DATA COMMUNICATION (CC-2103)

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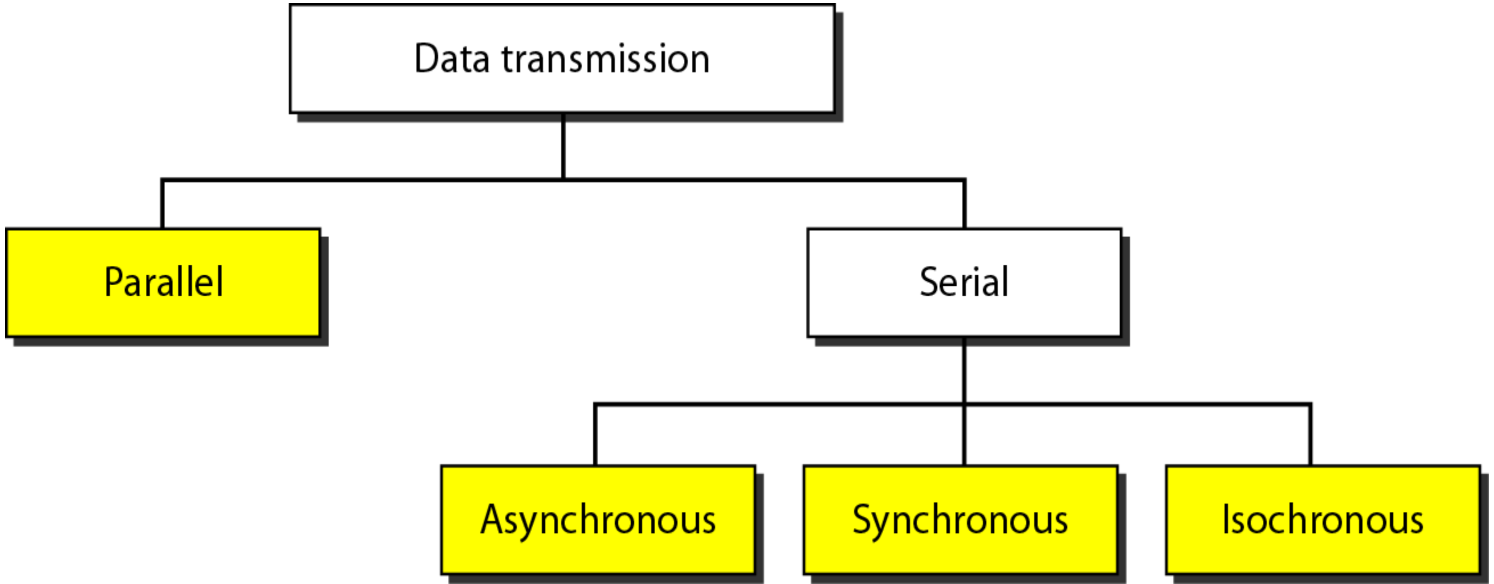
Digital Data Communication Techniques

- **TRANSMISSION MODES:**
- The transmission of binary data across a link can be accomplished in either parallel or serial mode.
- In parallel mode, multiple bits are sent with each clock tick.
- In serial mode, 1 bit is sent with each clock tick.



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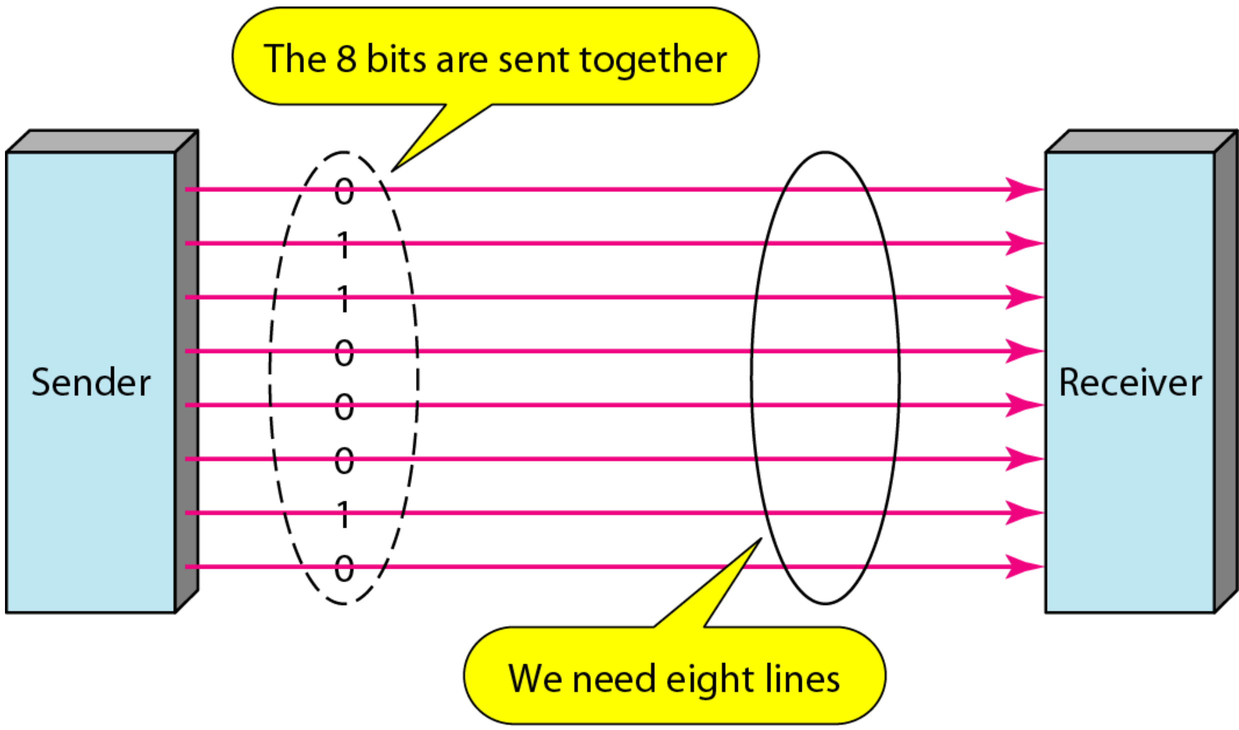
- **Parallel transmission:**
- Binary data, consisting of 1s and 0s, may be organized into groups of n bits each.
- Computers produce and consume data in groups of bits
- By grouping, we can send data n bits at a time instead of 1. This is called parallel transmission



