Computer Network

Data-Link Layer

Lecture : 10

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TCP/IP

TCP/IP Layer	Hardware	Software/Protocols
Application	None	HTTP, FTP, SMTP, POP3, IMAP, DNS, SSH
Transport	None	TCP, UDP
Internet	Routers	IP (IPv4/v6), ICMP, IGMP, ARP, RARP Routing(DVR(RIP), LSR(OSPF), BGP)
Data Link	Switches, Bridges, NICs	Ethernet (MAC framing), Wi-Fi (802.11 MAC), PPP, Frame Relay, HDLC
Physical	Cables (fiber, coaxial, twisted pair), Hubs, Repeaters, Connectors (RJ-45), Amplifier	ONLY physical standards (IEEE 802.3 for wiring, IEEE 802.11 PHY for Wi-Fi)

Data-Link Layer

Responsibility	
Framing	
Error Detection	Parity bit, CheckSum, CRC, HD
Error Recovery	
Flow Control	
Access Control	
Addressing	
Link Management	
Framing and Encapsulation	

1 2 3 4 5 6 7

2^0 2^1 2^2

P1 P2 D1 P3 D2 D3 D4

Hamming Distance(error detection and error correction)

It is used in digital communication and memory systems.

Error Detection & Correction Capability

•Detectable Errors:

Up to two-bit errors can be detected.

•Correctable Errors:

Only one-bit error can be corrected.

H.D

Dataword + P.B = 4 + 3

3

Codeword

16 1 3

Formulas to Remember

1. Number of Parity Bits (r):

$2^r \geq m+r+1$,where m is the number of data bits.

$2^r \geq 4+r+1$

$2^r \geq 5+r+1$

2. Total Codeword Length (n):

$$n = m + r$$

3. Positions of Parity Bits:

Parity bits are placed at positions that are powers of 2:

$$2^0, 2^1, 2^2, \ldots$$

Parity Check Equation:

Each parity bit covers specific data bits based on its binary representation.

Hamming Distance(error detection and error correction)

Interpreting the Formula

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- **To detect up to d errors**, we need a **minimum Hamming distance** of **d+1**.
- **To correct up to d errors**, we need a **minimum Hamming distance** of **2d+1**.

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Why Does Standard Hamming Code Detect 2 Errors and Correct 1?

Hamming code has a **minimum Hamming distance of 3**:

