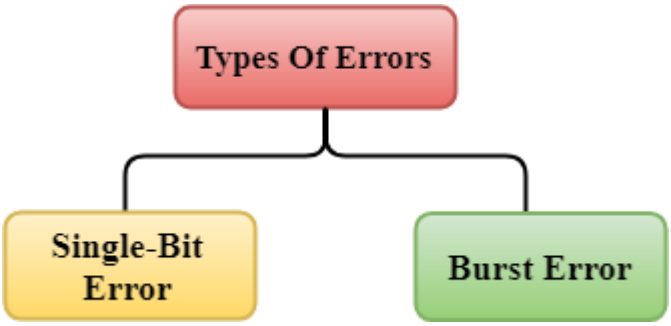
Data Link Layer :

Error Control

When data is transmitted from one device to another device, the system does not guarantee whether the data received by the device is identical to the data transmitted by another device.

An Error is a situation when the message received at the receiver end is not identical to the message transmitted.

Types Of Errors

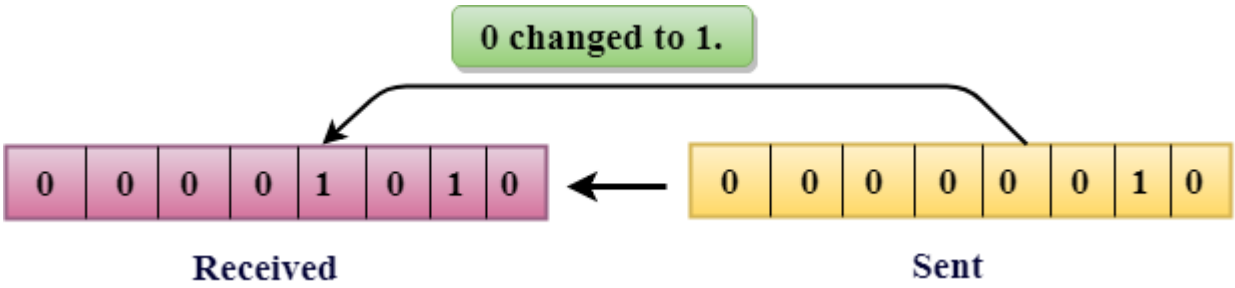


Errors can be classified into two categories:

- Single-Bit Error
- Burst Error

Single-Bit Error:

The only one bit of a given data unit is changed from 1 to 0 or from 0 to 1.

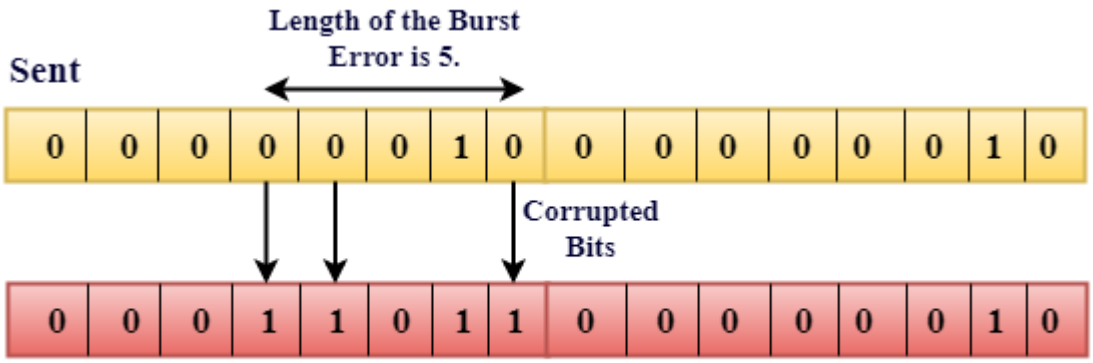


In the above figure, the message which is sent is corrupted as single-bit, i.e., 0 bit is changed to 1.

Burst Error:

The two or more bits are changed from 0 to 1 or from 1 to 0 is known as Burst Error.

The Burst Error is determined from the first corrupted bit to the last corrupted bit.



The duration of noise in Burst Error is more than the duration of noise in Single-Bit.

Burst Errors are most likely to occur in Serial Data Transmission.

The number of affected bits depends on the duration of the noise and data rate.

Error Detecting Techniques:

The most popular Error Detecting Techniques are:

- Single parity check
- Checksum
- Cyclic redundancy check

Single Parity Check-

In this technique,

- One extra bit called as **parity bit** is sent along with the original data bits.
- Parity bit helps to check if any error occurred in the data during the transmission.