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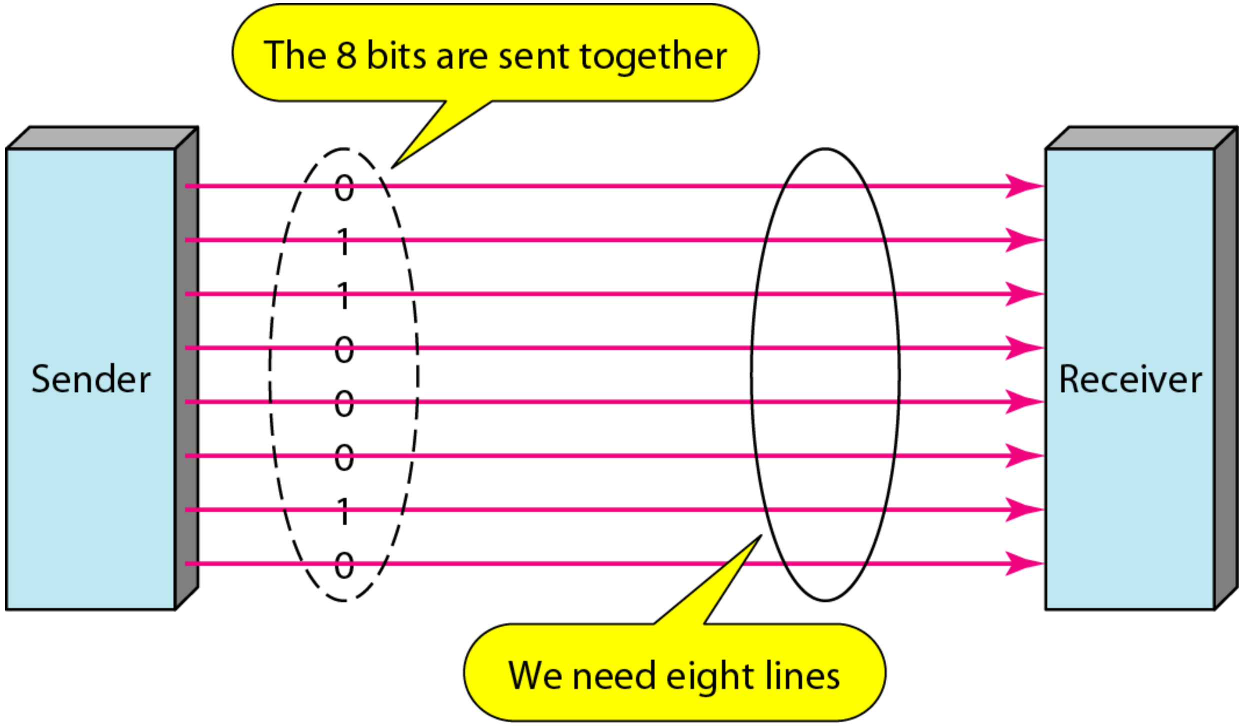
- **Parallel transmission:**
- The mechanism for parallel transmission is a conceptually simple one: Use n wires to send n bits at one time.
- That way each bit has its own wire, and all n bits of one group can be transmitted with each clock tick from one device to another



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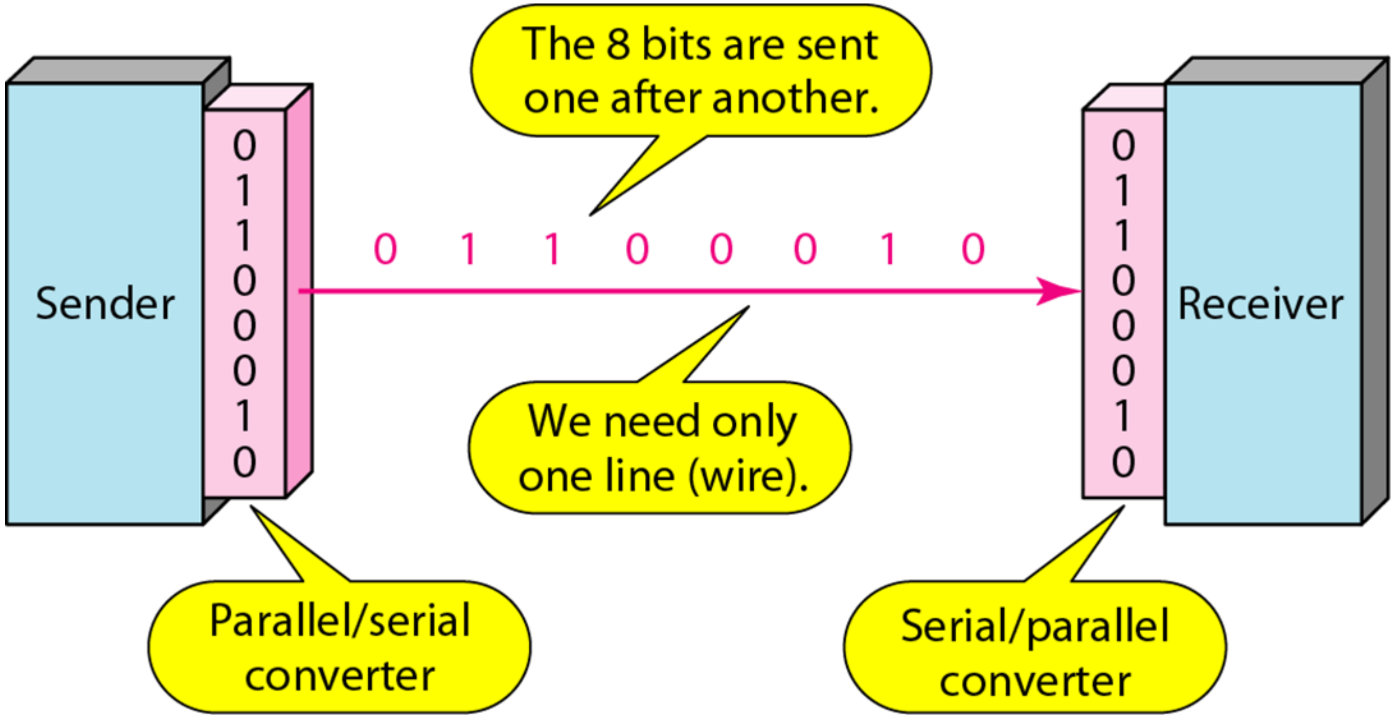
- **Serial Transmission:**
- In serial transmission one bit follows another



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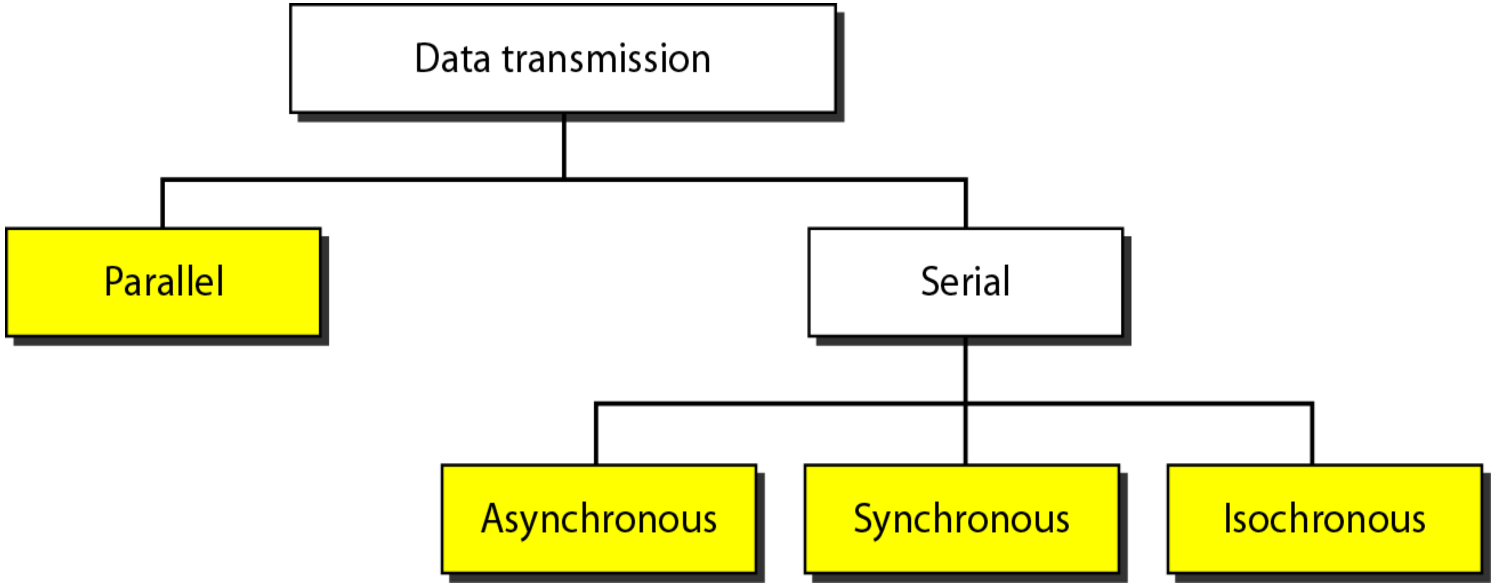
- **Serial Transmission:**
- **The advantage of serial over parallel transmission is that with only one communication channel, serial transmission reduces the cost of transmission over parallel by roughly a factor of n.**