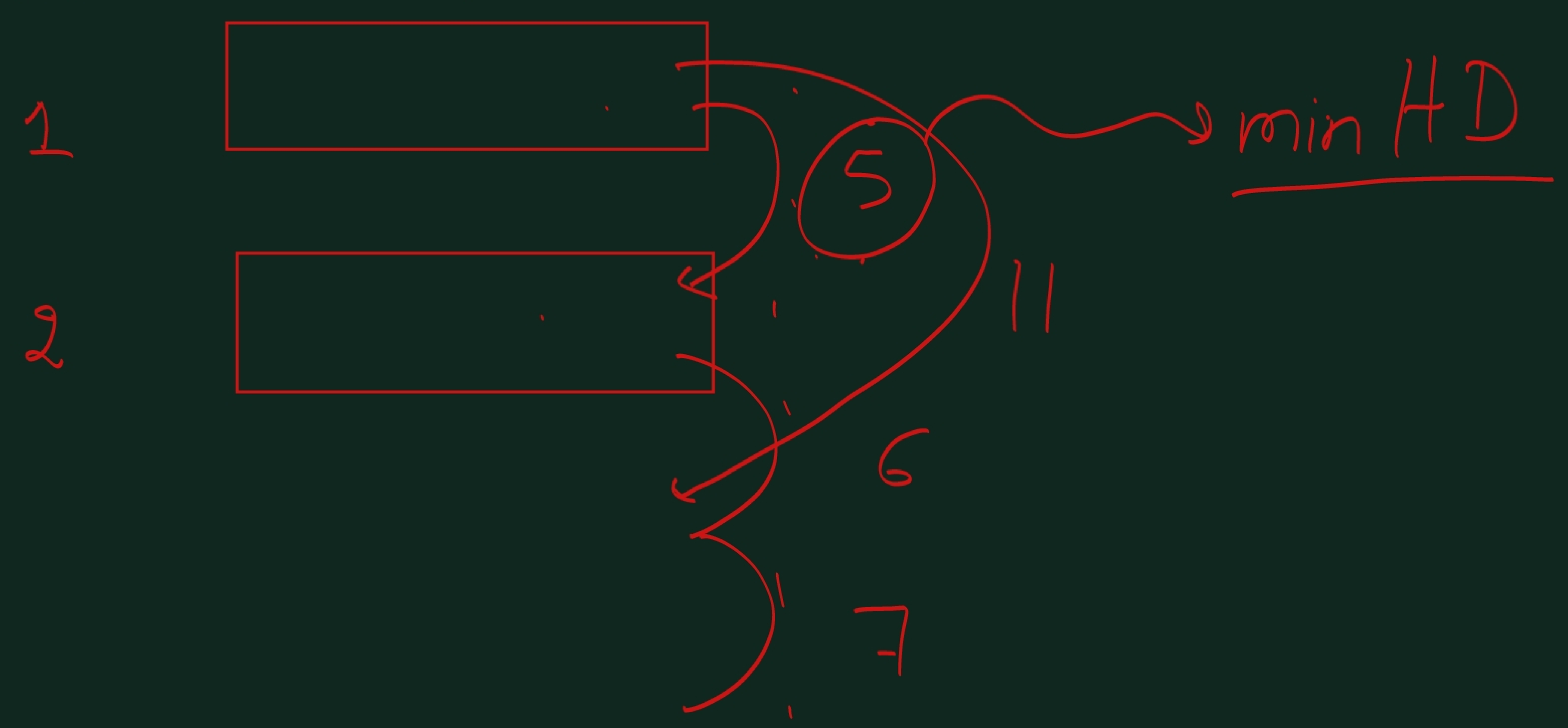
- If **1-bit flips**, it moves the received word 1 step away from the original → **correctable**.
- If **2 bits flip**, the word is now **2 steps away** and might resemble another valid word → **detectable but not correctable**.
- If **3 bits flip**, it can turn into another valid codeword → **not even detectable**.

Thus, standard **Hamming(7,4) or Hamming(11,7) codes can correct only 1-bit error and detect up to 2-bit errors**.

(7,4)

4   7

HD



16

0110101

1010100

XOR

1100001 $\rightsquigarrow$ 3

HD

$\text{detect}(d) = 2$

$(d+1) = 3$

$\text{Correct}(x) = 1$

$2x+1 = 3$

standard Hamming code is constructed with **minimum**

Hamming distance = 3.

Code Type	**1-bit Error**	**2-bit Error**	**More than 2**
Standard Hamming	Corrects	Detects	Fails
SEC-DED (Hamming + P)	Corrects	Detects	Fails
BCH, Reed-Solomon	Can Correct	Can Correct	Possible

Hamming Distance(error detection and error correction)

Step 1: Consider a Valid Hamming Codeword

We will use **Hamming(7,4)**, where 4 data bits are encoded into a **7-bit codeword**.

Let's say the **valid codeword** generated is:

C=0110011. This follows all parity rules and is a **valid codeword**.

P3 {4, 5, 6, 7} X

A Single-Bit Flip (Correctable Error)

If **only 1-bit flips**, let's say the **3rd bit flips from 1 to 0**:

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Position	1	2	3	4	5	6	7
S Valid C	0	1	1	0	0	1	1
R Received	0	1	0 Error	0	0	1	1

← Valid Codeword

2^0 2^1 P2 2^2 P3 2^3

P2 {2, 3, 6, 7, 10, 11}

P1 {1, 3, 5, 7} : Even no of 1's

Hamming Distance(error detection and error correction)

A Two-Bit Flip (Detectable but NOT Correctable)

Now, suppose **two bits flip** instead:

The **3rd bit flips from 1 to 0**. The **6th bit flips from 1 to 0**

Position	1	2	3	4	5	6	7
Valid	0	1	1	0	0	1	1
Error	0	1	0	0	0	0	1

A 3-bit error (Another Valid Codeword)

Position	1	2	3	4	5	6	7
Valid	0	1	1	0	0	1	1
Error	1	0	0	0	0	1	1

This **happens to be another valid codeword** because it still satisfies parity rules!
The receiver **won't even realize there was an error** because it **looks like a correct codeword**. (1^{st}, 2^{nd},3^{rd} bit gets flipped)

Hamming Distance(error detection and error correction)

Determine the Number of Parity Bits
Given **7-bit data(1101001) (m=7)**, find r = ?

