12

Data Communication

Week 12 Data Link Layer (Error Detection)

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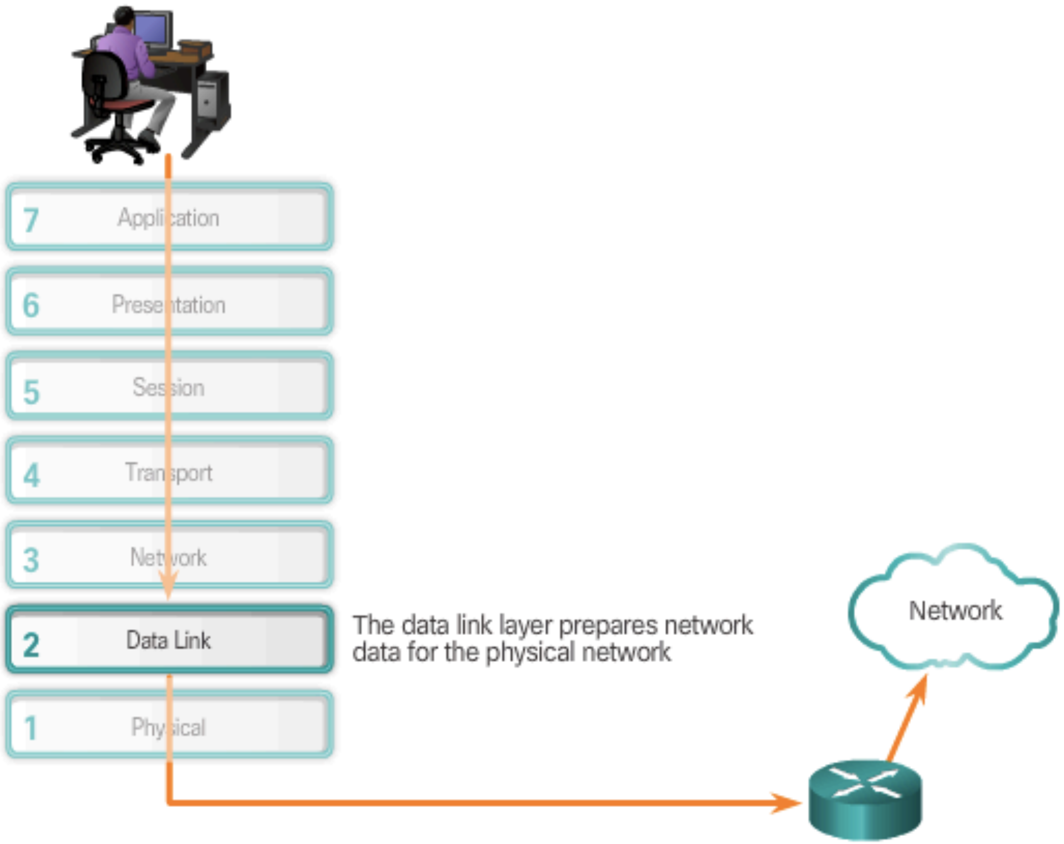
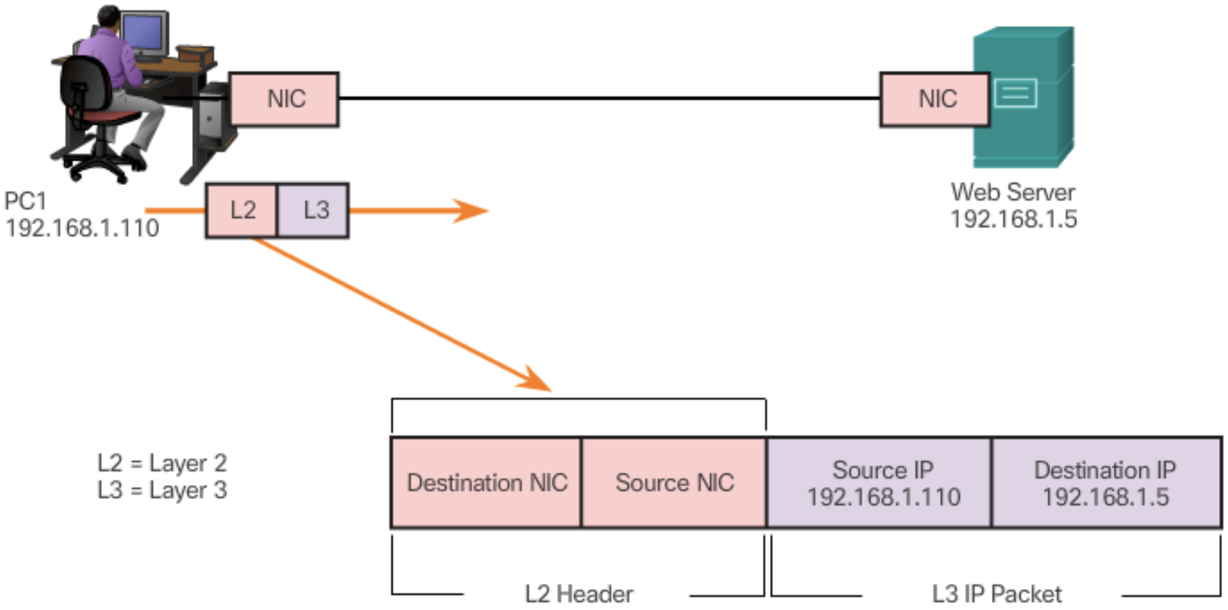
Introduction to Data Link Layer



The data link layer of the OSI model (Layer 2), as shown in Figure, is responsible for:

- Allowing the upper layers to access the media
- Accepting Layer 3 packets and packaging them into frames
- Preparing network data for the physical network
- Controlling how data is placed and received on the media
- Exchanging frames between nodes over a physical network media, such as UTP or fiber-optic
- Receiving and directing packets to an upper layer protocol
- Performing error detection

Data Link Layer



- The Layer 2 notation for network devices connected to a common media is called a node. Nodes build and forward frames. As shown in Figure 2, the OSI data link layer is responsible for the exchange of Ethernet frames between source and destination nodes over a physical network media.
- The data link layer effectively separates the media transitions that occur as the packet is forwarded from the communication processes of the higher layers. The data link layer receives packets from and directs packets to an upper layer protocol, in this case IPv4 or IPv6. This upper layer protocol does not need to be aware of which media the communication will use.

Introduction to the Ethernet Frame

IEEE 802.3

7	1	6	6	2	46 to 1500	4
Preamble	Start of Frame Delimiter	Destinatio n Address	Source Address	Length	802.2 Header and Data	Frame Check Sequence

Preamble and Start Frame Delimiter Fields
Used for synchronization between the sending and receiving devices

Length/Type Field
Defines the exact length of the frame's data field/ describes which protocol is implemented

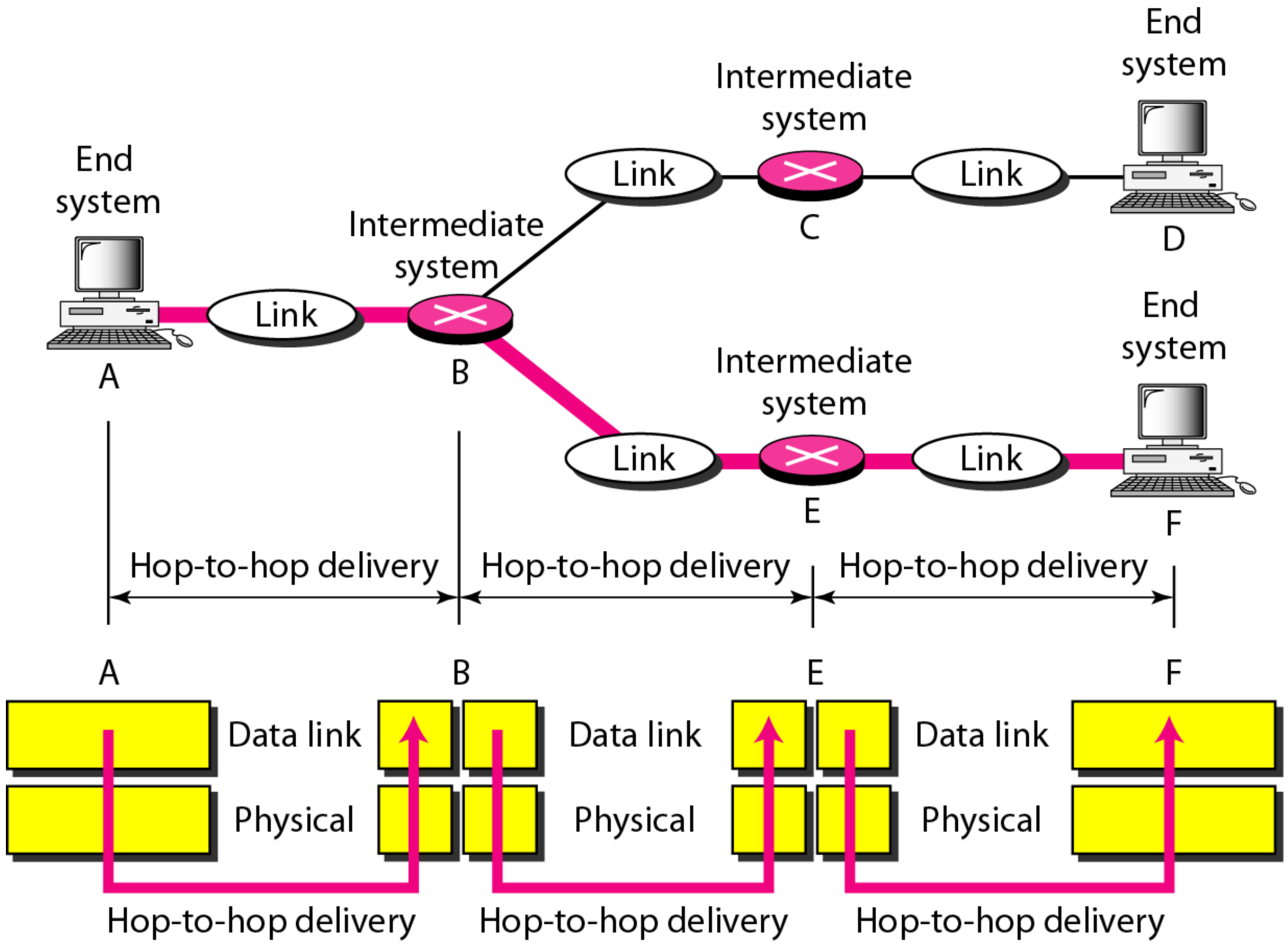
Data and Pad Fields
Contain the encapsulated data from a higher layer, an IPv4 packet

Introduction to the Ethernet Frame

IEEE 802.3

7	1	6	6	2	46 to 1500	4
Preamble	Start of Frame Delimiter	Destination Address	Source Address	Length	802.2 Header and Data	Frame Check Sequence

Frame Check Sequence Field
Used to detect errors in a frame with cyclic redundancy check (4 bytes), if calculations match at source and receiver, no error occurred.