Steps Involved-

Error detection using single parity check involves the following steps-

Step-01:

At sender side,

- Total number of 1’s in the data unit to be transmitted is counted.
- The total number of 1’s in the data unit is made even in case of even parity.
- The total number of 1’s in the data unit is made odd in case of odd parity.
- This is done by adding an extra bit called as **parity bit**.

Step-02:

- The newly formed code word (Original data + parity bit) is transmitted to the receiver.

Step-03:

At receiver side,

- Receiver receives the transmitted code word.
- The total number of 1’s in the received code word is counted.

Then, following cases are possible-

- If total number of 1’s is even and even parity is used, then receiver assumes that no error occurred.
- If total number of 1’s is even and odd parity is used, then receiver assumes that error occurred.
- If total number of 1’s is odd and odd parity is used, then receiver assumes that no error occurred.
- If total number of 1’s is odd and even parity is used, then receiver assumes that error occurred.

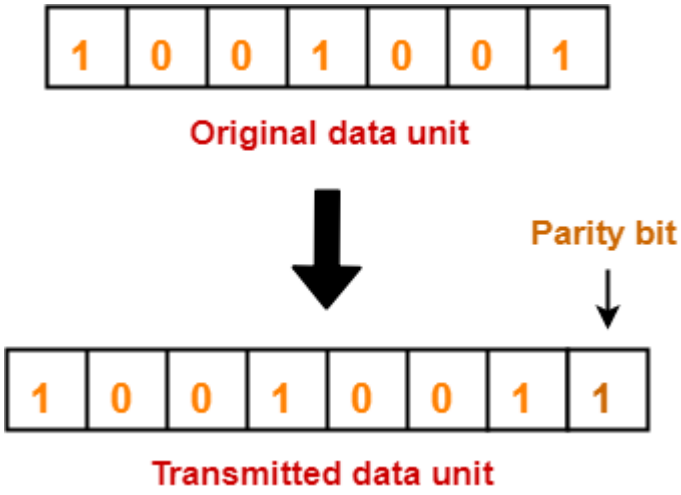
Parity Check Example-

Consider the data unit to be transmitted is 1001001 and even parity is used.

Then,

At Sender Side-

- Total number of 1’s in the data unit is counted.
- Total number of 1’s in the data unit = 3.
- Clearly, even parity is used and total number of 1’s is odd.
- So, parity bit = 1 is added to the data unit to make total number of 1’s even.
- Then, the code word 10010011 is transmitted to the receiver.



At Receiver Side-

- After receiving the code word, total number of 1's in the code word is counted.
- Consider receiver receives the correct code word = 10010011.
- Even parity is used and total number of 1's is even.
- So, receiver assumes that no error occurred in the data during the transmission.

Advantage-

- This technique is guaranteed to detect an odd number of bit errors (one, three, five and so on).
- If odd number of bits flip during transmission, then receiver can detect by counting the number of 1's.

Checksum-

Checksum is an error detection method.

Error detection using checksum method involves the following steps-

Step-01:

At sender side,

- If m bit checksum is used, the data unit to be transmitted is divided into segments of m bits.
- All the m bit segments are added.
- The result of the sum is then complemented using 1's complement arithmetic.

- The value so obtained is called as **checksum**.

Step-02:

- The data along with the checksum value is transmitted to the receiver.

Step-03:

At receiver side,

- If m bit checksum is being used, the received data unit is divided into segments of m bits.
- All the m bit segments are added along with the checksum value.
- The value so obtained is complemented and the result is checked.

Then, following two cases are possible-

Case-01: Result = 0

If the result is zero,

- Receiver assumes that no error occurred in the data during the transmission.
- Receiver accepts the data.

Case-02: Result ≠ 0

If the result is non-zero,

- Receiver assumes that error occurred in the data during the transmission.
- Receiver discards the data and asks the sender for retransmission.

Checksum Example-

Consider the data unit to be transmitted is-

10011001111000100010010010000100

Consider 8 bit checksum is used.

Step-01:

At sender side,

The given data unit is divided into segments of 8 bits as-

10011001	11100010	00100100	10000100

Now, all the segments are added and the result is obtained as-

- 10011001 + 11100010 + 00100100 + 10000100 = 1000100011
- Since the result consists of 10 bits, so extra 2 bits are wrapped around.
- 00100011 + 10 = 00100101 (8 bits)
- Now, 1's complement is taken which is 11011010.
- Thus, checksum value = 11011010

Step-02:

- The data along with the checksum value is transmitted to the receiver.