Arrange Data and Parity Bits
The total number of bits in the Hamming code will be:
n = m + r = 7 + 4 = 11

Place **parity bits at positions**: 1, 2, 4, 8

DW : 7
Codeword
11

Position	1	2	3	4	5	6	7	8	9	10	11
Bit Type	P1	P2	D1	P3	D2	D3	D4	P4	D5	D6	D7

2^0 2^1 2^2

Position	1	2	3	4	5	6	7	8	9	10	11
Bit	**P1**	**P2**	**1**	**P3**	**1**	**0**	**1**	**P4**	**0**	**0**	**1**

0 1 0 1

P1 {1, 3, 5, 7, 9, 11}

P2 {2, 3, 6, 7, 10, 11}
= 0

P3 {4, 5, 6, 7, }

Hamming Distance(error detection and error correction)

P3 P2 P1

2^3 2^2 2^1 2^0

1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0

LSB

$P1 \{1, 3, 5, 7, \ldots\}$

$P2 \{2, 3, 6, 7, 10, 11, \ldots\}$

$P3 \{4, 5, 6, 7, 12, 13, 14, 15\}$

$P8 \{8,$

Hamming Distance(error detection and error correction)

Calculate Parity Bits

Parity bits are calculated based on even parity.

- **P1 (Covers positions: 1, 3, 5, 7, 9, 11)** P1=Parity(1,1,1,0,1) = 0
- **P2 (Covers positions: 2, 3, 6, 7, 10, 11)** P2=Parity(1,0,1,0,1) = 1
- **P3 (Covers positions: 4, 5, 6, 7)** P3=Parity(1,0,1) = 0
- **P4 (Covers positions: 8, 9, 10, 11)** P4=Parity(0,0,1) =1

Position	1	2	3	4	5	6	7	8	9	10	11
Bit	0	1	1	0	1	0	1	1	0	0	1

Position	1	2	3	4	5	6	7	8	9	10	11
Bit	P1	P2	1	P3	1	0	1	P4	0	0	1

0 1

Hamming Distance(error detection and error correction)

S
R

Position	1	2	3	4	5	6	7	8	9	10	11
Bit	0	1	1	0	1/0	0	1	1	0	0	1

P1 $\boxed{1}$

P2 $\boxed{0}$

P3 $\boxed{1}$

P4 $\boxed{0}$

0	1	0	1
P4	P3	P2	P1

$\Downarrow$

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2. Consider a binary code that consists of only four valid code words as given below:

00000,01011,10101,11110

Let the minimum Hamming distance of the code be p and the maximum number of erroneous bits that can be corrected by the code be q. Then the values of p and q are

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A. p=3, q=1
B. p=3, q=2
C. p=4, q=2
D. p=4, q=1

3. Assume that a 12-bit Hamming codeword consisting of 8-bit data and 4 check bits is $\mathbf{d_8d_7d_6d_5c_8d_4d_3d_2c_4d_1c_2c_1}$, where the data bits and the check bits are given in the following tables:

Data Bits							
D8	**D7**	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**
1	**1**	**0**	**X**	**0**	**1**	**0**	**1**

Check bits			
C8	**C4**	**C2**	**C1**
Y	**0**	**1**	**0**

Which one of the following choices gives the correct values of x and y?

GATE: 2021

A. X is 0, y is 0
B. X is 0, y is 1
C. X is 1, y is 0
D. X is 1, y is 1

$d_8\ d_7\ d_6\ d_5\ c_8\ d_4\ d_3\ d_2\ c_4\ d_1\ c_2\ c_1$

Thank You