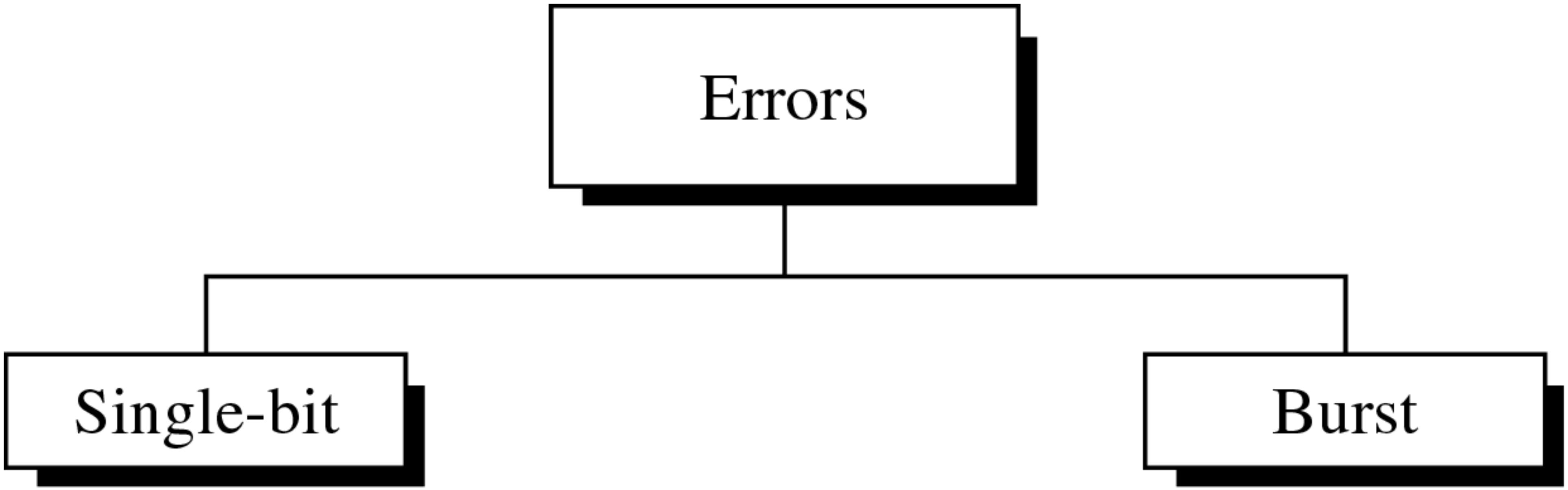


- The data link layer also adds reliability to the physical layer by adding mechanisms to detect and retransmit damaged, duplicate, or lost frames. When two or more devices are connected to the same link, data link layer protocols are necessary to determine which device has control over the link at any given time.

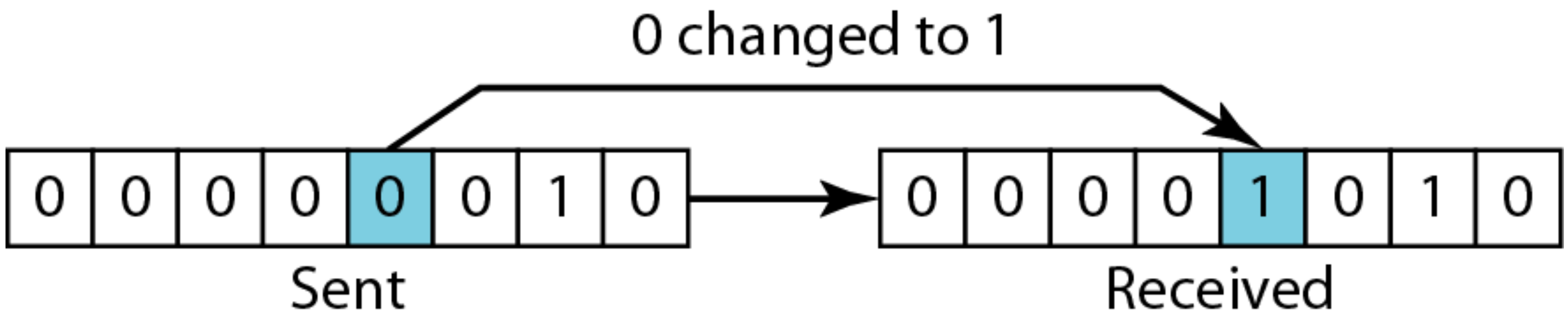
Error Control

- Data can be corrupted during transmission. For reliable communication, error must be detected and corrected are implemented either at the data link layer or the transport layer of the OSI model
- The general definitions of the terms are as follows:
    - **Error detection** is the detection of errors caused by noise or other impairments during transmission from the transmitter to the receiver.
    - **Error correction** is the detection of errors and reconstruction of the original, error-free data.

Types of Error



Single Bit Error

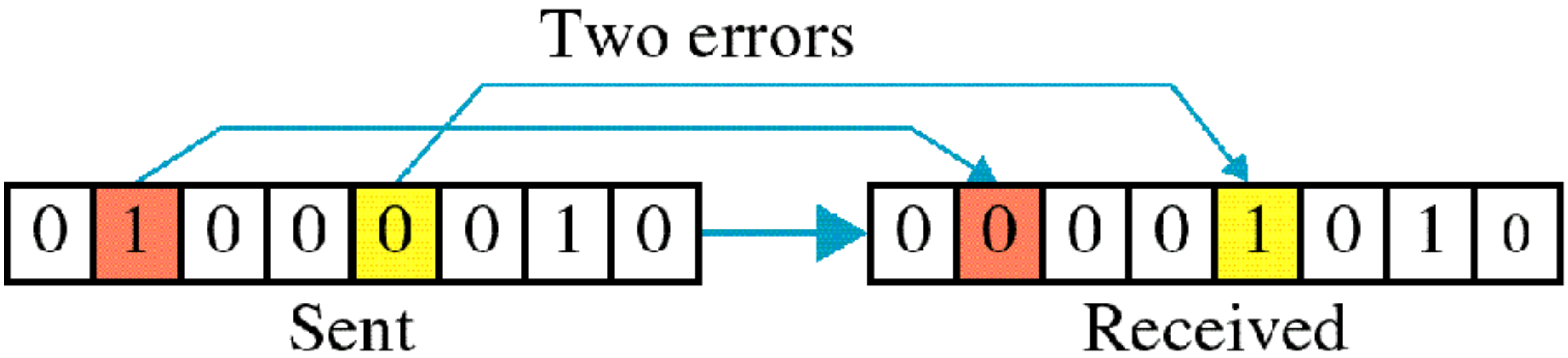


- Single bit error is when only one bit in the data unit has changed
- example : ASCII STX (Hex: 02) change 0 to 1, received ASCII LF (Hex: 0A)

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

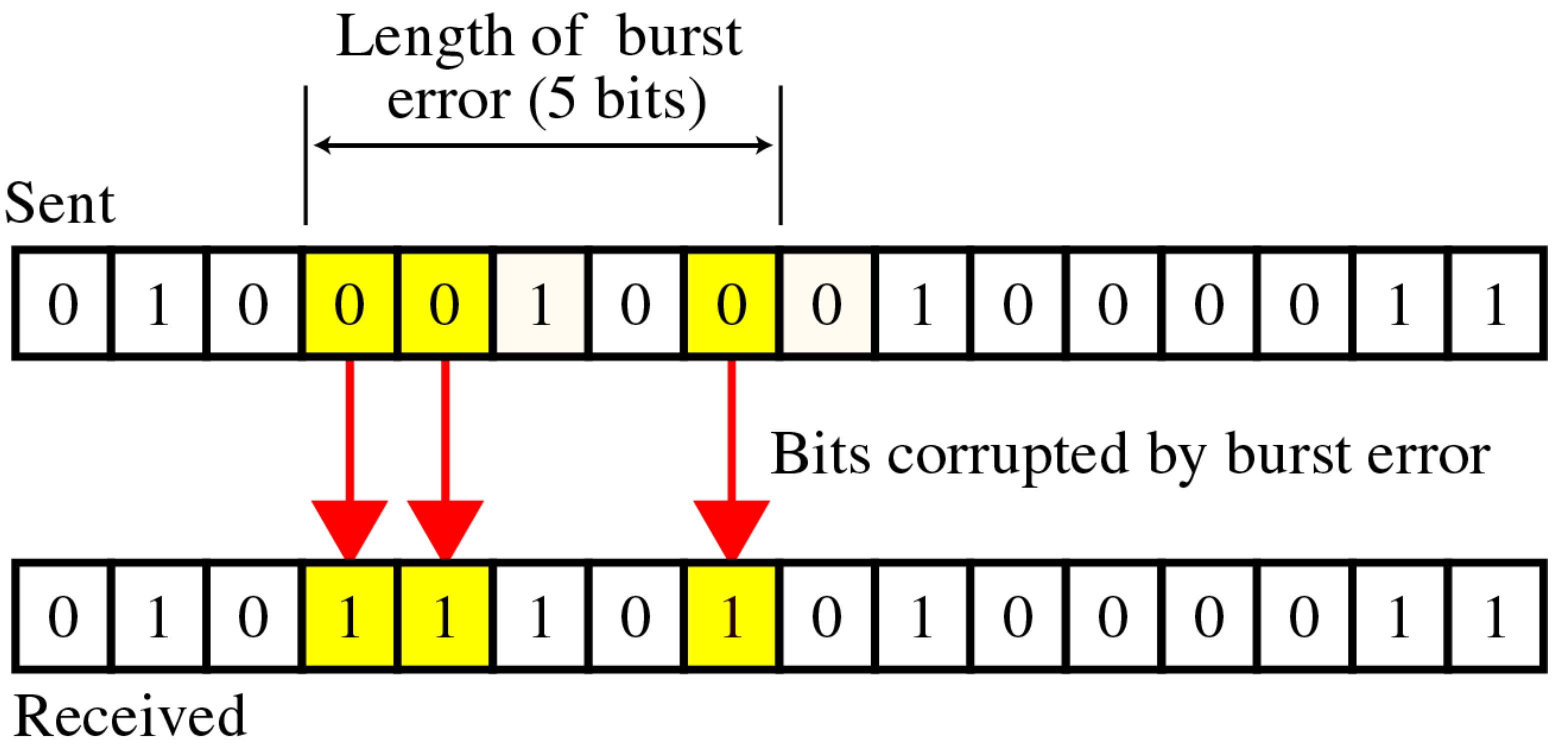
Multiple Bit Error



- Multiple-Bit Error is when two or more nonconsecutive bits in the data unit have changed
- example : ASCII B (Hex: 42) change into ASCII LF (Hex: A)