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- **Asynchronous Transmission:**
- Asynchronous transmission is so named because the timing of a signal is unimportant.
- Instead, information is received and translated by agreed upon patterns.
- Patterns are based on grouping the bit stream into bytes. Each group, usually 8 bits, is sent along the link as a unit.
- The sending system handles each group independently, relaying it to the link whenever ready, without regard to a timer.

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- **Asynchronous Transmission:**
- Without synchronization, the receiver cannot use timing to predict when the next group will arrive.
- To alert the receiver to the arrival of a new group, therefore, an extra bit is added to the beginning of each byte. This bit, usually a 0, is called the start bit.
- To let the receiver know that the byte is finished, 1 or more additional bits are appended to the end of the byte. These bits, usually 1s, are called stop bits.
- By this method, each byte is increased in size to at least 10 bits, of which 8 bits is information and 2 bits or more are signals to the receiver.
- In addition, the transmission of each byte may then be followed by a gap of varying duration. This gap can be represented either by an idle channel or by a stream of additional stop bits.

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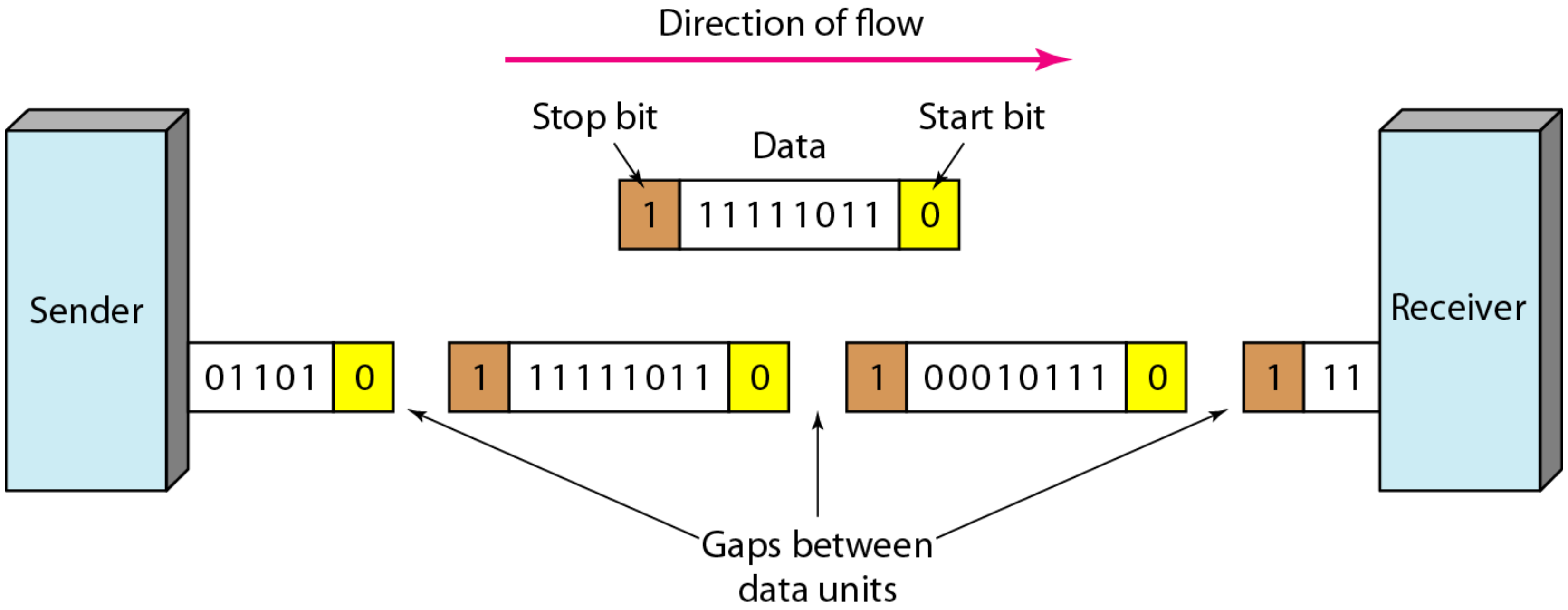
- Asynchronous Transmission:



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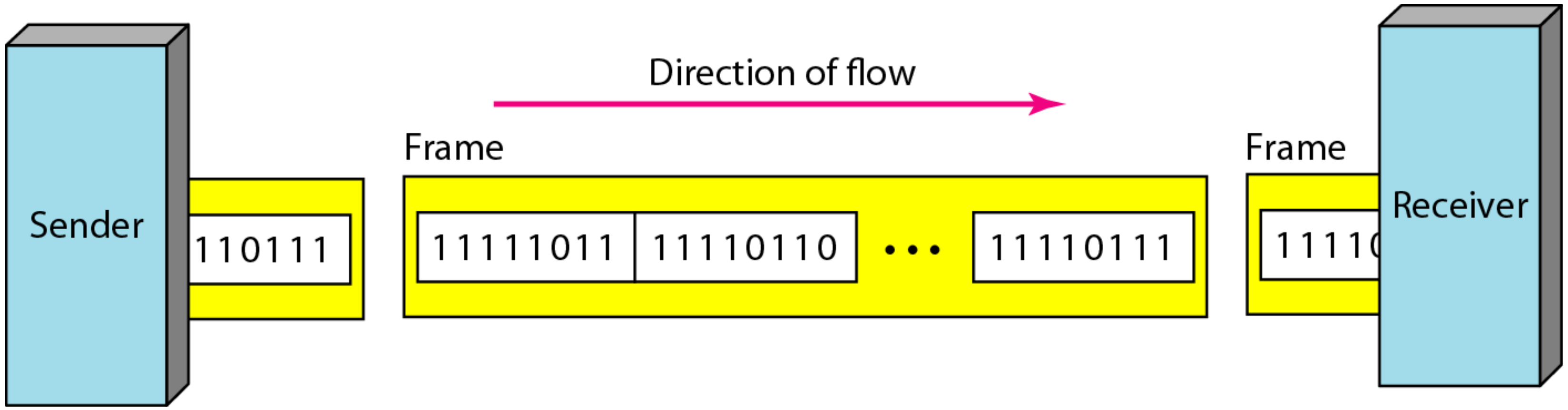
- **Synchronous Transmission:**
- In synchronous transmission, bits are usually sent as bytes and many bytes are grouped in a frame. A frame is identified with a start and an end byte
- In synchronous transmission, we send bits one after another without start or stop bits or gaps.
- It is the responsibility of the receiver to group the bits.



