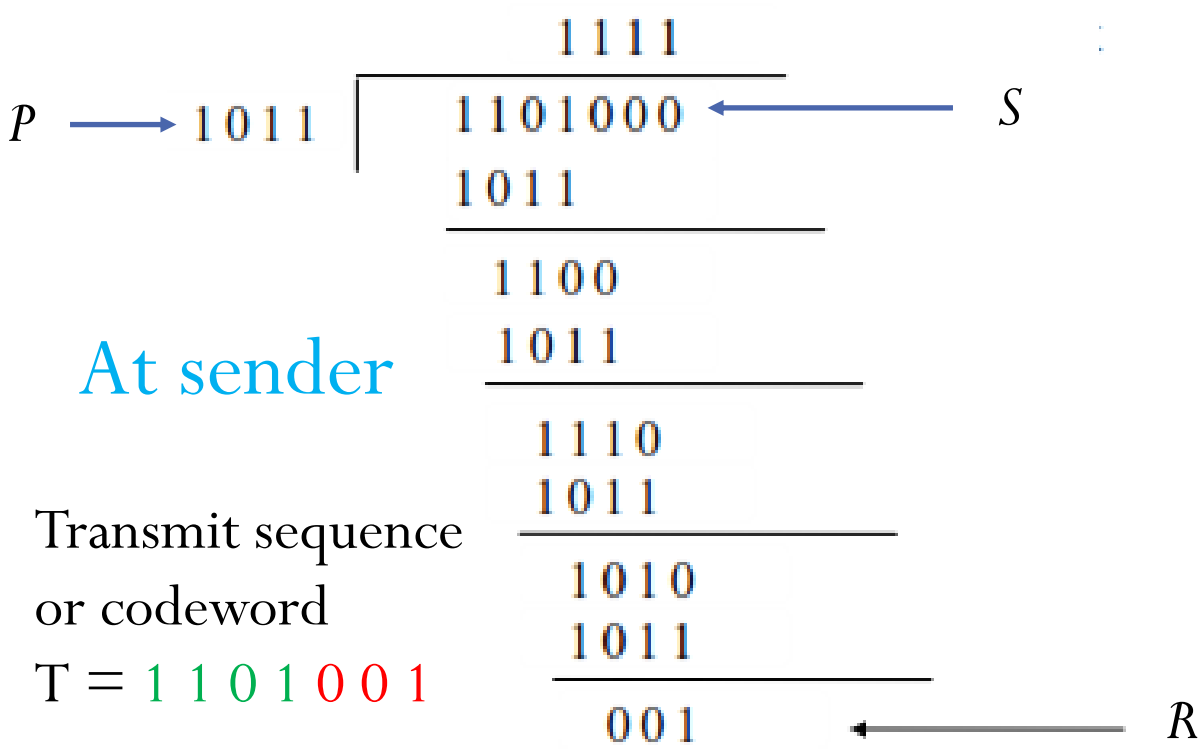
1. Consider the case where M=*1101 and P=1011*.

2. Since P consists of 4 bits, append K=3 bits zeros (000) at the end of M, S=1101000

3. Divide S by P to get 3 bits remainder.

Cyclic Redundancy Check….

Example 1



At sender

Transmit sequence
or codeword
T = 1 1 0 1 0 0 1

Cyclic Redundancy Check….

Example 1


```
1011 | 1 1 0 1 0 0 1
       1 0 1 1
       -------
         1 1 0 0
         1 0 1 1
         -------
           1 1 1 0
           1 0 1 1
           -------
             1 0 1 1
             1 0 1 1
             -------
               0 0 0 0
```

At Receiver

Since the remainder is zero, there is no error in the received sequence

Cyclic Redundancy Check….

Example 1

What if any bit gets altered in the channel?

Suppose that the second bit (red) has altered from 1 to 0.

```
1011 | 1 0 0 1 0 0 1
       1 0 1 1
       -------
         1 0 0 0
         1 0 1 1
         -------
           1 1 1
```

The nonzero remainder indicates an erroneous reception.

The frame will not be acknowledged.

The sender will resend the frame.

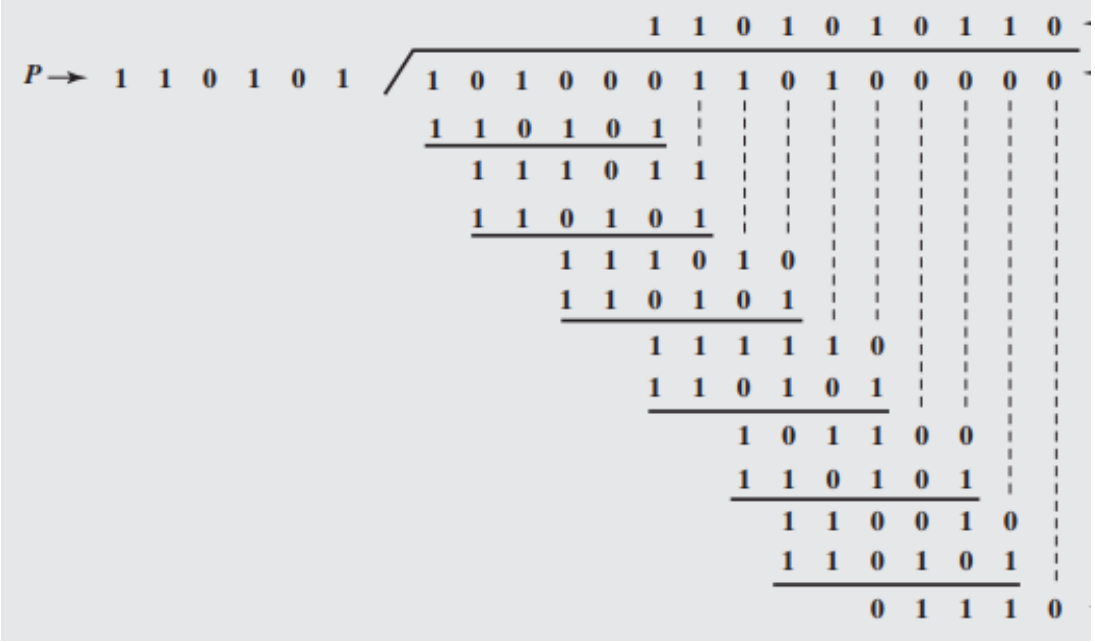
Cyclic Redundancy Check….