Step-03:

At receiver side,

- The received data unit is divided into segments of 8 bits.
- All the segments along with the checksum value are added.
- Sum of all segments + Checksum value = 00100101 + 11011010 = 11111111
- Complemented value = 00000000

Since the result is 0, receiver assumes no error occurred in the data and therefore accepts it.

PRACTICE PROBLEM BASED ON CHECKSUM ERROR DETECTION METHOD-

Problem-

Checksum value of 1001001110010011 and 1001100001001101 of 16 bit segment is-

1. 1010101000011111
2. 1011111000100101
3. 1101010000011110

4. 1101010000111111

Solution-

We apply the above discussed algorithm to calculate the checksum.

- 1001001110010011 + 1001100001001101 = 10010101111100000
- Since, the result consists of 17 bits, so 1 bit is wrapped around and added to the result.
- 0010101111100000 + 1 = 0010101111100001
- Now, result consists of 16 bits.
- Now, 1's complement is taken which is 1101010000011110
- Thus, checksum value = 1101010000011110

Thus, Option (C) is correct.

Cyclic Redundancy Check-

- Cyclic Redundancy Check (CRC) is an error detection method.
- It is based on binary division.

CRC Generator-

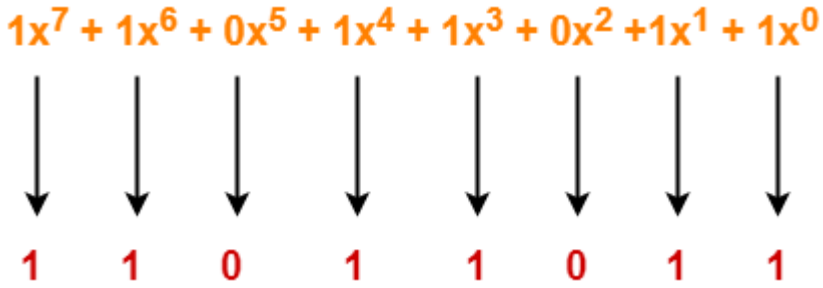
- CRC generator is an algebraic polynomial represented as a bit pattern.
- Bit pattern is obtained from the CRC generator using the following rule-

> The power of each term gives the position of the bit and the coefficient gives the value of the bit.

Example-

Consider the CRC generator is $x^7 + x^6 + x^4 + x^3 + x + 1$.

The corresponding binary pattern is obtained as-



Thus, for the given CRC generator, the corresponding binary pattern is 11011011.

Properties Of CRC Generator-

The algebraic polynomial chosen as a CRC generator should have at least the following properties-

Rule-01:

- It should not be divisible by x.
- This condition guarantees that all the burst errors of length equal to the length of polynomial are detected.

Rule-02:

- It should be divisible by x+1.
- This condition guarantees that all the burst errors affecting an odd number of bits are detected.

Important Notes-

If the CRC generator is chosen according to the above rules, then-

- CRC can detect all single-bit errors
- CRC can detect all double-bit errors provided the divisor contains at least three logic 1's.
- CRC can detect any odd number of errors provided the divisor is a factor of x+1.
- CRC can detect all burst error of length less than the degree of the polynomial.
- CRC can detect most of the larger burst errors with a high probability.

Steps Involved-

Error detection using CRC technique involves the following steps-

Step-01: Calculation Of CRC At Sender Side-

At sender side,

- A string of n 0's is appended to the data unit to be transmitted.
- Here, n is one less than the number of bits in CRC generator.
- Binary division is performed of the resultant string with the CRC generator.
- After division, the remainder so obtained is called as **CRC**.
- It may be noted that CRC also consists of n bits.

Step-02: Appending CRC To Data Unit-

At sender side,

- The CRC is obtained after the binary division.
- The string of n 0's appended to the data unit earlier is replaced by the CRC remainder.

Step-03: Transmission To Receiver-

- The newly formed code word (Original data + CRC) is transmitted to the receiver.

Step-04: Checking at Receiver Side-

At receiver side,

- The transmitted code word is received.
- The received code word is divided with the same CRC generator.
- On division, the remainder so obtained is checked.

The following two cases are possible-

Case-01: Remainder = 0

If the remainder is zero,

- Receiver assumes that no error occurred in the data during the transmission.

- Receiver accepts the data.

Case-02: Remainder ≠ 0

If the remainder is non-zero,

- Receiver assumes that some error occurred in the data during the transmission.
- Receiver rejects the data and asks the sender for retransmission.

