Error Detection and Correction

- **Types of Errors**
- **Detection**
- **Correction**

Basic concepts

★ Networks must be able to transfer data from one device to another with complete accuracy.

★ Data can be corrupted during transmission.

★ For reliable communication, errors must be detected and corrected.

★ **Error detection and correction** are implemented either at the **data link layer** or the **transport layer** of the OSI model.
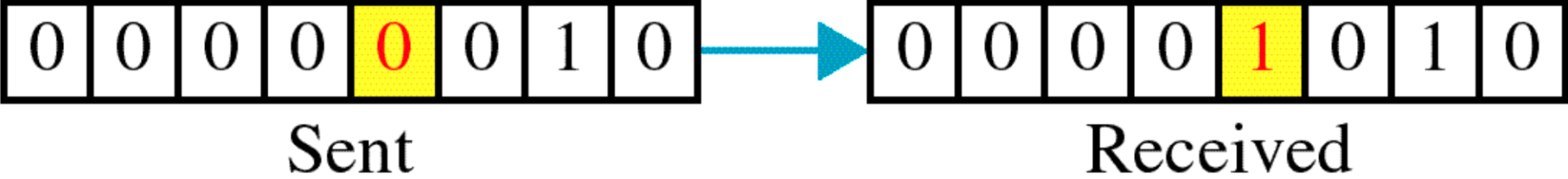
Types of Errors

Single Bit Error
Burst Error

Single-bit error

0 changed to 1

| 0 | 0 | 0 | 0 | **0** | 0 | 1 | 0 |

Sent

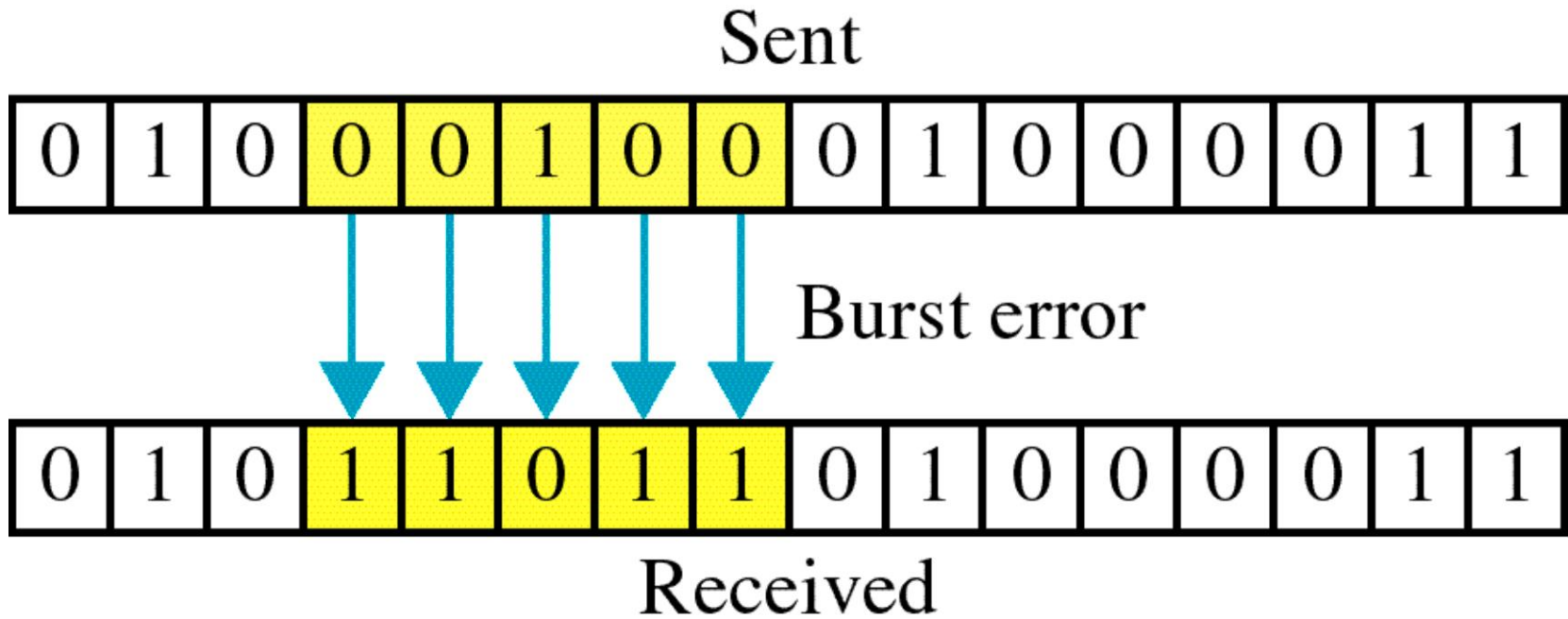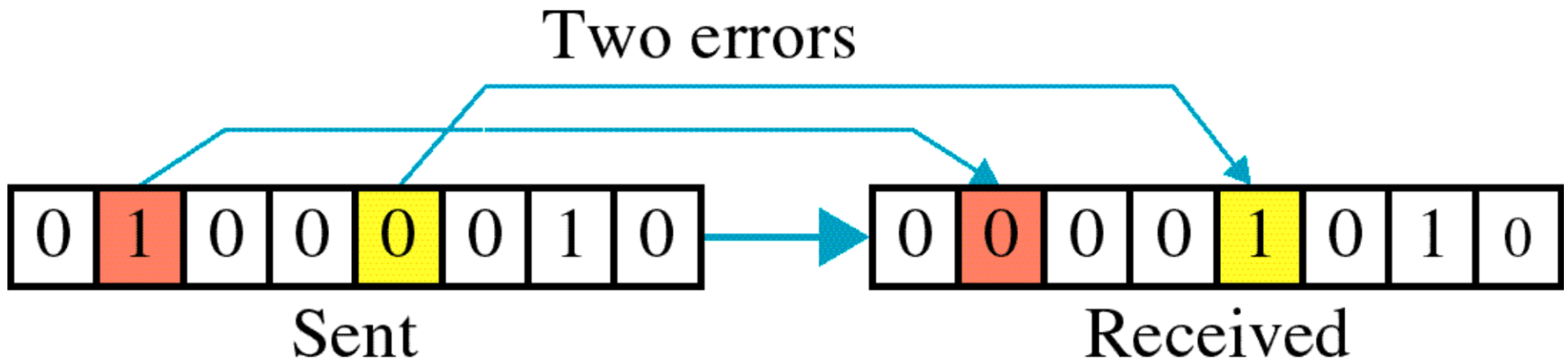| 0 | 0 | 0 | 0 | **1** | 0 | 1 | 0 |

Received

Single bit errors are the **least likely** type of errors in serial data transmission because the noise must have a very short duration which is very rare. However this kind of errors can happen in parallel transmission.