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- **Isochronous:**
- In real-time audio and video, in which uneven delays between frames are not acceptable, synchronous transmission fails.
- For example, TV images are broadcast at the rate of 30 images per second; they must be viewed at the same rate.
- If each image is sent by using one or more frames, there should be no delays between frames.
- In isochronous transmission we cannot have uneven gaps between frames.
- Transmission of bits is fixed with equal gaps.

- **Type of Error:**
- Whenever bits flow from one point to another, they are subject to unpredictable changes because of interference.
- This interference can change the shape of the signal.
- In a single-bit error, a 0 is changed to a 1 or a 1 to a O.
- In a burst error, multiple bits are changed.
- Some applications require that errors be detected and corrected.

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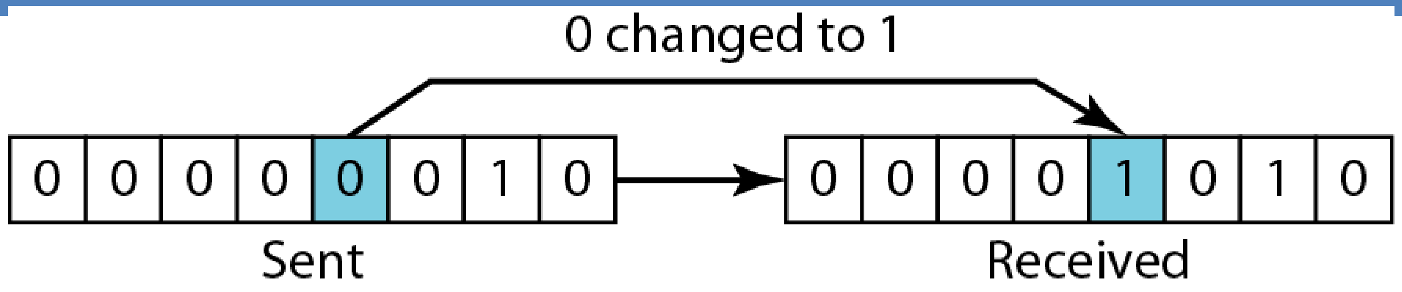
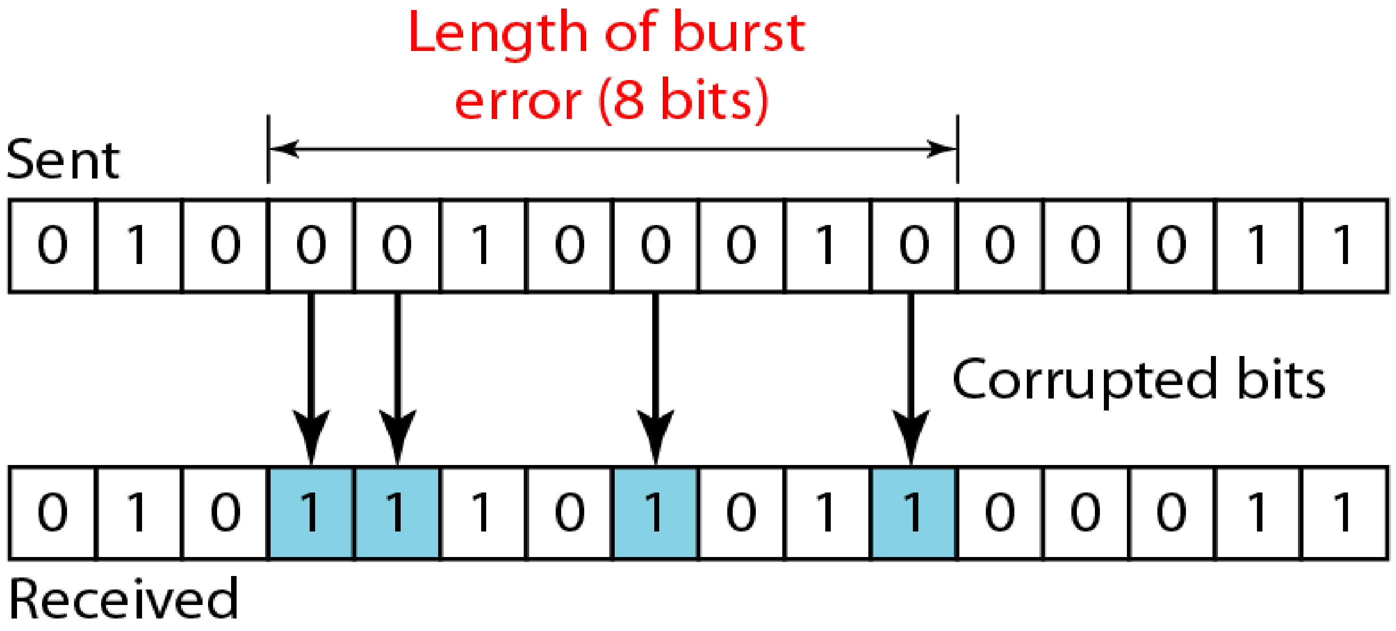
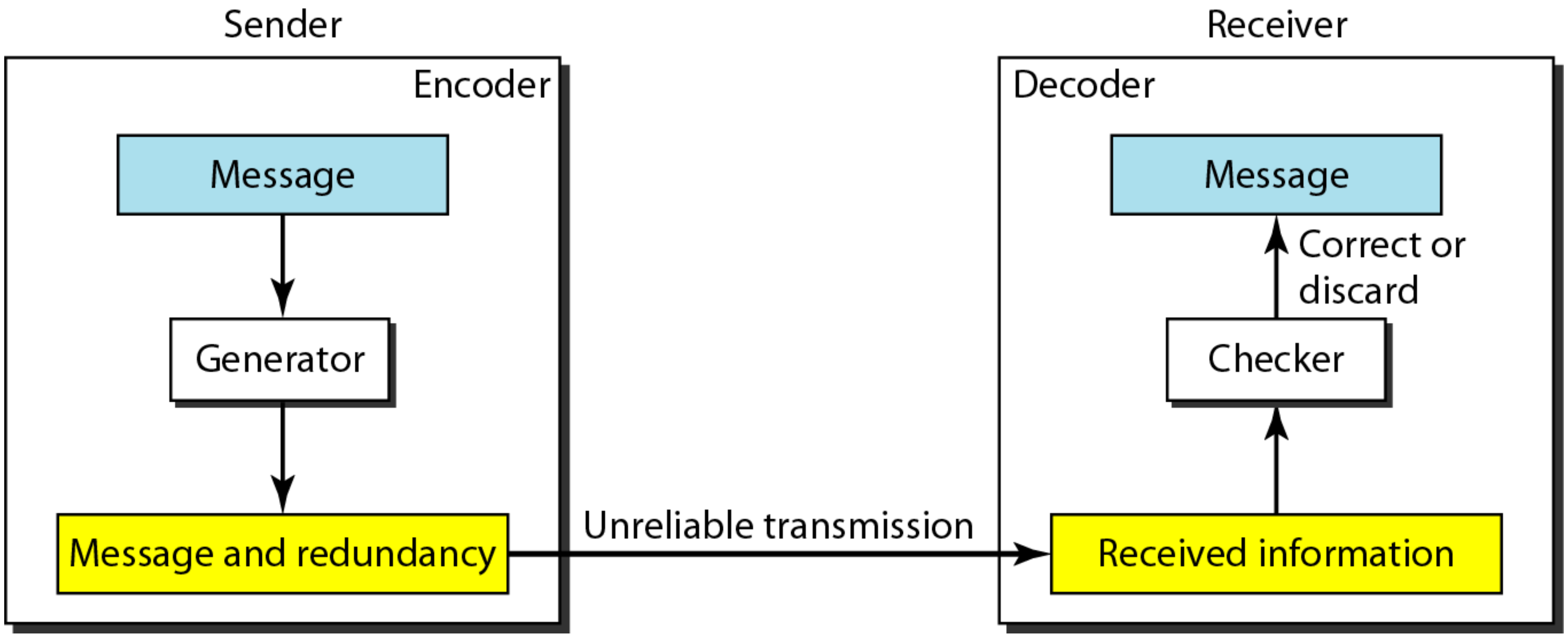
- Type of Error:
  - Single Bit Error



  - Burst error



- **Redundancy:**
- To detect or correct errors, we need to send extra (redundant) bits with data.