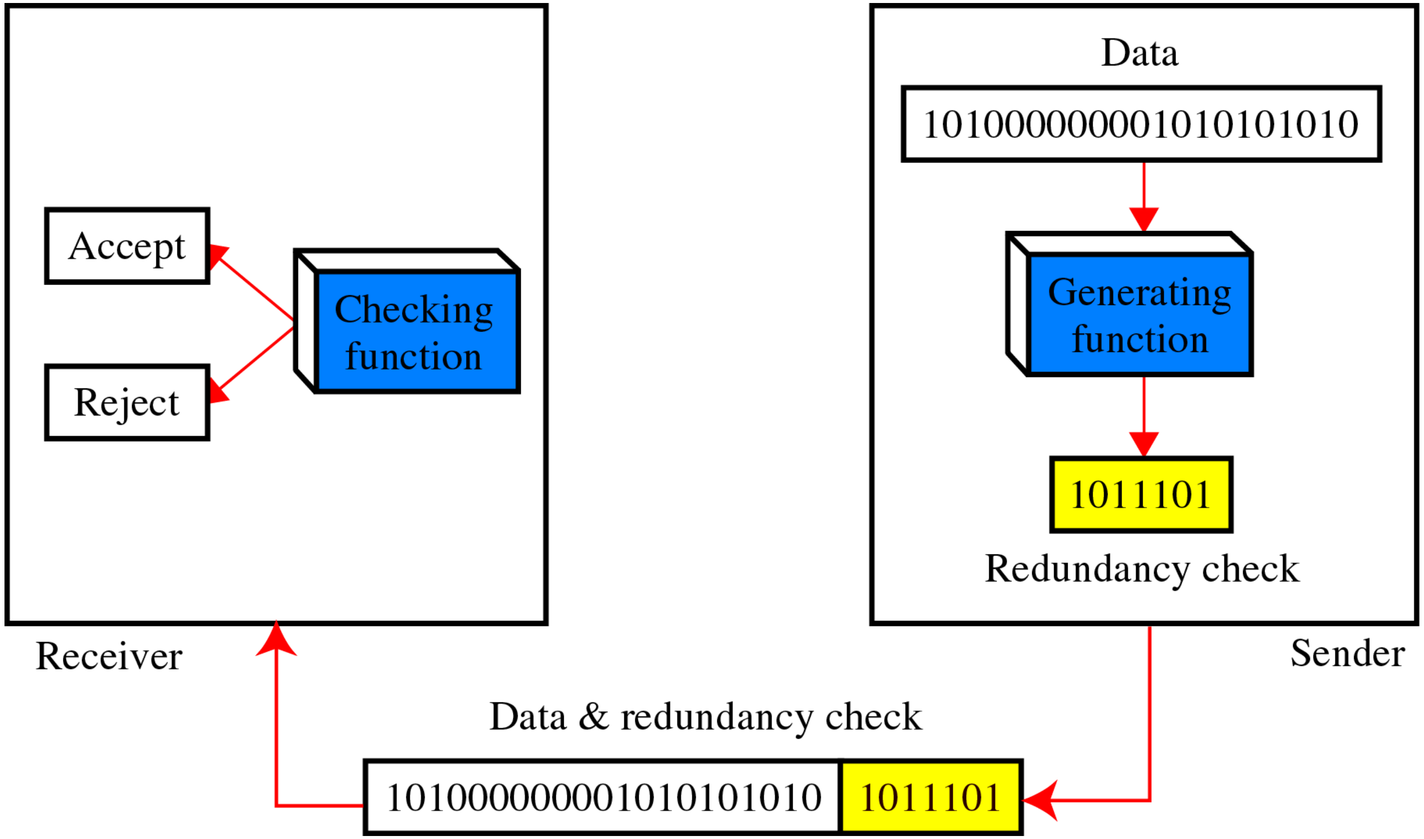
Burst Error

- Burst Error means that two or more consecutive bits in the data unit have changed

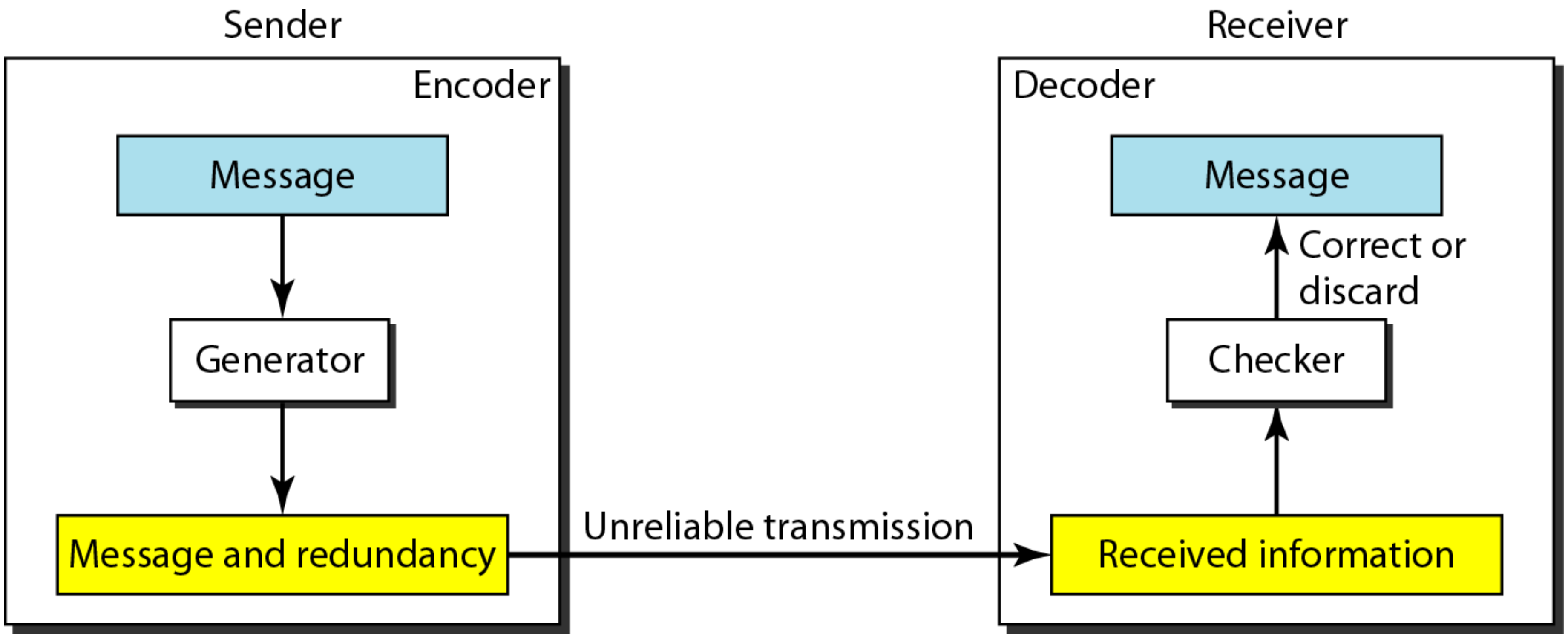


Redundancy Concepts

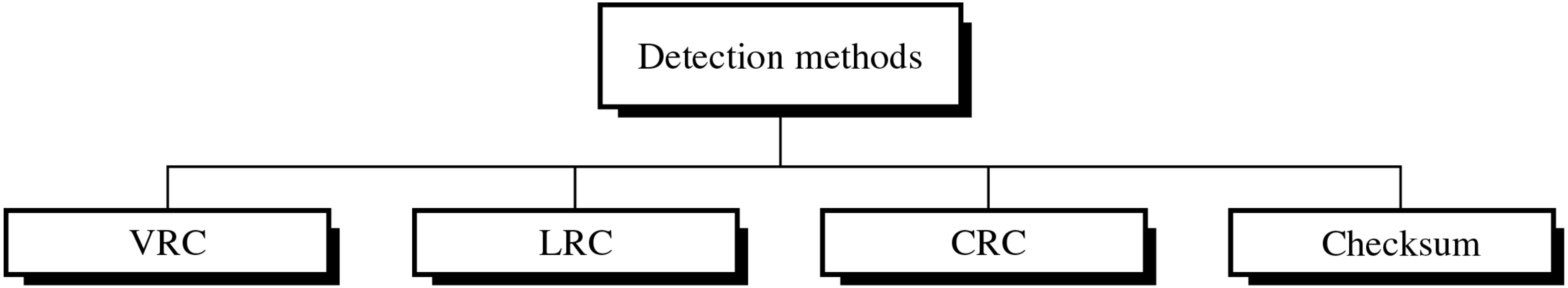
- The general idea for achieving error detection and correction is to add some redundancy (i.e., some extra data) to a message, which receivers can use to check consistency of the delivered message, and to recover data determined to be corrupted.