Example:

★If data is sent at 1Mbps then each bit lasts only 1/1,000,000 sec. or 1 μs.

★For a single-bit error to occur, the noise must have a duration of only 1 μs, which is very rare.

Burst error

Sent

0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1

Burst error

0	1	0	1	1	0	1	1	0	1	0	0	0	0	1	1

Received

Two errors

Sent

Received

The term **burst error** means that two or more bits in the data unit have changed from 1 to 0 or from 0 to 1.

Burst errors does not necessarily **mean that the errors occur in consecutive bits**, the length of the burst is measured from the first corrupted bit to the last corrupted bit. Some bits in between may not have been corrupted.

★**Burst error is most likely to happen in serial transmission** since the duration of noise is normally longer than the duration of a bit.

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

Example:

➡If data is sent at rate = 1Kbps then a noise of 1/100 sec can affect 10 bits.(1/100*1000)

➡If same data is sent at rate = 1Mbps then a noise of 1/100 sec can affect 10,000 bits.(1/100*10^6)
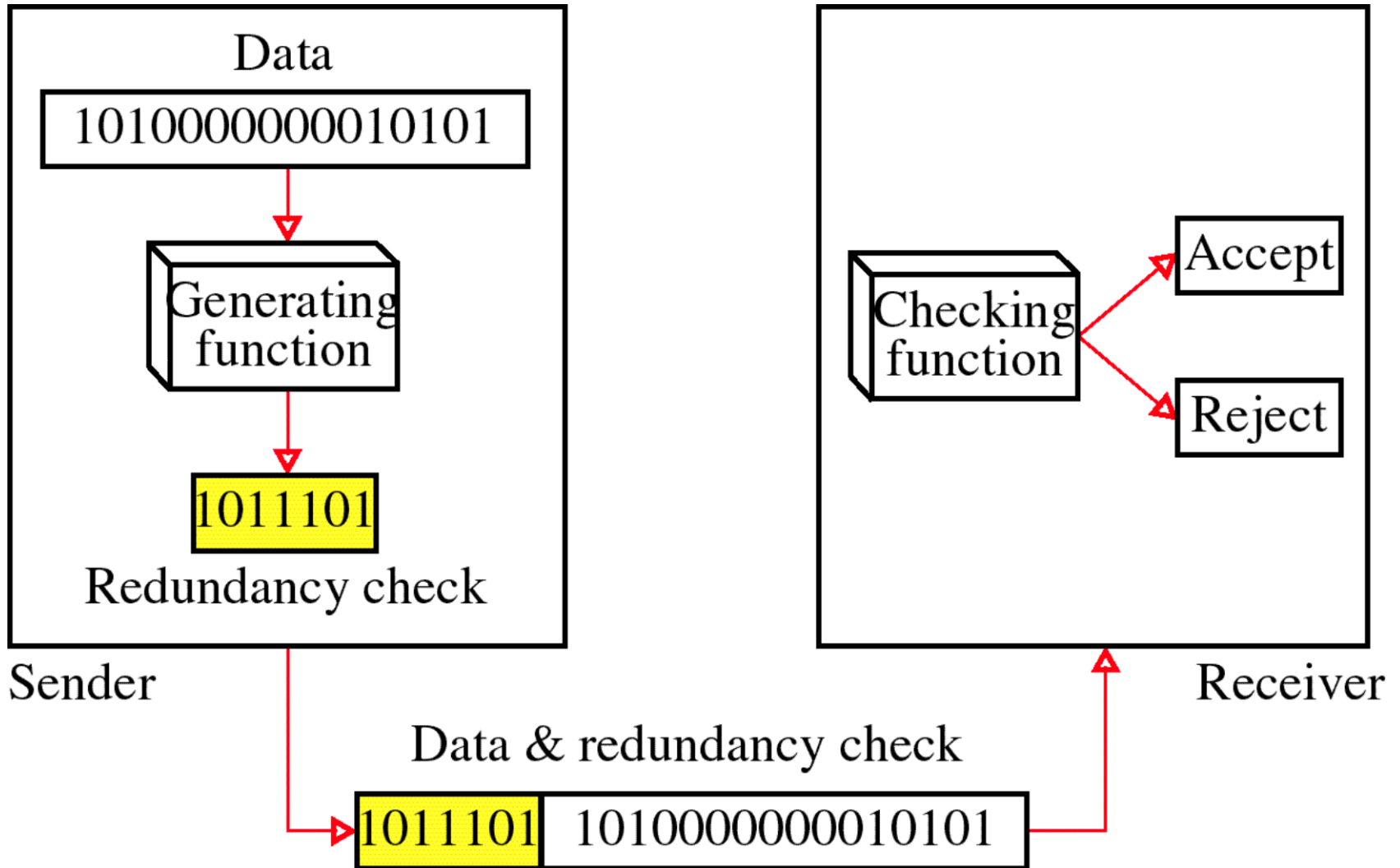
Error detection

Error detection means to decide whether the received data is correct or not without having a copy of the original message.

Error detection **uses the concept of redundancy**, **which means** adding extra bits for detecting errors at the destination.