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- **Redundancy:**
- To be able to detect or correct errors, we need to send some extra bits with our data.
- These redundant bits are added by the sender and removed by the receiver.
- Their presence allows the receiver to detect or correct corrupted bits
- The correction of errors is more difficult than the detection. In error detection, we are
- looking only to see if any error has occurred. The answer is a simple yes or no.
- A single-bit error is the same for us as a burst error.

- **Redundancy:**
- In error correction, we need to know the exact number of bits that are corrupted and more importantly, their location in the message.
- The number of errors and the size of the message are important factors.
- If we need to correct one single error in an 8-bit data unit, we need to consider eight possible error locations; if we need to correct two errors in a data unit of the same size, we need to consider 28 possibilities.
- You can imagine the receiver's difficulty in finding 10 errors in a data unit of 1000 bits

- **Cyclic Redundancy Check:**
- Cyclic codes are special linear block codes with one extra property. In a cyclic code, if a codeword is cyclically shifted (rotated), the result is another codeword.

- **Cyclic Redundancy Check:**
- A CRC code with C(7, 4)

Dataword	*Codeword*	*Dataword*	*Codeword*
0000	0000000	1000	1000101
0001	0001011	1001	1001110
0010	0010110	1010	1010011
0011	0011101	1011	1011000
0100	0100111	1100	1100010
0101	0101100	1101	1101001
0110	0110001	1110	1110100
0111	0111010	1111	1111111