- Error-detection and correction schemes can be either systematic or non-systematic:
    - In a systematic scheme, the transmitter sends the original data, and attaches a fixed number of check bits (or parity data), which are derived from the data bits by some deterministic algorithm. If only error detection is required, a receiver can simply apply the same algorithm to the received data bits and compare its output with the received check bits; if the values do not match, an error has occurred at some point during the transmission.
    - In a system that uses a non-systematic code, the original message is transformed into an encoded message that has at least as many bits as the original message.


Sender
Encoder
Message
Generator
Message and redundancy
Unreliable transmission
Receiver
Decoder
Message
Correct or
discard
Checker
Received information

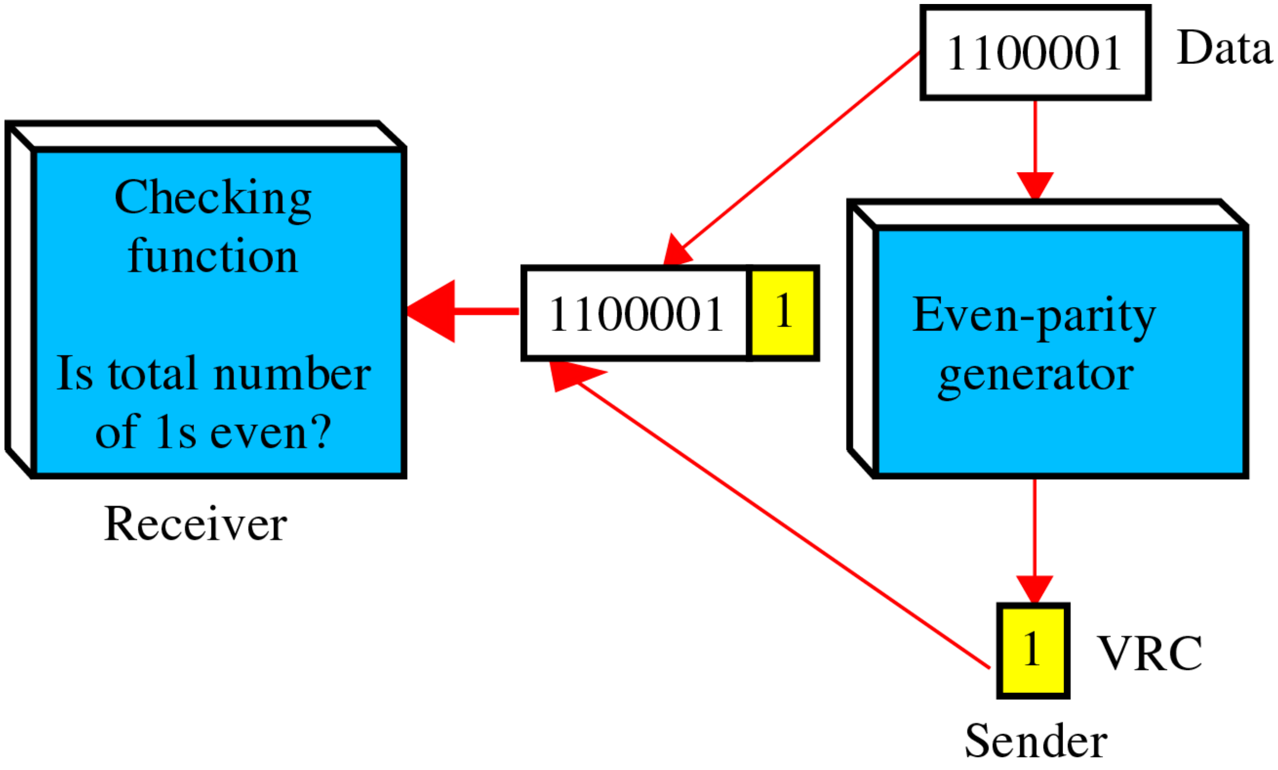
Error Detection Methods



- Vertical Redundancy Check (VRC)
- Longitudinal Redundancy Check (LRC)
- Cyclic Redundancy Check (CRC)
- Checksum

Vertical Redundancy Check (VRC)

- A parity bit is added to every data unit so that the total number of 1s (including the parity bit) becomes even for even-parity check or odd for odd-parity check
- VRC can detect all single-bit errors. It can detect multiple-bit or burst errors only the total number of errors is odd/even



Example of Even Parity

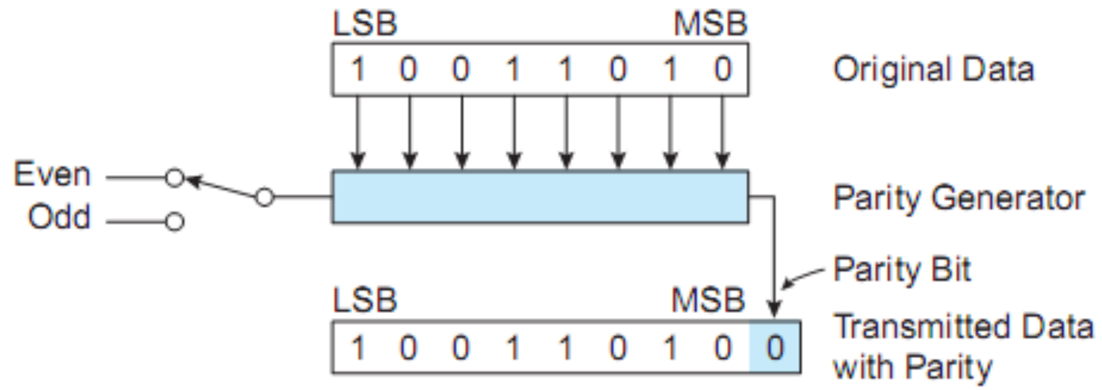
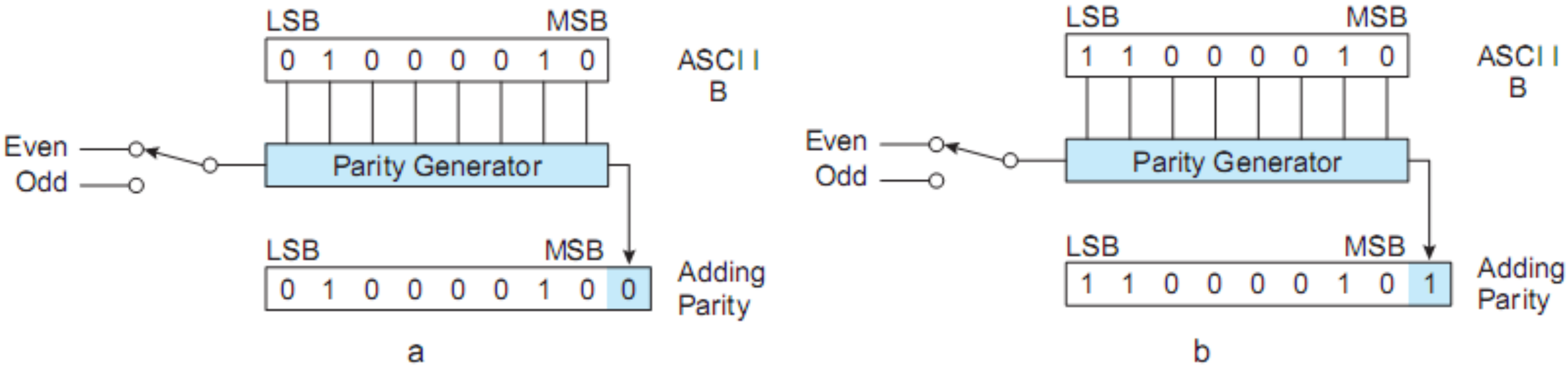
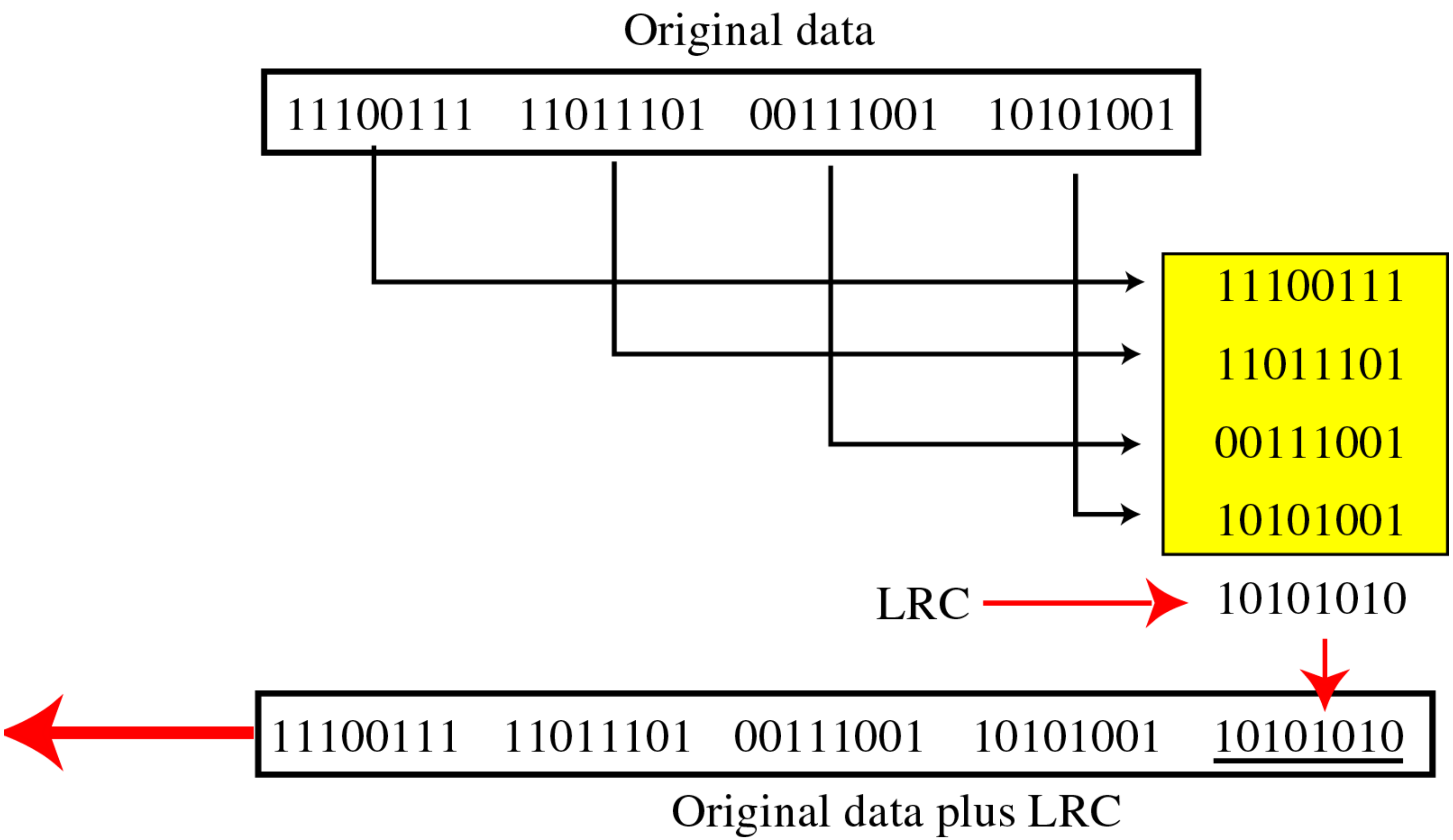