Redundancy

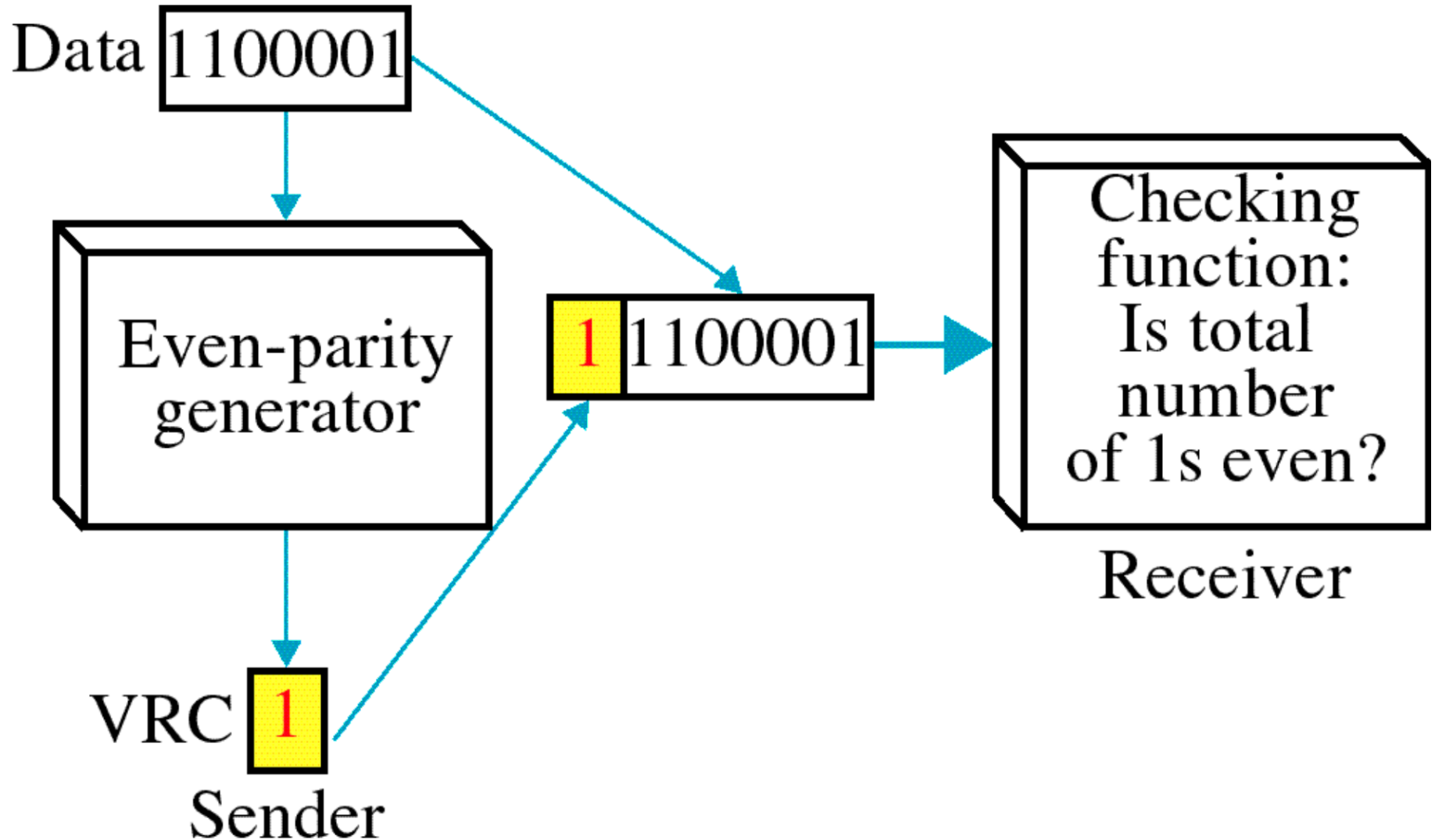It is a method of inserting additional bits along with the data

Redundancy

Four types of redundancy checks are used in data communications

1. Simple Parity Check (VPC)
2. Two Dimensional Parity Check
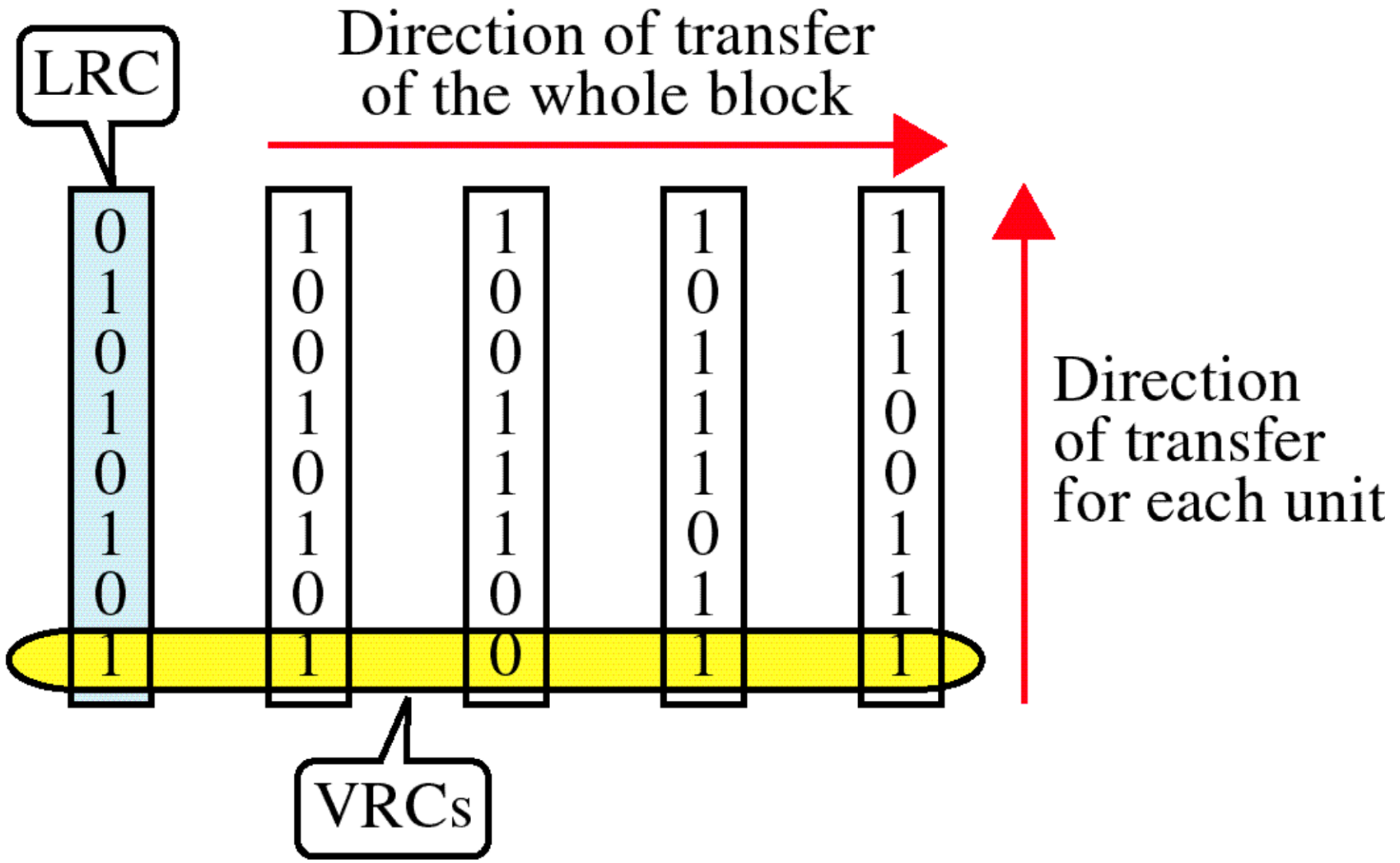3. Cyclic Redundancy Check
4. Checksum

Vertical Redundancy Check
VRC

Data `1100001`

Even-parity generator

`1` `1100001`

VRC `1`

Sender

Checking function: Is total number of 1s even?