Example 2

- Message M = 1010001101
- Pattern P = 110101
- Length of P=6
- Append K=6-1=5 zeros at the end of M
- S=101000110100000
- Now divide S by P to find 5 bits remainder [1].

Cyclic Redundancy Check….

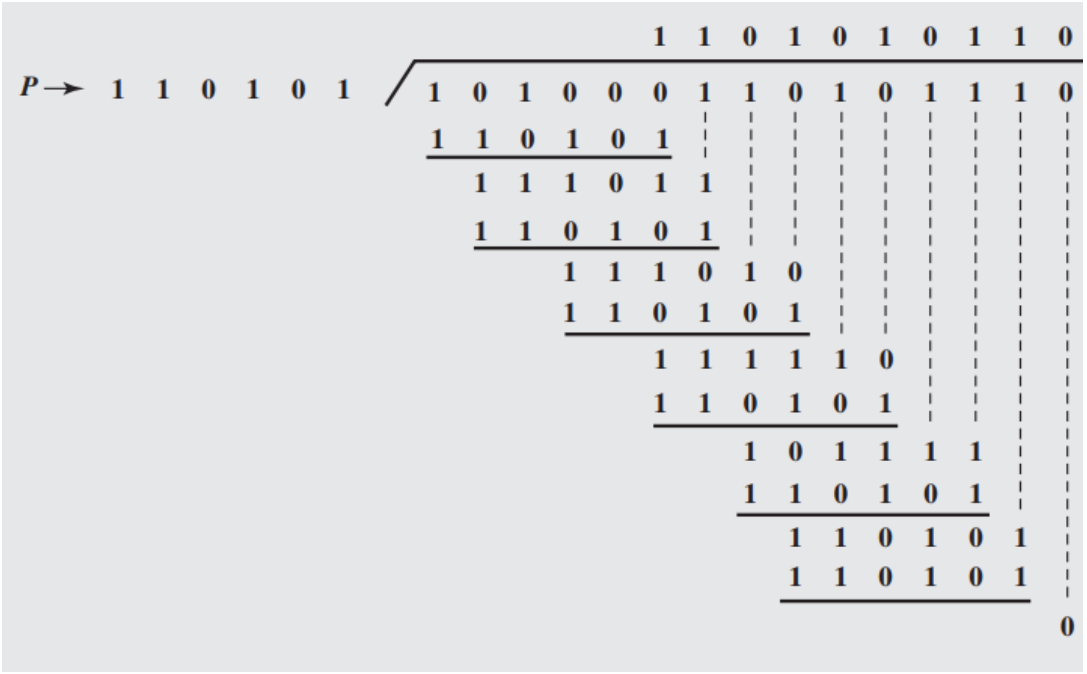
Example 2



- Transmitted sequence, T=1010001101**01110**
- At the receiving end, T is divided by P to see if the remainder is zero. The zero remainder indicates error free reception.

Cyclic Redundancy Check….

Example 1



Because there is no remainder, it is assumed that there have been no errors.

Homework

1. Detect whether the received sequence 101110101 is error free if the pattern sequence is 1010.

References

[1] W. Stallings, *Data and Computer Communication*, 10th ed., Pearson Education, Inc., 2014, USA, pp. 194 - 196.

[2] B. Sklar, *Digital Communications*, 2nd ed., Prentice Hall. 2017, USA, pp. 328 - 345.

Recommended Books

1. **Data Communications and Networking**, *B. A. Forouzan*, McGraw-Hill, Inc., Fourth Edition, 2007, USA.
2. **Computer Networking: A Top-Down Approach**, *J. F., Kurose, K. W. Ross*, Pearson Education, Inc., Sixth Edition, USA.
3. **Official Cert Guide CCNA 200-301 , vol. 1**, *W. Odom*, Cisco Press, First Edition, 2019, USA.
4. **CCNA Routing and Switching**, *T. Lammle*, John Wily & Sons, Second Edition, 2016, USA.
5. **TCP/IP Protocol Suite**, *B. A. Forouzan*, McGraw-Hill, Inc., Fourth Edition, 2009, USA.
6. **Data and Computer Communication**, *W. Stallings*, Pearson Education, Inc., Tenth Education, 2013, USA.