FIGURE 3-1 Appending Parity Bit



Longitudinal Redundancy Check (LRC)

- Parity bits of all the positions are assembled into a new data unit, which is added to the end of the data block



Exclusive OR (XOR)

$0 \oplus 0 = 0$ $\qquad$ $1 \oplus 1 = 0$

a. Two bits are the same, the result is 0.

$0 \oplus 1 = 1$ $\qquad$ $1 \oplus 0 = 1$

b. Two bits are different, the result is 1.

$$\begin{array}{cccccc} & 1 & 0 & 1 & 1 & 0 \\ \oplus & 1 & 1 & 1 & 0 & 0 \\ \hline & 0 & 1 & 0 & 1 & 0 \end{array}$$

c. Result of XORing two patterns

Example

EXAMPLE 3-4

Determine the states of the LRC bits for the asynchronous ASCII message "Help!"

SOLUTION

The first step in understanding the process is to list each of the message's characters with their ASCII code and even VRC parity bit:

LSB						MSB	VRC	CHARACTER
0	0	0	1	0	0	1	0	H
1	0	1	0	0	1	1	0	e
0	0	1	1	0	1	1	0	l
0	0	0	0	1	1	1	1	p
1	0	0	0	0	1	0	0	!

Next, for each vertical column, find the LRC bit by applying the exclusive OR function. To make this process easier, you can consider the results of the exclusive OR process as being low or zero (0), if the number of ones (1) are even, and one (1) if the count is odd. For instance, in the LSB column, there are two 1's, so the LRC bit for that column is a 0. And for the rest:

LSB						MSB	VRC	CHARACTER
0	0	0	1	0	0	1	0	H
1	0	1	0	0	1	1	0	e
0	0	1	1	0	1	1	0	l
0	0	0	0	1	1	1	1	p
1	0	0	0	0	1	0	0	!
0	0	0	0	1	0	0	1	LRC

EXAMPLE 3-5

Show how a good message would produce an LRC of 0 at the receiver.

SOLUTION

Repeat the process as before, but include the LRC character this time. Note that the number of 1s in each column are always even if there are no errors present:

LSB						MSB	VRC	CHARACTER
0	0	0	1	0	0	1	0	H
1	0	1	0	0	1	1	0	e
0	0	1	1	0	1	1	0	l
0	0	0	0	1	1	1	1	p
1	0	0	0	0	1	0	0	!
0	0	0	0	1	0	0	1	LRC
0	0	0	0	0	0	0	0	Receiver LRC

EXAMPLE 3-6

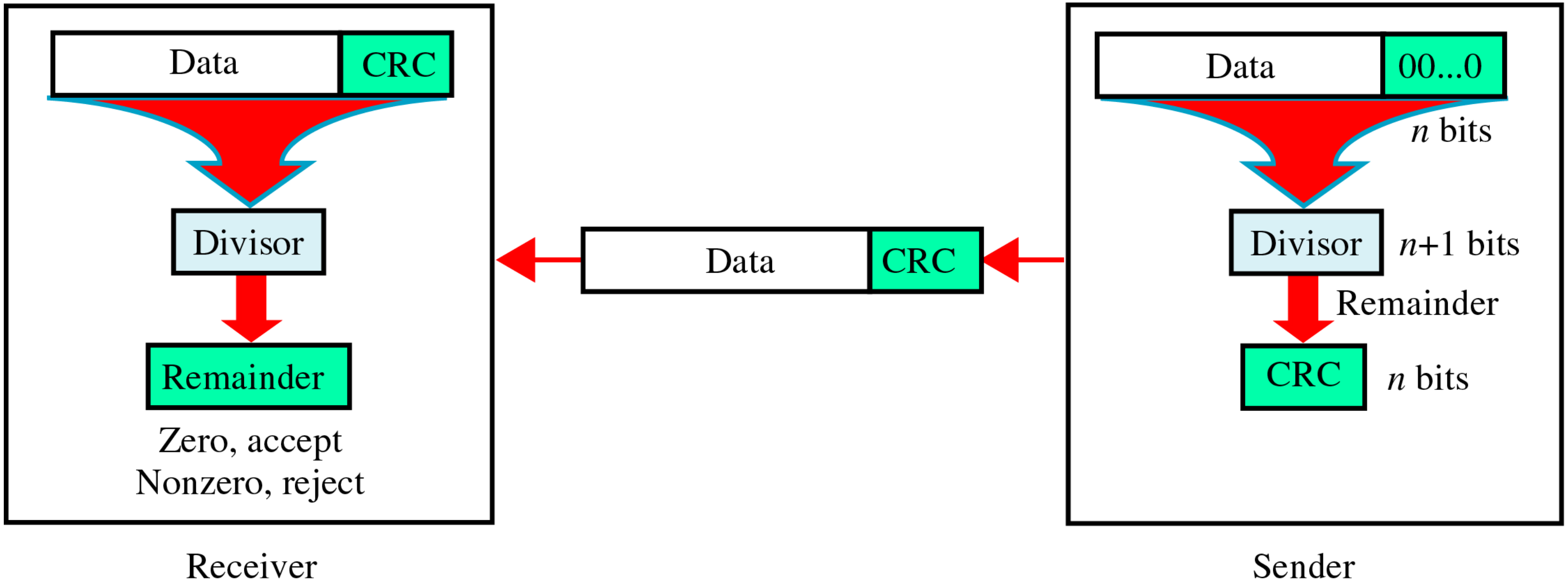
Illustrate how LRC/VRC is used to correct a bad bit.

SOLUTION

We will use the same message, but by placing an error in the received data would cause the l character to print as an *h*. You can compare the data with the good example to satisfy yourself as to which bit is bad and confirm that the LRC process does indeed pick out the same bit.

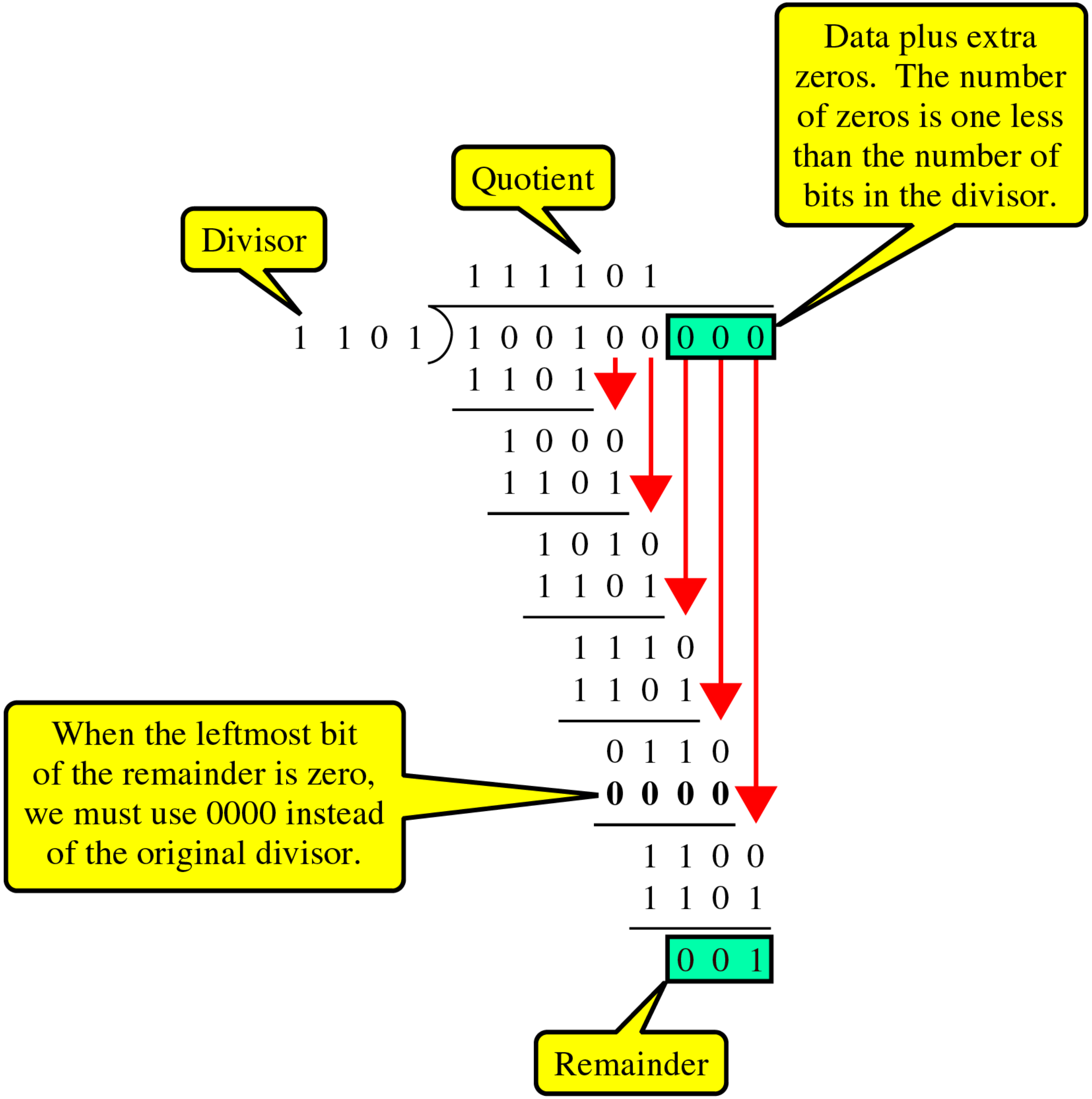
LSB						MSB	VRC	CHARACTER
0	0	0	1	0	0	1	0	H
1	0	1	0	0	1	1	0	e
0	0	0	1	0	1	1	0	h
0	0	0	0	1	1	1	1	p
1	0	0	0	0	1	0	0	!
0	0	0	0	1	0	0	1	LRC
0	0	1	0	0	0	0	1	Received LRC