Receiver

Performance

➔ It can detect single bit error

➔ It can detect burst errors only if the total number of errors is odd.

Two Dimensional Parity Check/2D Parity Checking

Performance

- It is used to detect burst error

- If 2 bits in one data damaged and two bits exactly in other data also changed the checker will not detect error.

	Original	Changed
	11110000	01110001
•	11000011	01000010

Cyclic Redundancy Check
CRC
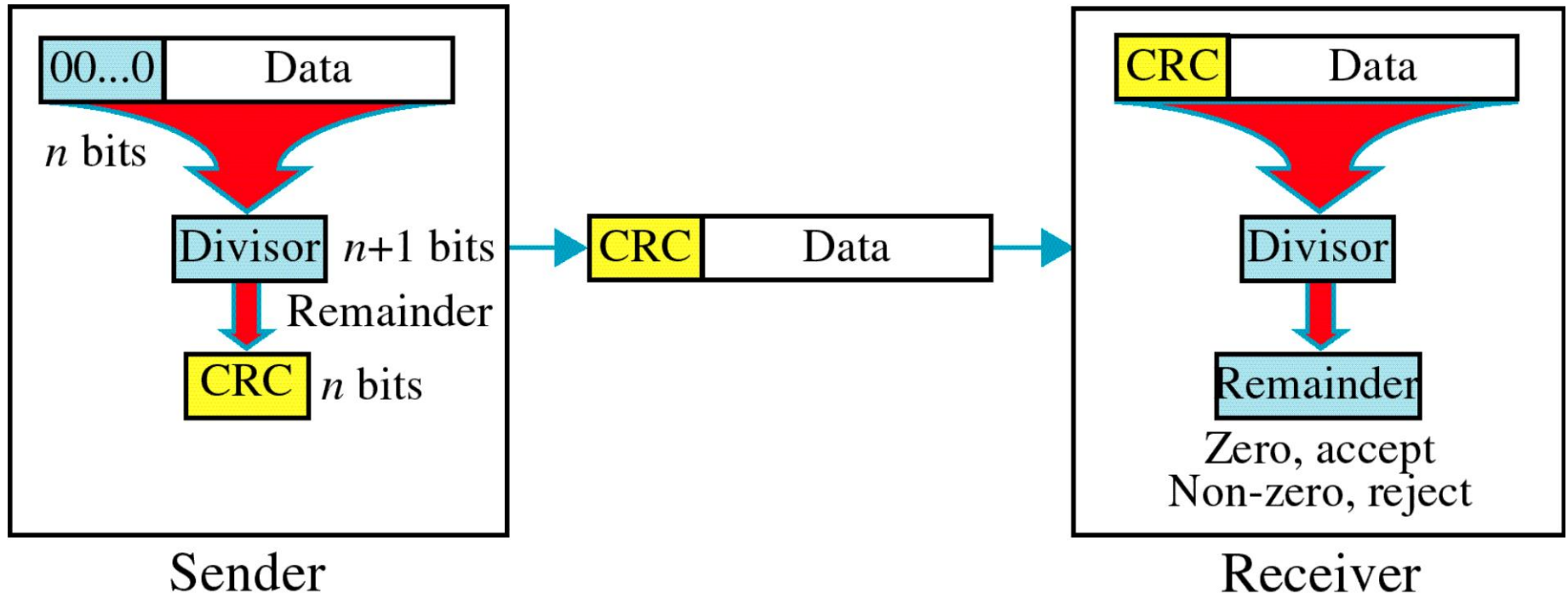
Cyclic Redundancy Check

- Given a k-bit frame or message, the transmitter generates an n-bit sequence, known as a *frame check sequence (FCS)*, so that the resulting frame, consisting of (k+n) bits, is exactly divisible by some predetermined number.