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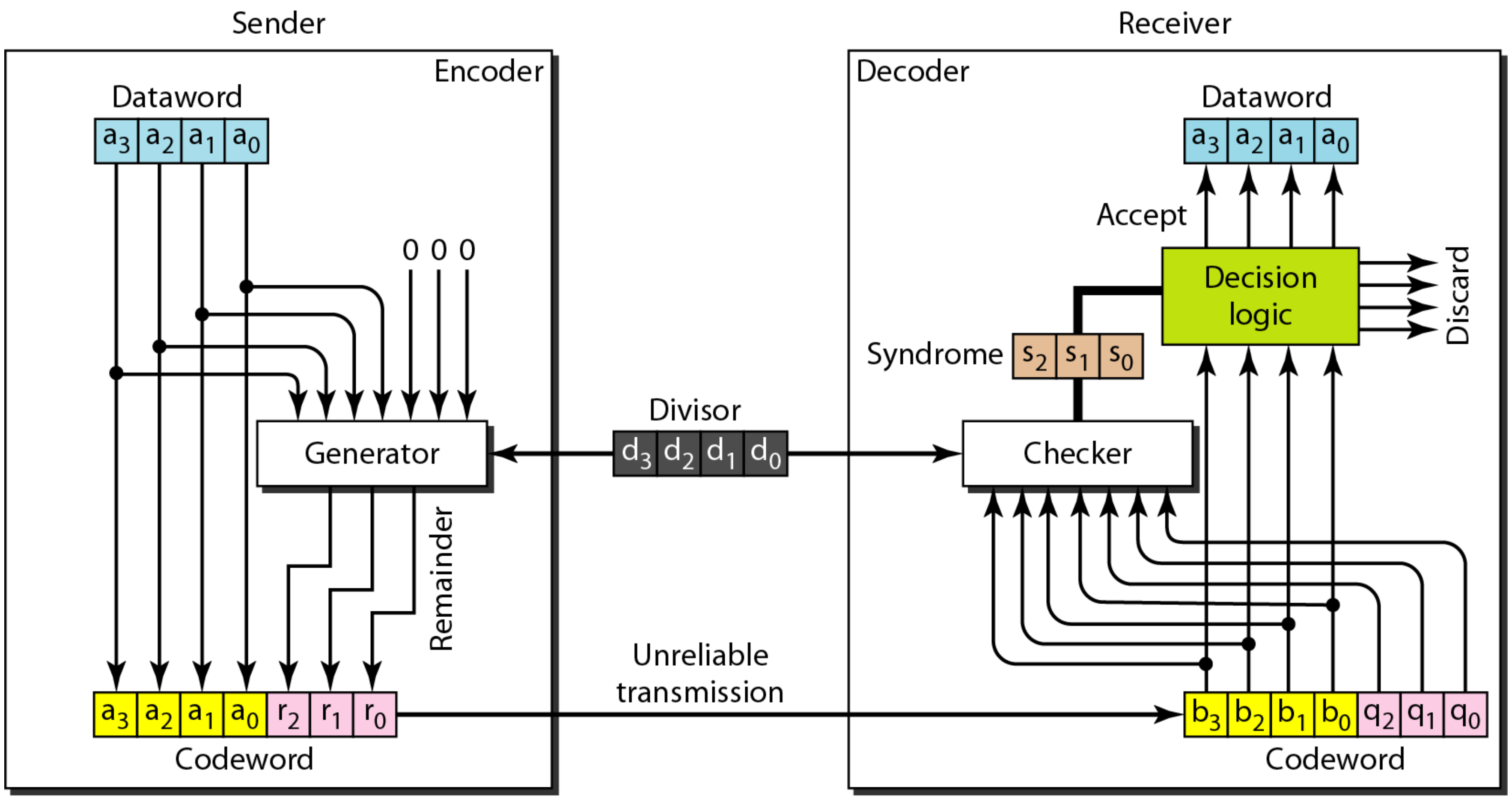
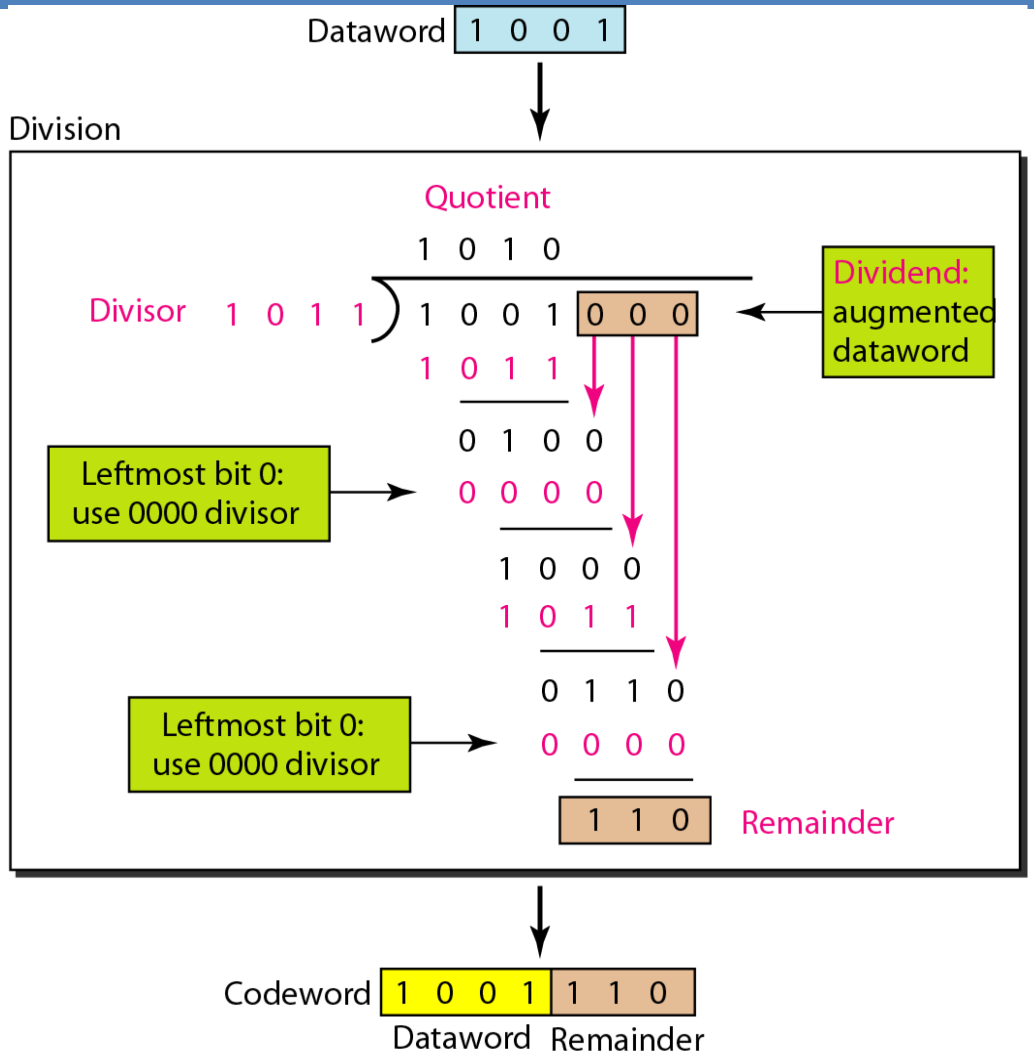
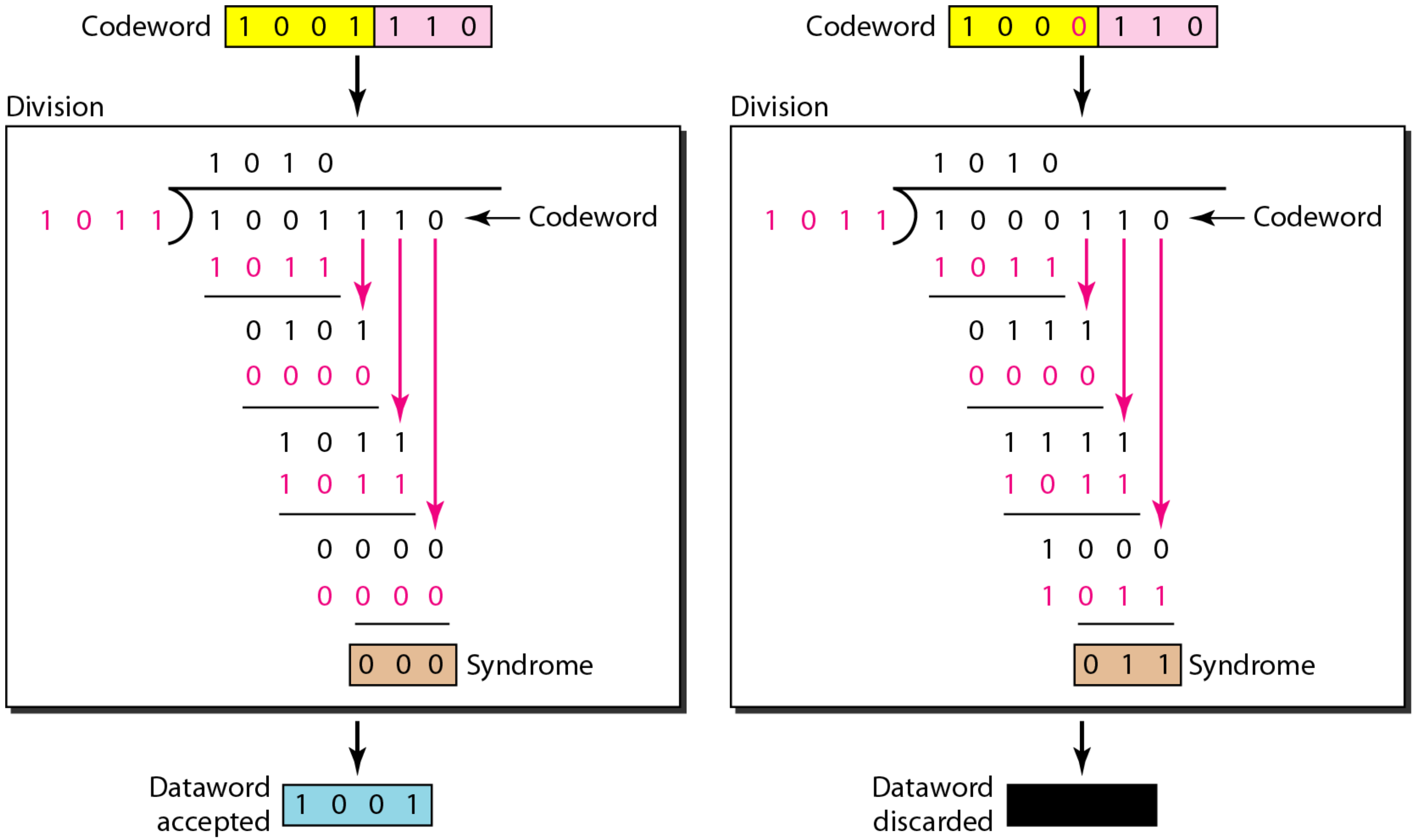
- Cyclic Redundancy Check:



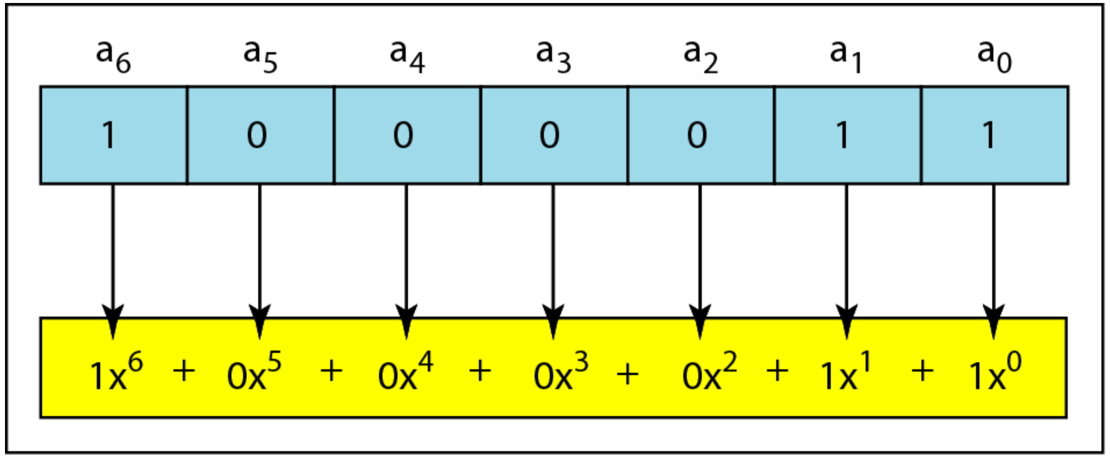
- **Cyclic Redundancy Check:**



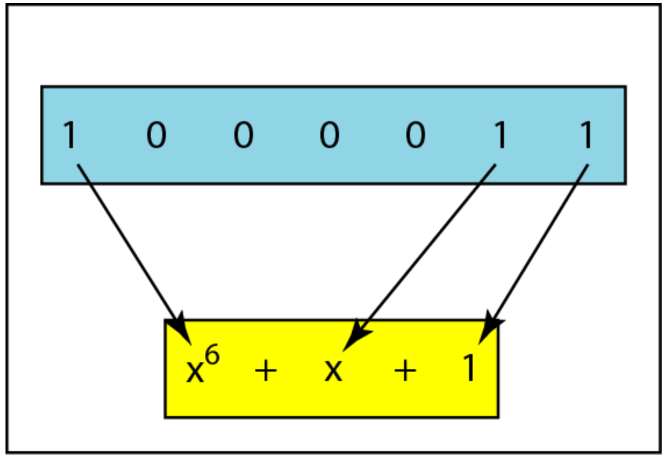
- **Cyclic Redundancy Check:**



- **Using Polynomials:**
- We can use a polynomial to represent a binary word.
- Each bit from right to left is mapped onto a power term.
- The rightmost bit represents the “0” power term. The bit next to it the “1” power term, etc.
- If the bit is of value zero, the power term is deleted from the expression.

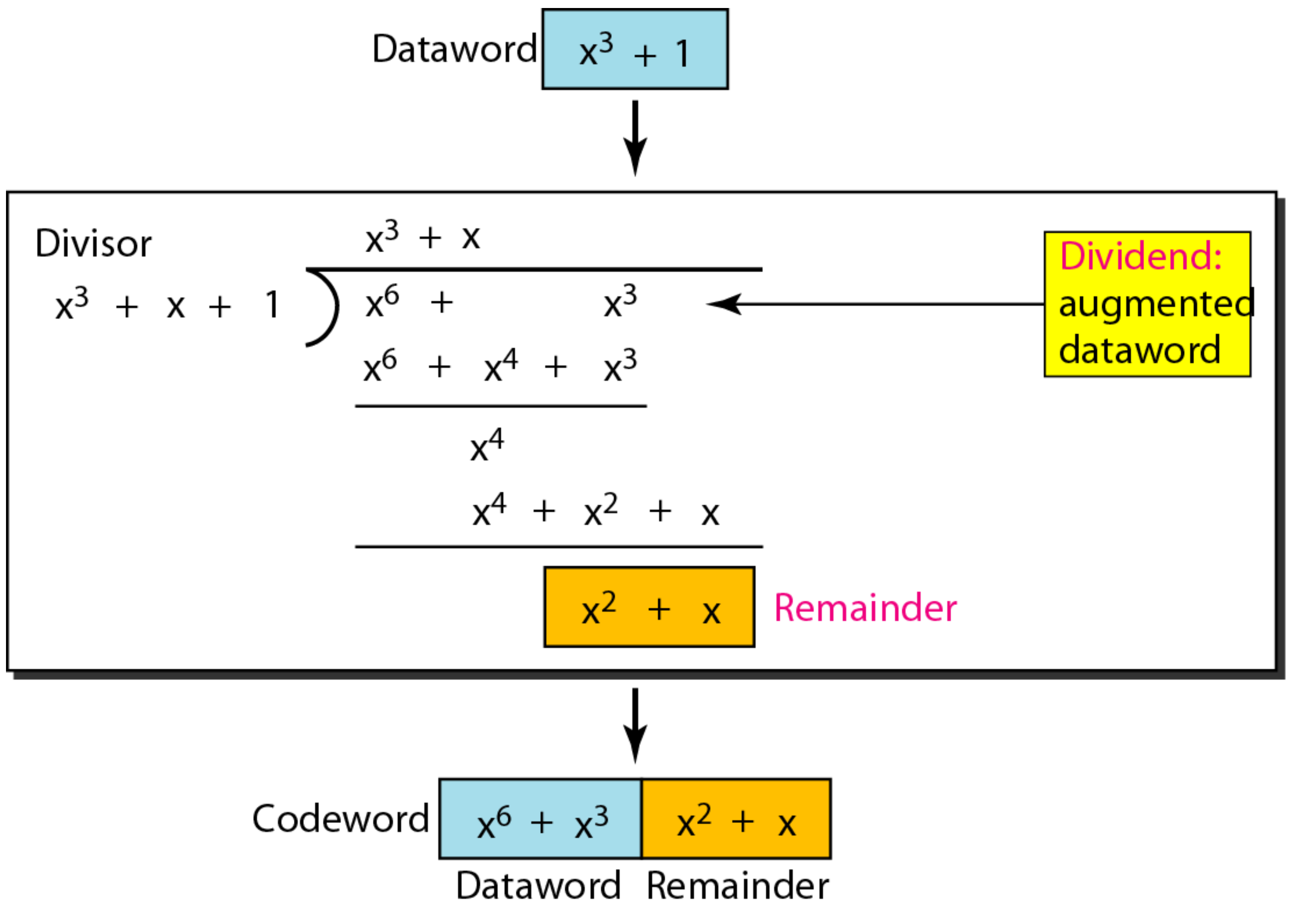


a. Binary pattern and polynomial



b. Short form

- **CRC division using polynomials:**



- **CRC division using polynomials:**
- The divisor in a cyclic code is normally called the generator polynomial or simply the generator.
- In a cyclic code,
  - If $s(x) \neq 0$, one or more bits are corrupted.
  - If $s(x) = 0$, either

    a. No bit is corrupted. or

    b. Some bits are corrupted, but the decoder failed to detect them.

- **Error Correction can be handled in two ways:**
- **Backward error correction:** Once the error is discovered, the receiver requests the sender to retransmit the entire data unit.
- **Forward error correction:** In this case, the receiver uses the error-correcting code which automatically corrects the errors.
- A single additional bit can detect the error but cannot correct it
- For correcting the errors, one has to know the exact position of the error.
- **For example**, If we want to calculate a single-bit error, the error correction code will determine which one of the seven bits is in error. To achieve this, we have to add some additional redundant bits.

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- **Hamming Code**
- **Parity bits:** The bit which is appended to the original data of binary bits so that the total number of 1s is even or odd.
- **Even parity:** To check for even parity, if the total number of 1s is even, then the value of the parity bit is 0. If the total number of 1s occurrences is odd, then the value of the parity bit is 1.
- **Odd Parity:** To check for odd parity, if the total number of 1s is even, then the value of parity bit is 1. If the total number of 1s is odd, then the value of parity bit is 0.

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- **Hamming Code**
- $2^r >= d+r+1$
- **Algorithm of Hamming code:**
- An information of 'd' bits are added to the redundant bits 'r' to form d+r.
- The location of each of the (d+r) digits is assigned a decimal value.
- The 'r' bits are placed in the positions 1,2,.....2k-1.
- At the receiving end, the parity bits are recalculated. The decimal value of the parity bits determines the position of an error.

- Relationship b/w Error position & binary number.