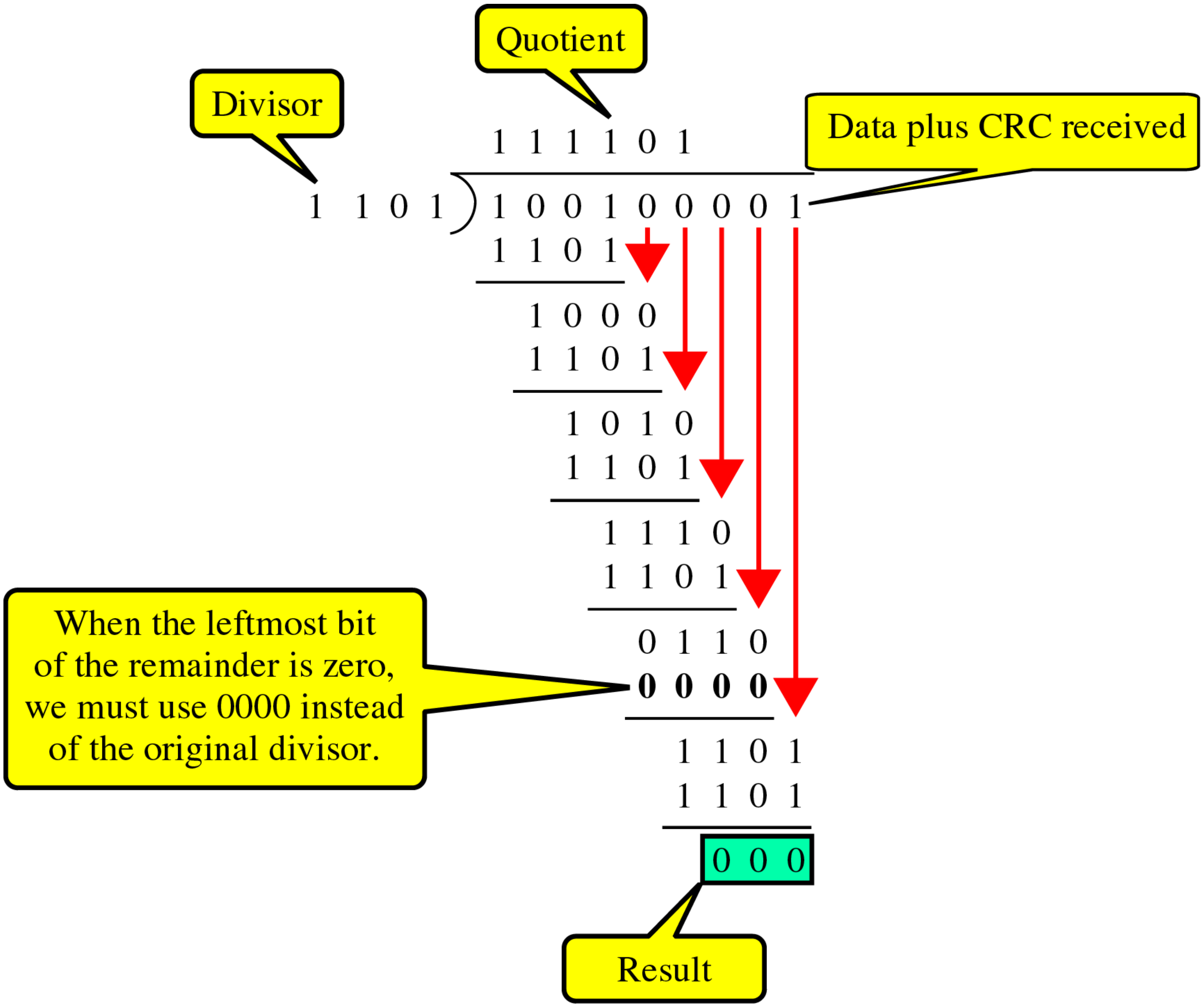
Cyclic Redundancy Check (CRC)



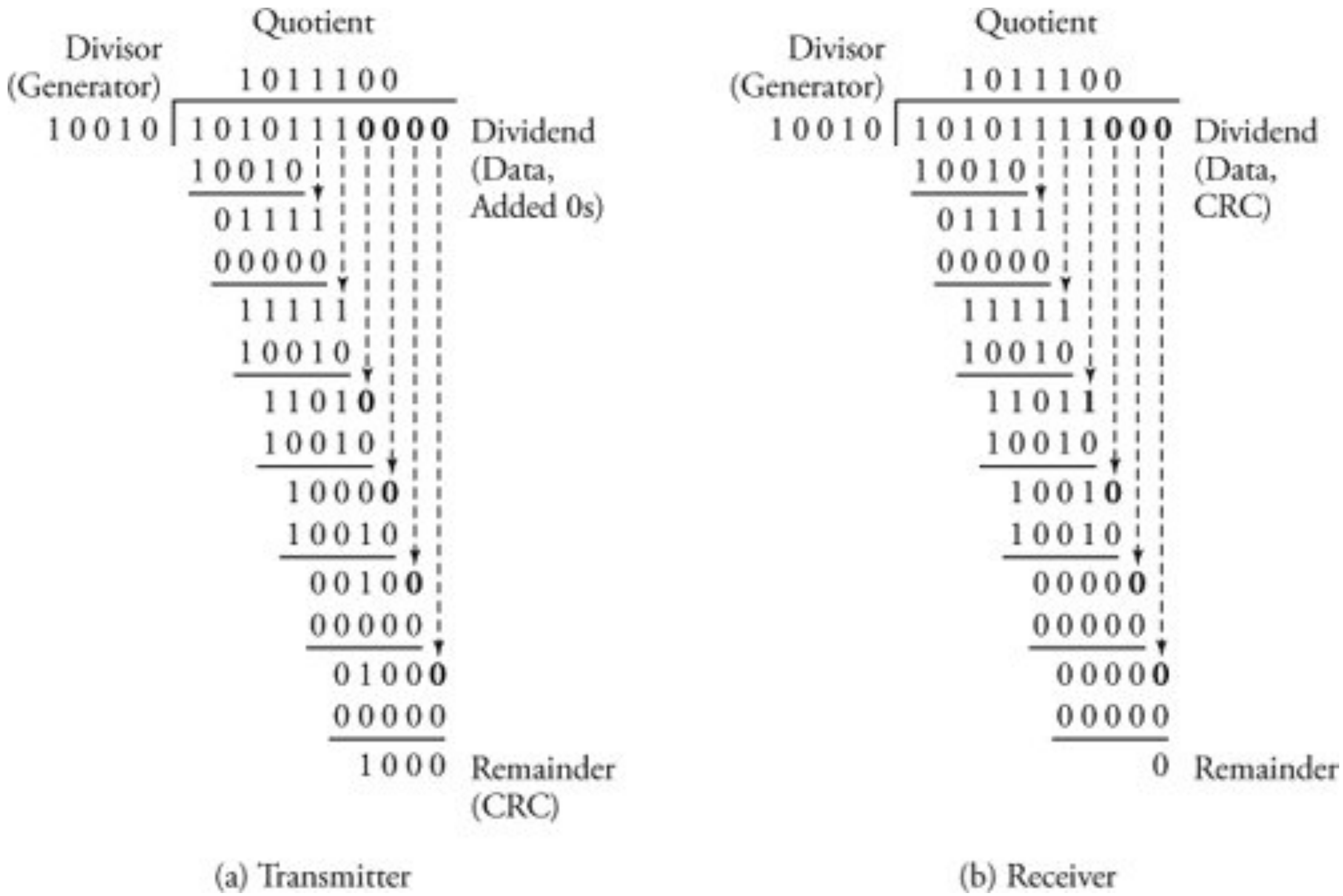
Example:

- Using Modular 2 Division
- Data : 1 0 0 1 0 0
- Divisor : 1 1 0 1



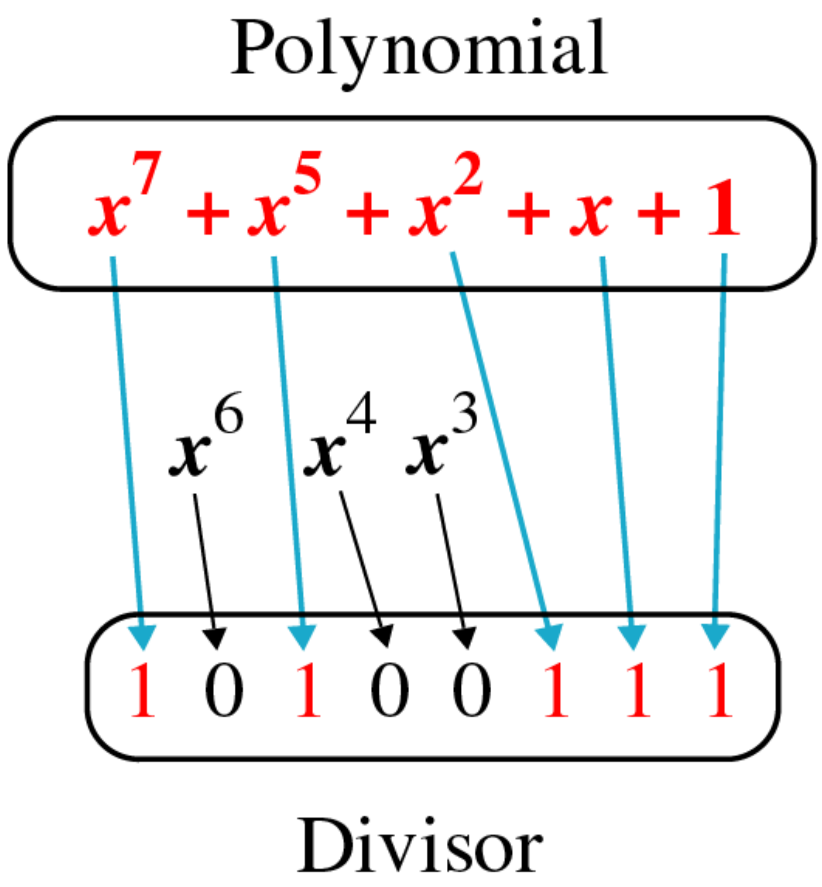

Quotient
Divisor
Data plus CRC received
1 1 1 1 0 1
1 1 0 1
1 0 0 1 0 0 0 0 1
1 1 0 1
1 0 0 0
1 1 0 1
1 0 1 0
1 1 0 1
1 1 1 0
1 1 0 1
0 1 1 0
0 0 0 0
1 1 0 1
1 1 0 1
0 0 0
When the leftmost bit of the remainder is zero, we must use 0000 instead of the original divisor.
Result

Example (2)

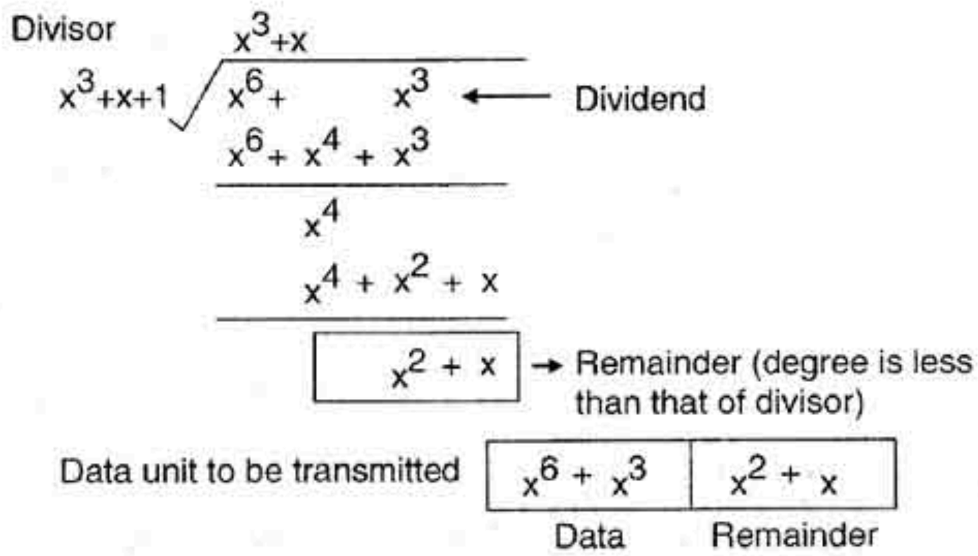

Quotient
Divisor
(Generator)
1011100
10010
1010111 0000
Dividend
(Data,
Added 0s)
1000
Remainder
(CRC)
(a) Transmitter
Quotient
Divisor
(Generator)
1011100
10010
1010111 1000
Dividend
(Data,
CRC)
0
Remainder
(b) Receiver

Polynomials

- CRC generator (divisor) is most often represented not as a string of 1s and 0s, but as an algebraic polynomial.



Data	1001	$x^3 + 1$
Division (polynomial generator)	1011	$x^3 + x + 1$



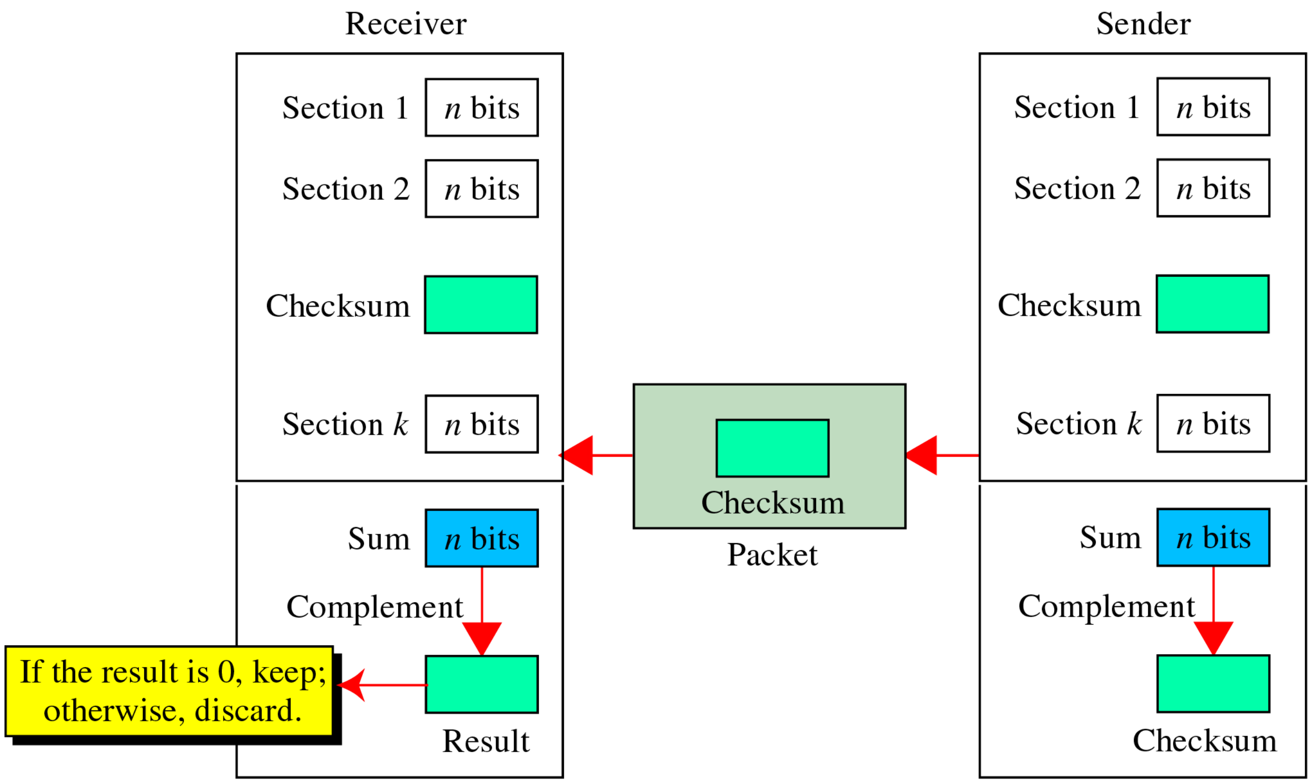
CRC division using polynomial

Standard Polynomials

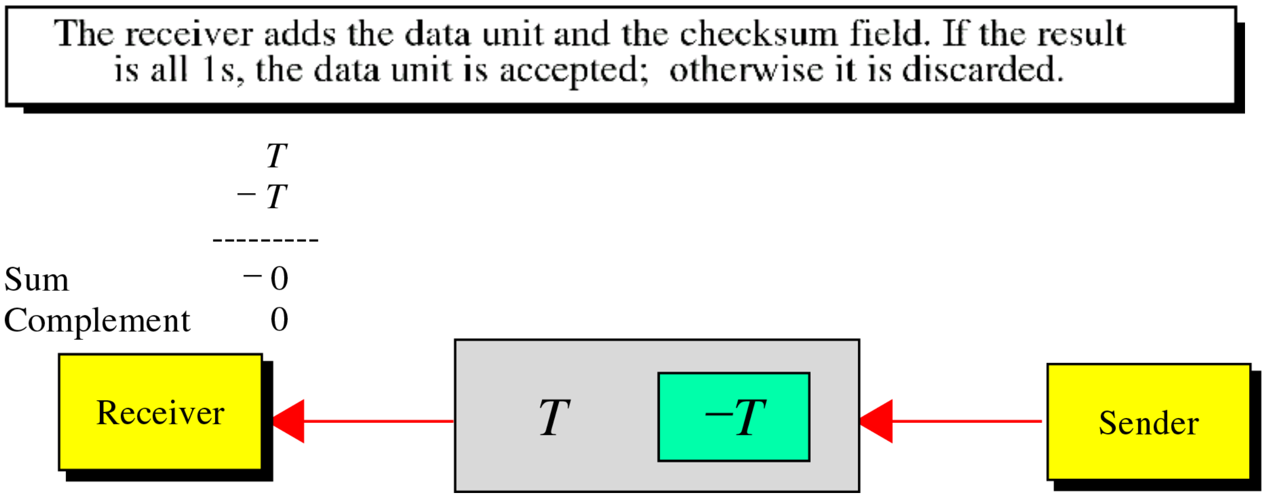
Name	*Polynomial*	*Application*
CRC-8	$x^8 + x^2 + x + 1$	ATM header
CRC-10	$x^{10} + x^9 + x^5 + x^4 + x^2 + 1$	ATM AAL
CRC-16	$x^{16} + x^{12} + x^5 + 1$	HDLC
CRC-32	$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} +$ $x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$	LANs