- The receiver then divides the incoming frame by the same number and, if there is no remainder, assumes that there was no error.
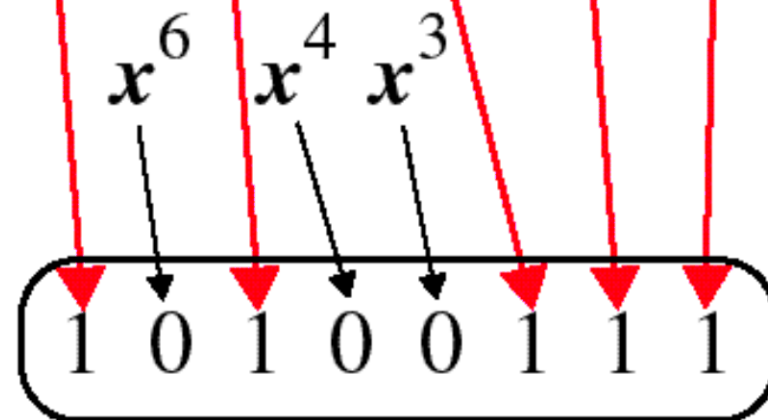
Binary Division
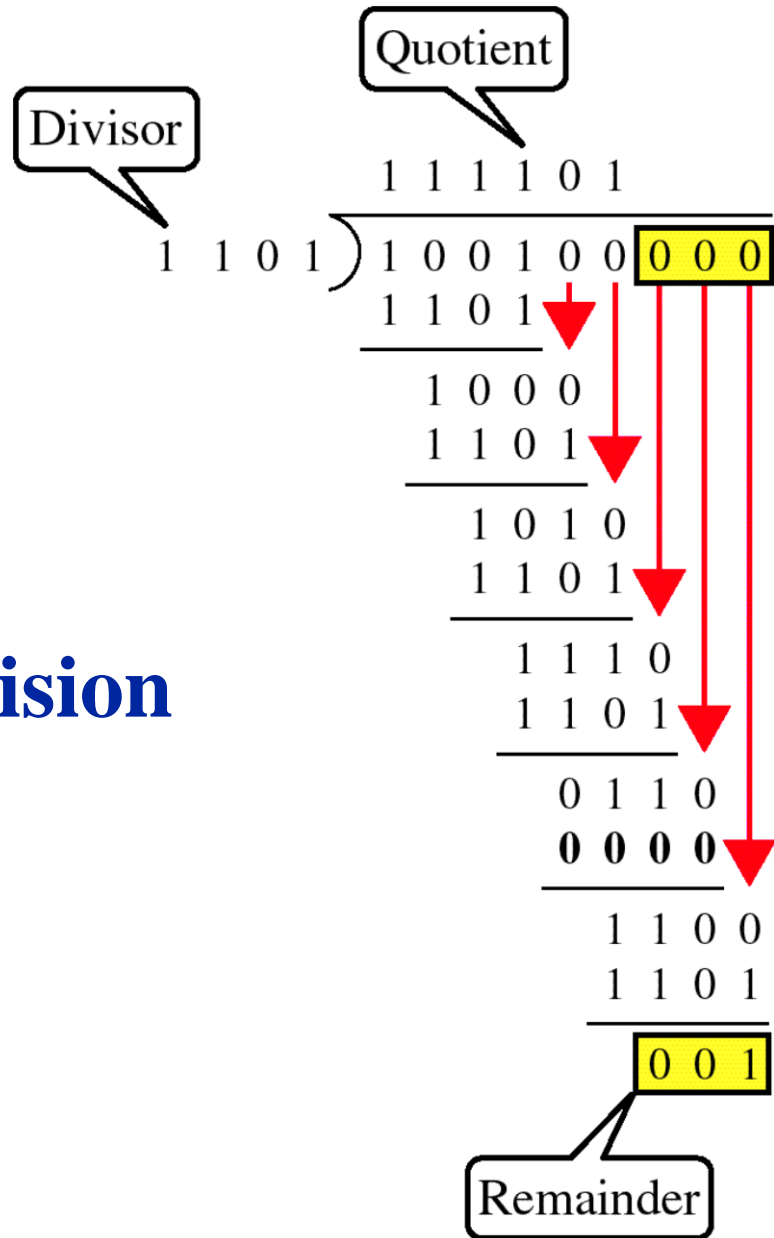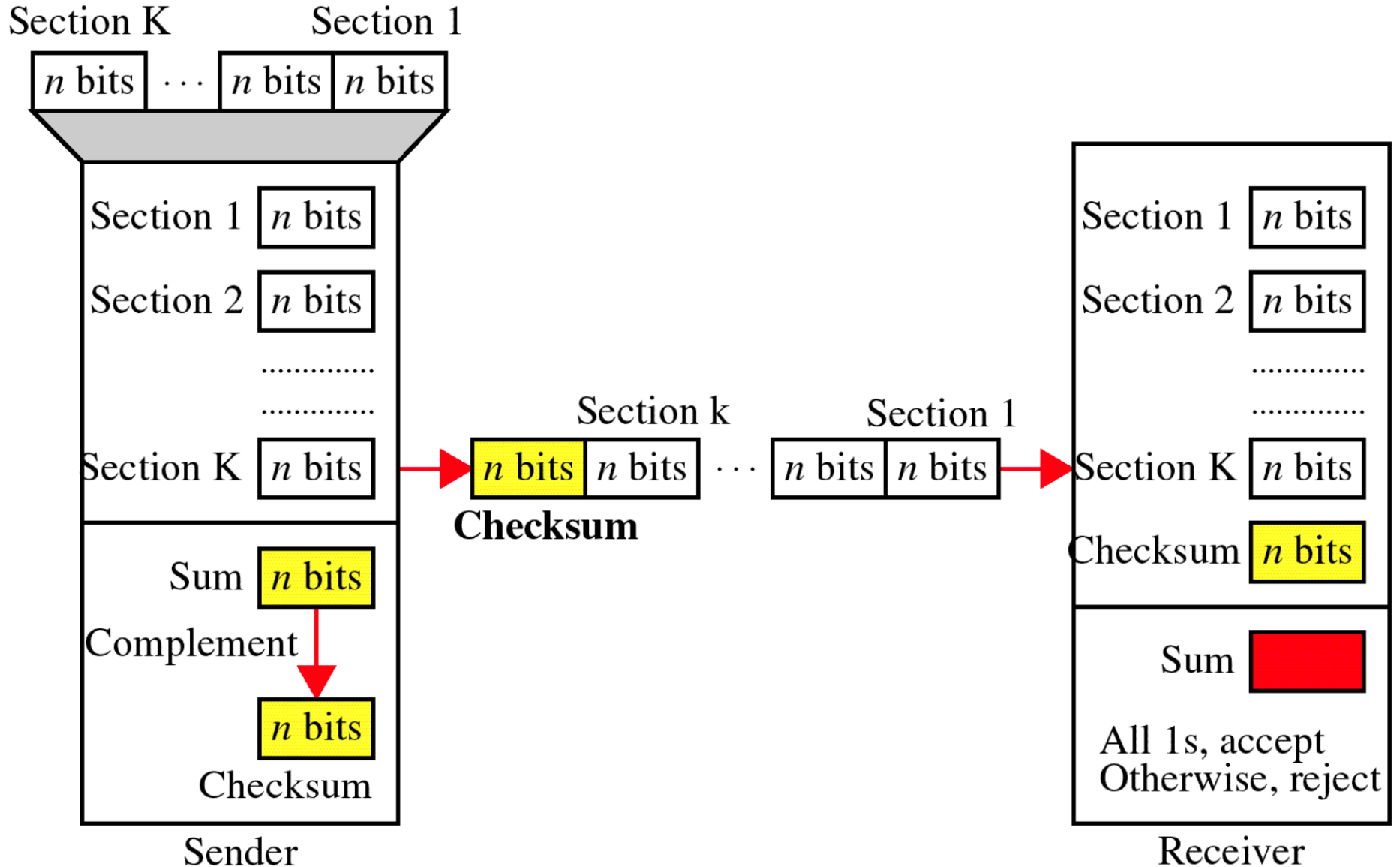
Polynomial

$$x^7 + x^5 + x^2 + x + 1$$

Polynomial and Divisor

Polynomial

$$x^7 + x^5 + x^2 + x + 1$$

$x^6 \quad x^4 \quad x^3$

1 0 1 0 0 1 1 1

Divisor

Checksum

At the sender

➲ The unit is divided into k sections, each of n bits.

➲ All sections are added together using one's complement to get the sum.

➲ The sum is complemented and becomes the checksum.

➲ The checksum is sent with the data

Sender Checksum

Data 10101001

Data 00111001

_____

Sum 11100010

1's 00011101

Receiver Checksum

Data 10101001

Data 00111001

1's   00111011

———————————————————

11111111

00000000

At the receiver

- The unit is divided into k sections, each of n bits.

- All sections are added together using one's complement to get the sum.

- The sum is complemented.

- If the result is zero, the data are accepted: otherwise, they are rejected.

Performance

➜ The checksum detects all errors involving an odd number of bits.

➜ It detects most errors involving an even number of bits.

➜ If one or more bits of a segment are damaged and the corresponding bit or bits of opposite value in a second segment are also damaged, the sums of those columns will not change and the receiver will not detect a problem.

Error Correction

It can be handled in two ways:

1) receiver can have the sender retransmit the entire data unit.