Error Position	Binary Number
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

- **Example**

Total number of data bits 'd' = 4

Number of redundant bits r : $2^r >= d+r+1$ $2^r >= 4+r+1$

Therefore, the value of r is 3 that satisfies the above relation.

Total number of bits = d+r = 4+3 = 7;

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- **Determining the position of the redundant bits**
- The number of redundant bits is 3.
- The three bits are represented by r1, r2, r4.
- The position of the redundant bits is calculated with corresponds to the raised power of 2.
- Therefore, their corresponding positions are 1, 2^1, 2^2.

7	6	5	4	3	2	1
1	0	1	r4	0	r2	r1

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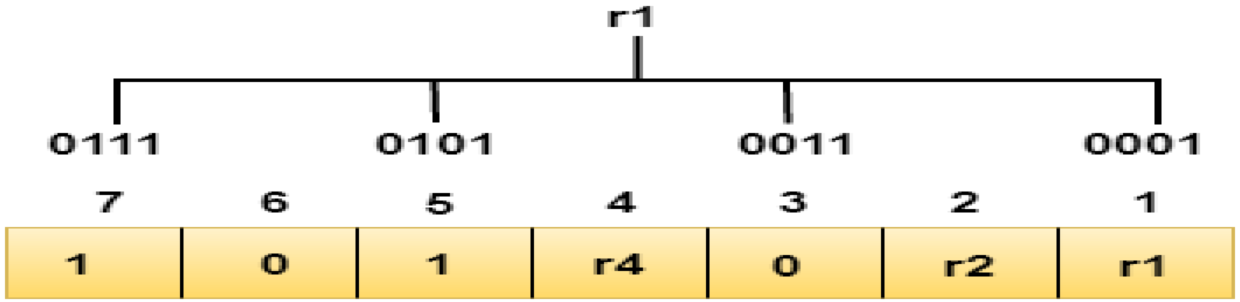
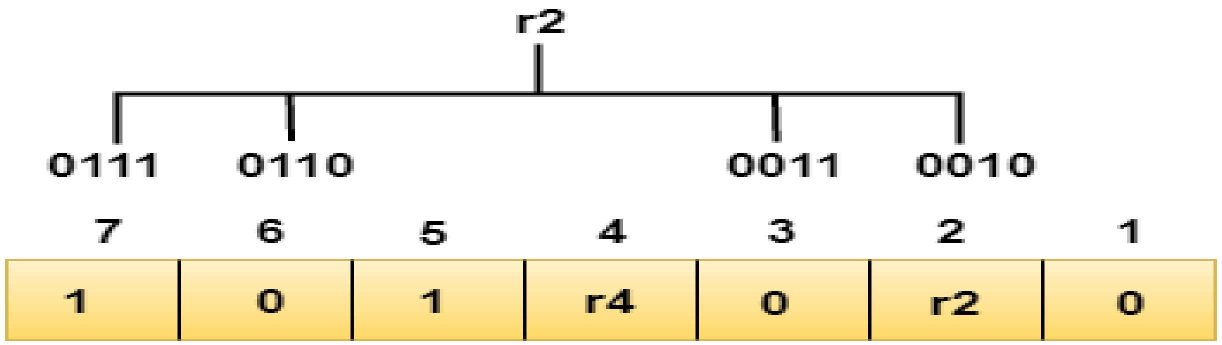
- **Determining the Parity bits**
- **Determining the r1 bit**
- The r1 bit is calculated by performing a parity check on the bit positions whose binary representation includes 1 in the first position.



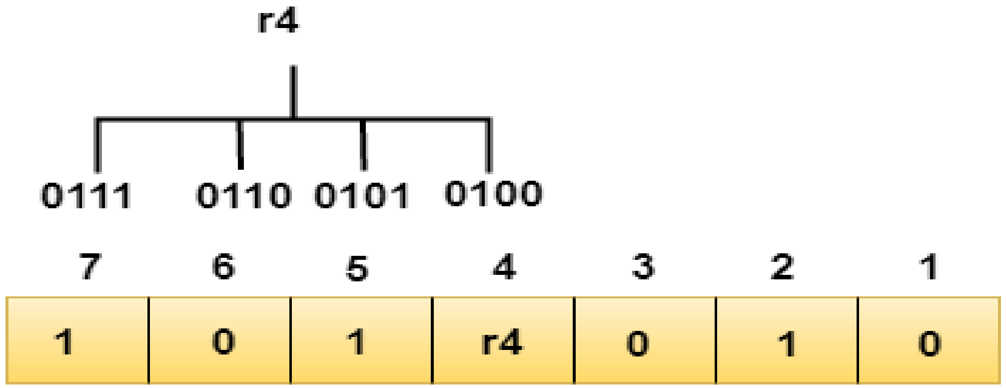
- Observe from the above figure that the bit positions that includes 1 in the first position are 1, 3, 5, 7. Now, we perform the even-parity check at these bit positions. **The total number of 1 at these bit positions corresponding to r1 is even, therefore, the value of the r1 bit is 0.**

- **Determining the r2 bit**
- The r2 bit is calculated by performing a parity check on the bit positions whose binary representation includes 1 in the second position.



- Observe from the above figure that the bit positions that includes 1 in the second position are 2, 3, 6, 7. Now, we perform the even-parity check at these bit positions. **The total number of 1 at these bit positions corresponding to r2 is odd, therefore, the value of the r2 bit is 1.**

- **Determining the r4 bit**
- The r4 bit is calculated by performing a parity check on the bit positions whose binary representation includes 1 in the third position.



- Observe from the above figure that the bit positions that includes 1 in the third position are 4, 5, 6, 7. Now, we perform the even-parity check at these bit positions. **The total number of 1 at these bit positions corresponding to r4 is even, therefore, the value of the r4 bit is 0.**

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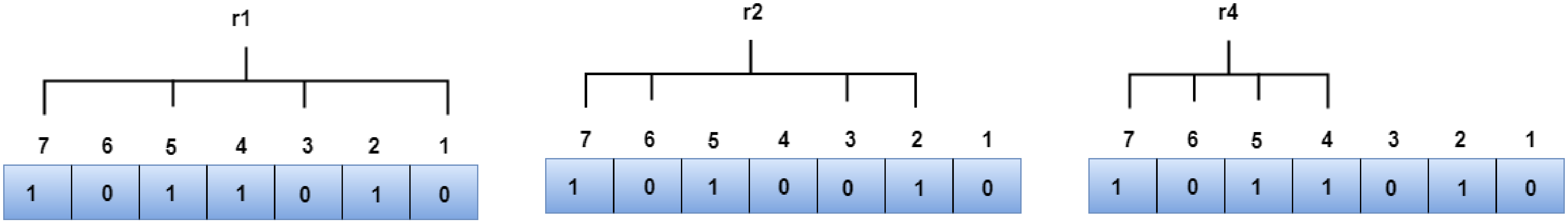
- Data transferred is given below:

7	6	5	4	3	2	1
1	0	1	0	0	1	0

- Suppose the 4th bit is changed from 0 to 1 at the receiving end, then parity bits are recalculated.

- **Data transferred is given below:**
- Suppose the 4th bit is changed from 0 to 1 at the receiving end, then parity bits are recalculated.



- **The binary representation of redundant bits, i.e., r4r2r1 is 100, and its corresponding decimal value is 4. Therefore, the error occurs in a 4th bit position. The bit value must be changed from 1 to 0 to correct the error.**

References

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