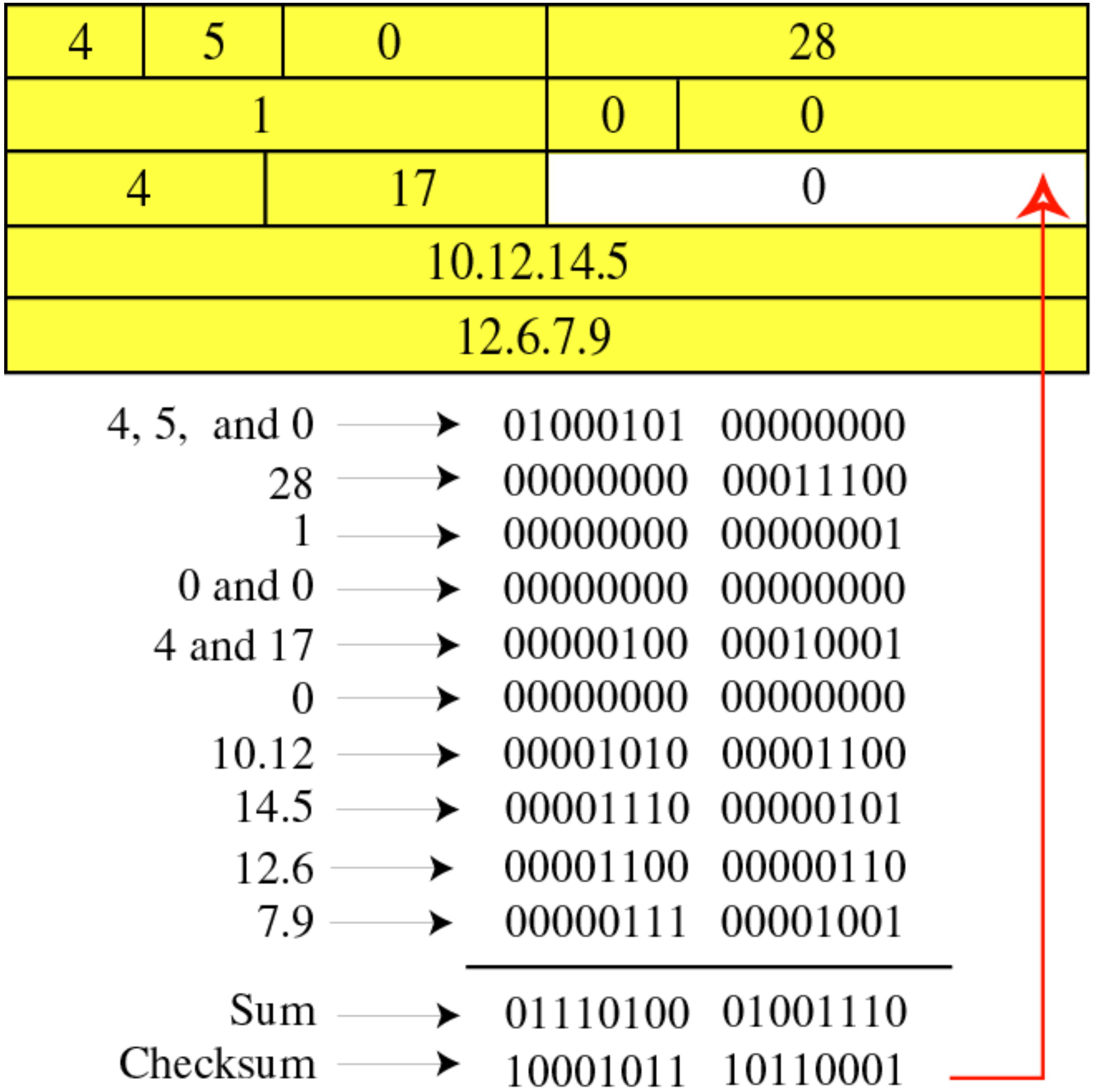
Checksum

- Used by the higher layer protocols
- based on the concept of redundancy (VRC, LRC and CRC)

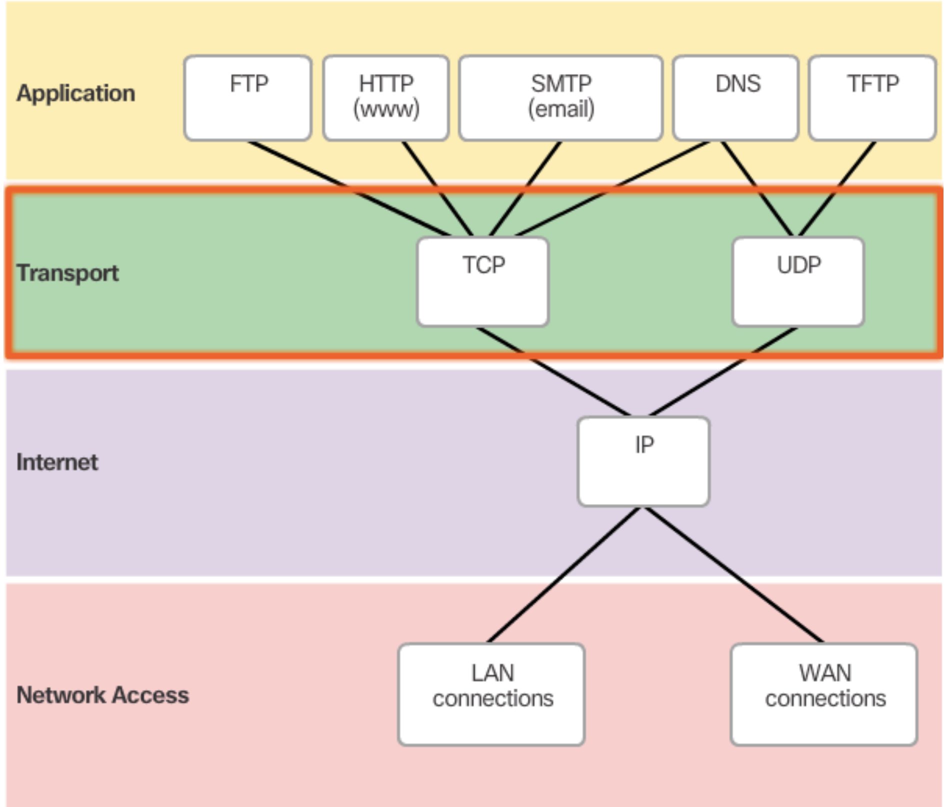


- To create the checksum the sender does the following:
  - The unit is divided into K sections, each of n bits.
  - Section 1 and 2 are added together using one’s complement.
  - Section 3 is added to the result of the previous step.
  - Section 4 is added to the result of the previous step.
  - The process repeats until section k is added to the result of the previous step.
  - The final result is complemented to make the checksum.

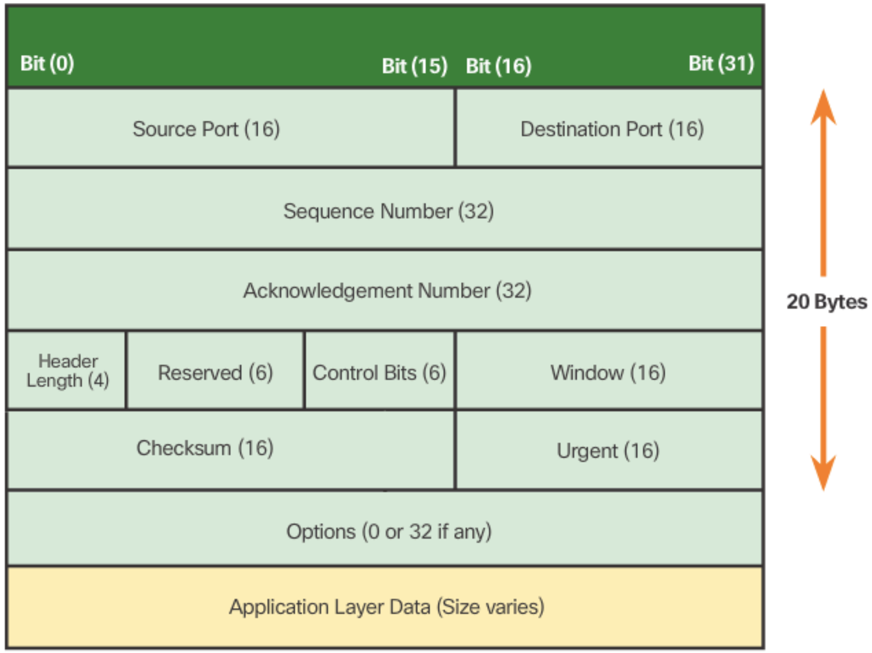



4
5
0
28
1
0
0
4
17
0
10.12.14.5
12.6.7.9
4, 5, and 0 → 01000101 00000000
28 → 00000000 00011100
1 → 00000000 00000001
0 and 0 → 00000000 00000000
4 and 17 → 00000100 00010001
0 → 00000000 00000000
10.12 → 00001010 00001100
14.5 → 00001110 00000101
12.6 → 00001100 00000110
7.9 → 00000111 00001001
Sum → 01110100 01001110
Checksum → 10001011 10110001

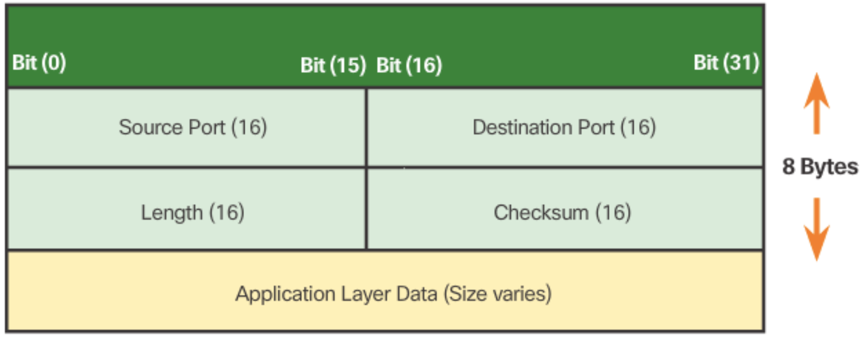
Transport Layer



TCP Segment



UDP Datagram



Latihan

1. Diketahui urutan bit informasi adalah sebagai berikut 1 1 0 1 0 1 1 1 0 1 1. Generator polynomial yang digunakan adalah 1 1 0 0 1 1. Tentukanlah Data yang dikirimkan (data informasi ditambah bit-bit redundancy) menggunakan metode CRC! Untuk apakah metode ini dilakukan?
2. Urutan data yang diterima oleh PC Penerima adalah: 1 1 1 1 1 0 0 0 0 1 1 1 0 . Digunakan generator polinomial seperti pada nomor soal diatas! Periksalah apakah data yang sampai mengalami error atau tidak!