2) The receiver can use an error-correcting code, which automatically corrects certain errors.

Single-bit error correction

To correct an error, the receiver reverses the value of the altered bit. To do so, it must know which bit is in error.

Number of redundancy bits needed
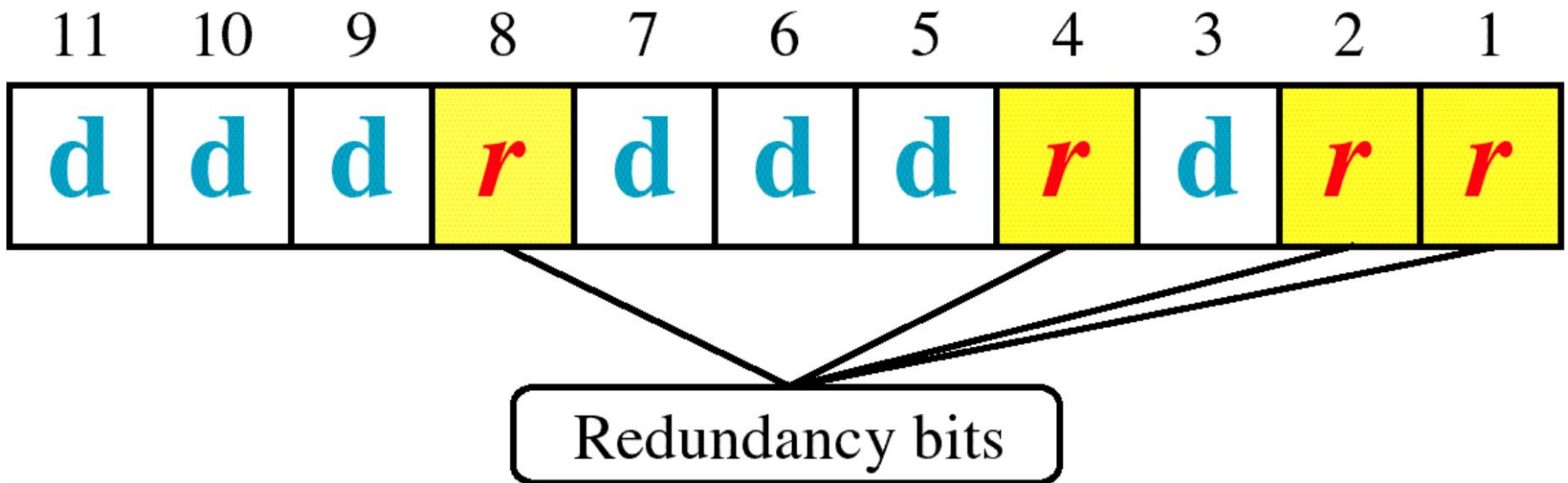
- Let data bits = m

- Redundancy bits = r

$\therefore$ Total message sent = $m+r$

The value of r must satisfy the following relation:
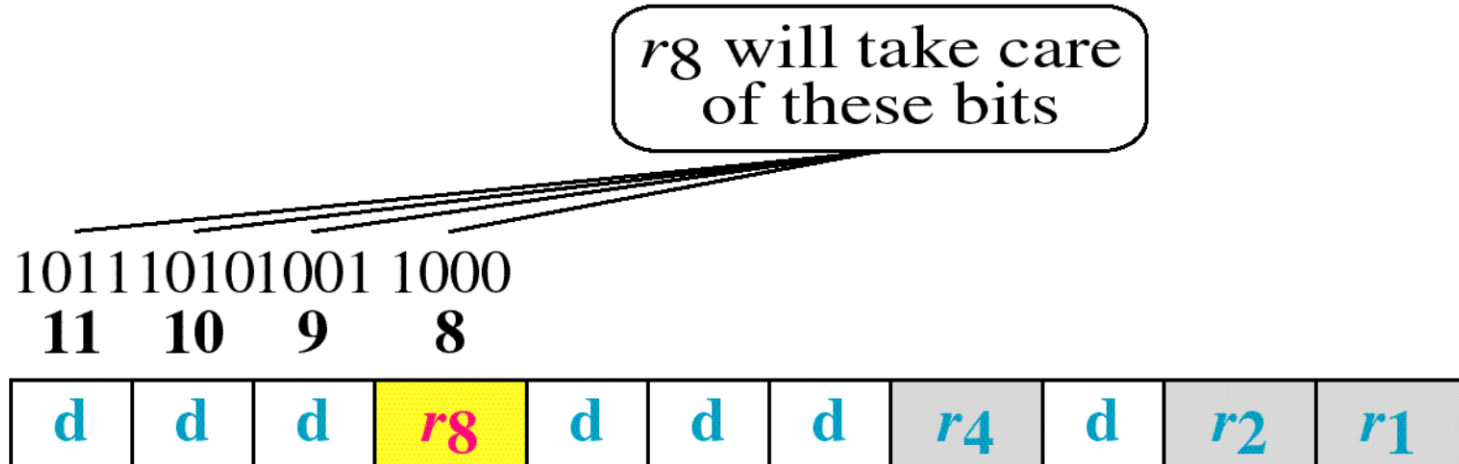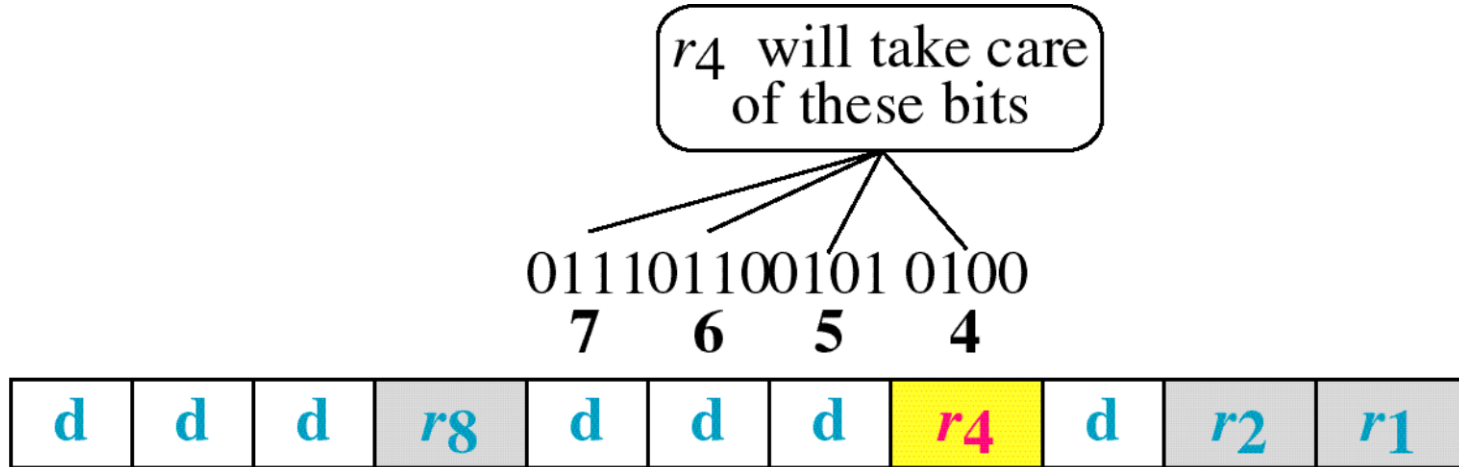
$$2^r \geq m+r+1$$