PRACTICE PROBLEMS BASED ON CYCLIC REDUNDANCY CHECK (CRC)-

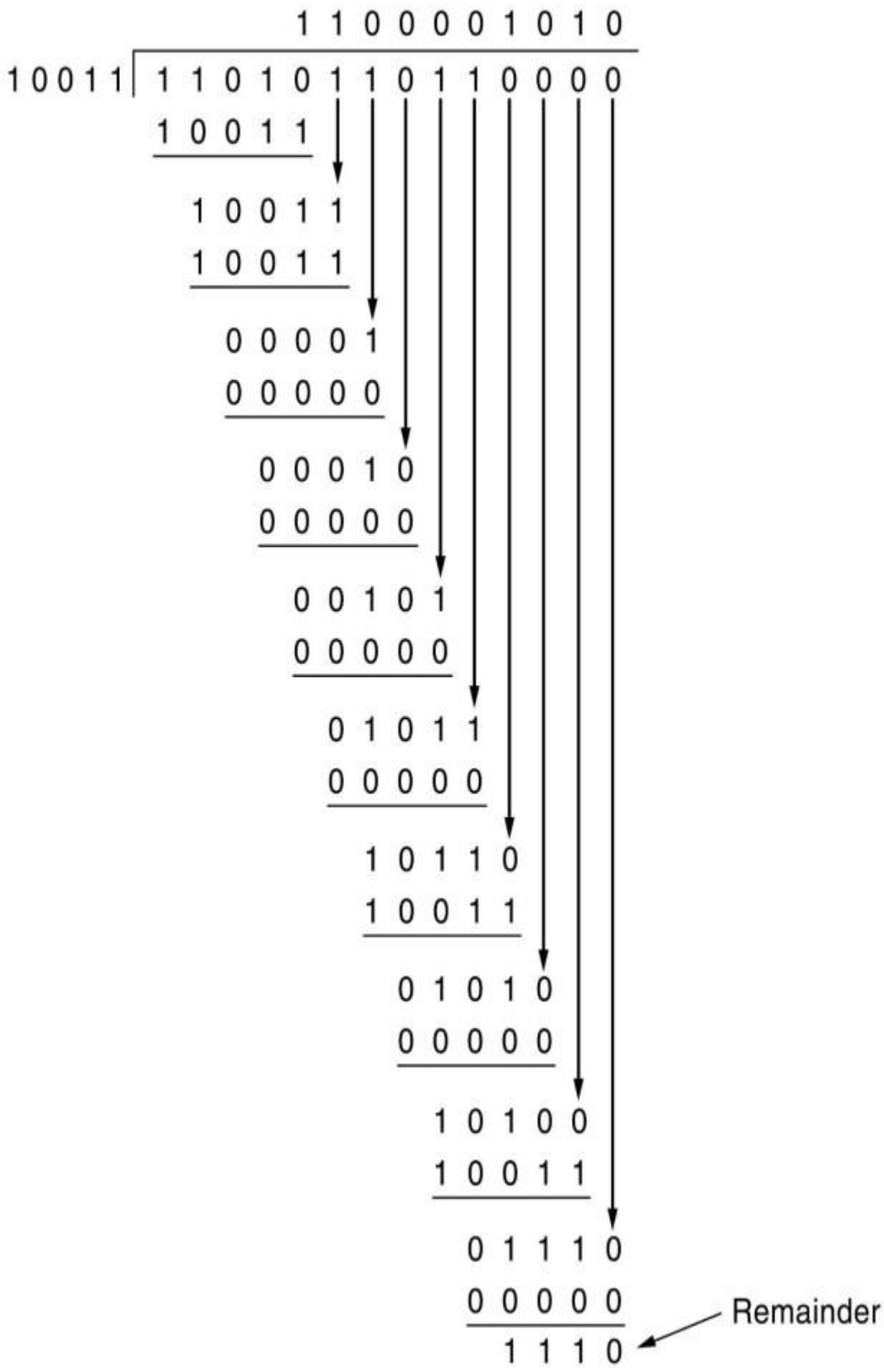
Problem-01:

A bit stream 1101011011 is transmitted using the standard CRC method. The generator polynomial is x^4+x+1. What is the actual bit string transmitted?

Solution-

- The generator polynomial $G(x) = x^4 + x + 1$ is encoded as 10011.
- Clearly, the generator polynomial consists of 5 bits.
- So, a string of 4 zeroes is appended to the bit stream to be transmitted.
- The resulting bit stream is 1101011011**0000**.

Now, the binary division is performed as-



From here, CRC = 1110.

Now,

- The code word to be transmitted is obtained by replacing the last 4 zeroes of 1101011011**0000** with the CRC.

  Thus, the code word transmitted to the receiver = 1101011011**1110**