Error Correction

Data (m) bits · · · Redundancy (r) bits

Total $m + r$ bits
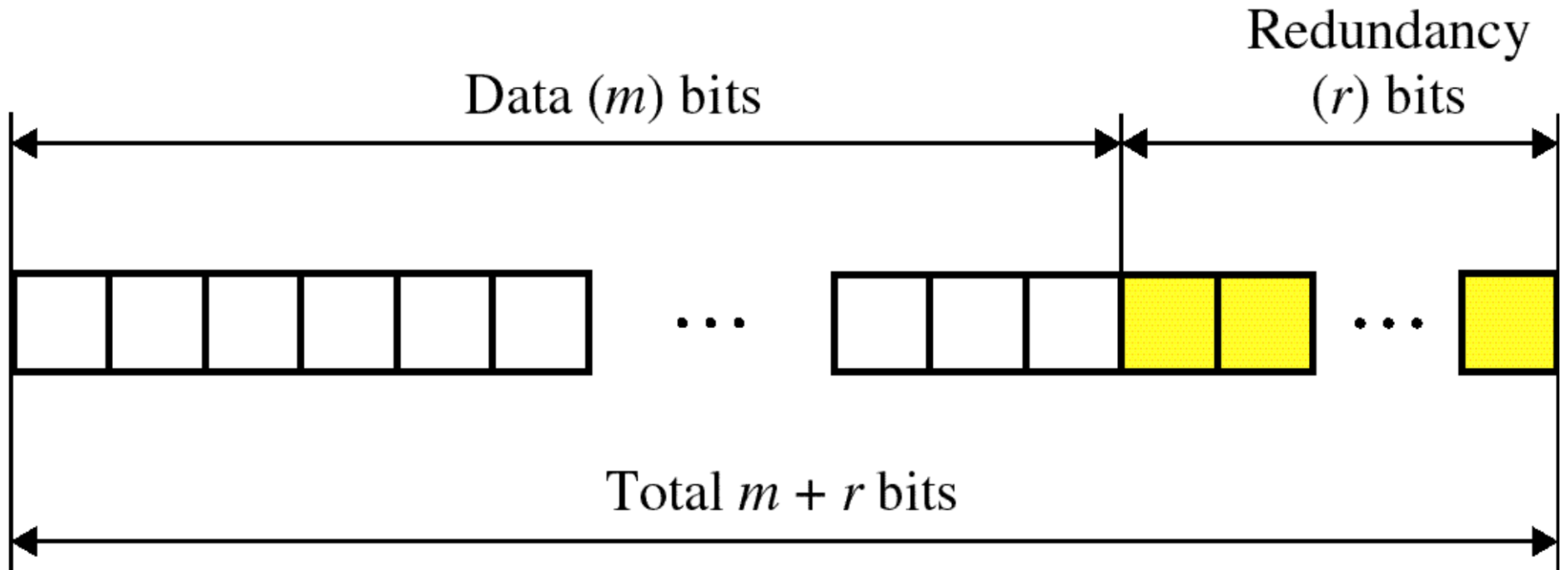
Hamming Code

Hamming Code

r1 will take care of these bits

1011   1001   0111   0101   0011   0001
11   9   7   5   3   1

| d | d | d | r8 | d | d | d | r4 | d | r2 | r1 |

r2 will take care of these bits

10111010   01110110   0011 0010
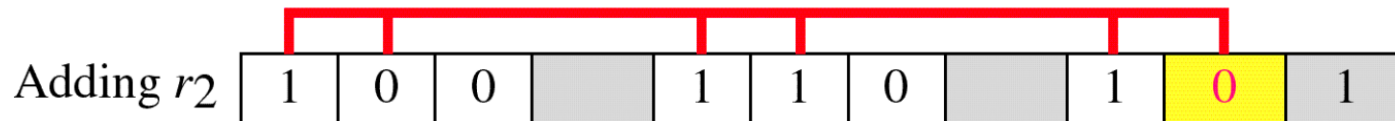11   10   7   6   3   2

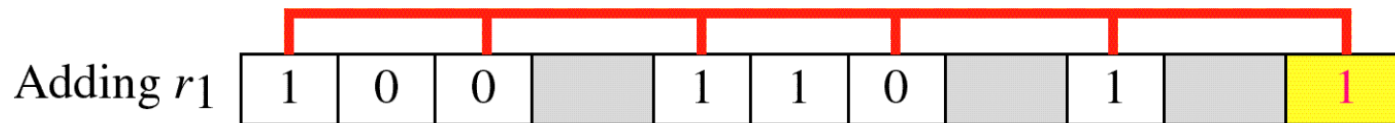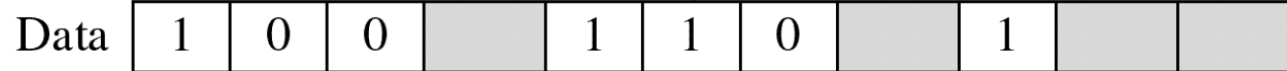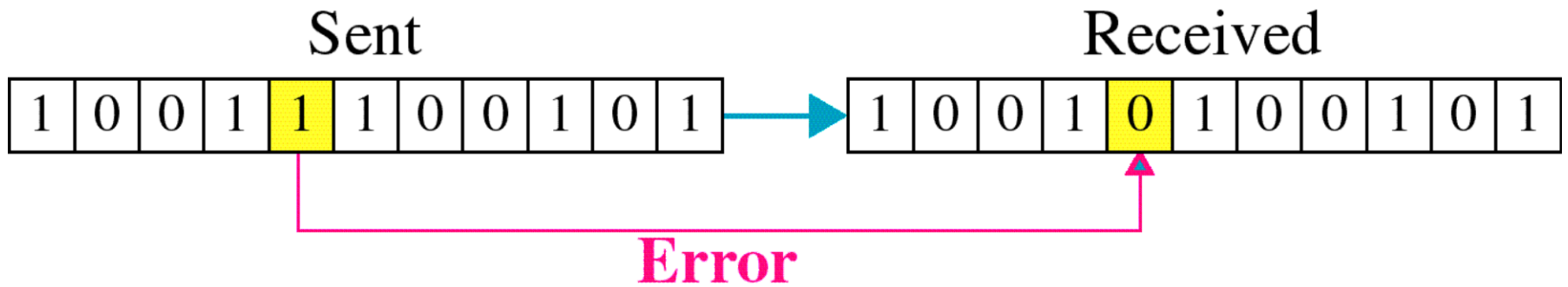| d | d | d | r8 | d | d | d | r4 | d | r2 | r1 |
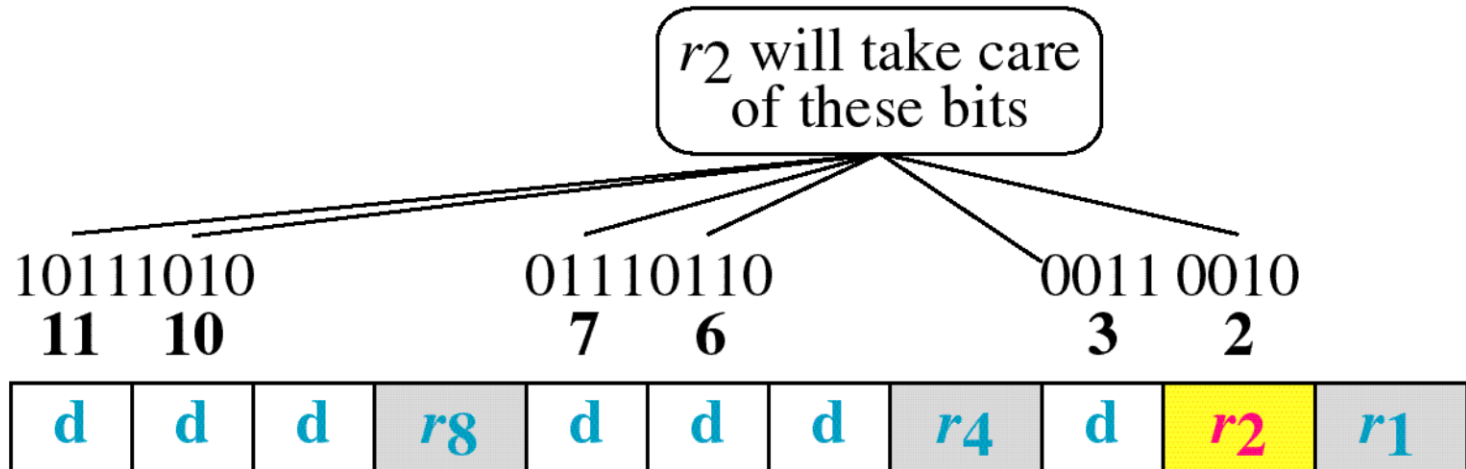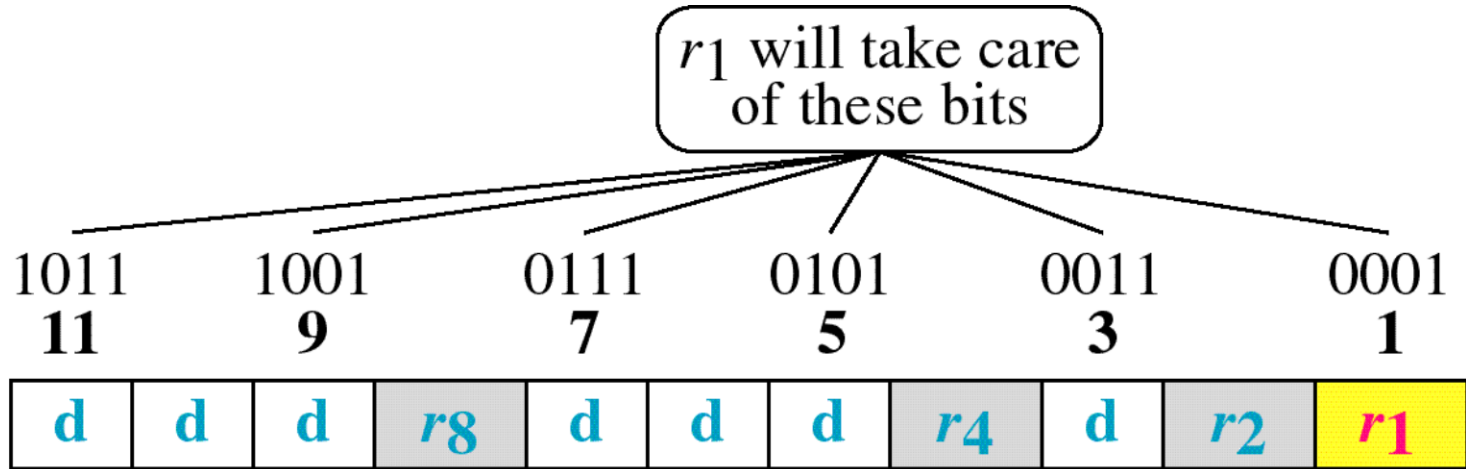
Hamming Code

Example of Hamming Code

Data: **1 0 0 1 1 0 1**
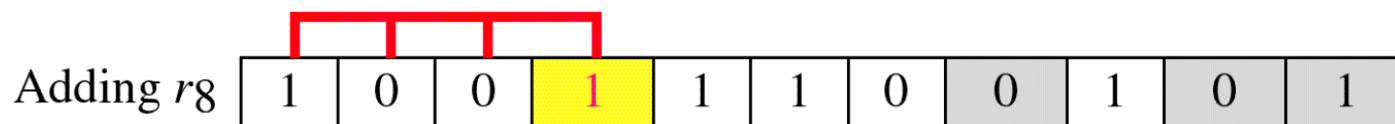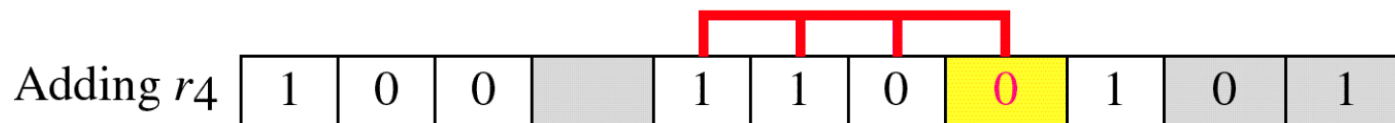
Code: **1 0 0 1 1 1 0 0 1 0 1**

Single-bit error

Error Detection

The bit in position 7 is in error.