

- For CRC-12 detects 99.97% of error with a length 12 or more.

- #. CRC K baad hum next technique jaha use kar hai hai woh hai hamming code.

Hamming Code : \rightarrow

- # Hamming Code →
 - Hamming code is based on the concept of hamming distance.
 - Hum data send karte hai, ABC jaise hamane send kiya,
 - Jo ABC k place par hum kya send karte hai uski ascii value.
 - Aur Hamming in ascii value ki place par kya use karta hai code words.
 - Hamming mein hum basically data nahi send karte, hai hum code word send karte hai. Jo ki jo send ho raha hai ~~it is~~ woh kya hai code words hai of fixed length.
 - Now suppose yeh hamare do code words hai

1101
1001

- Aapse pucha gaya inke bich ka hamming distance kitana hai.
- Joh in code words k bich mein hamming distance kaise find karegy.
- Joh hamming distance find karne k liye perform XOR on this hamming code words.

$$\oplus \begin{array}{r} 1101 \\ 1001 \\ \hline 0100 \end{array}$$

- Now un code ka hamane code word XOR perform kiya toh kya mila hamne 0100.
- Now in result mein kitane one's hai ~~two~~ one. (1)
- Joh number of one's in resulting XOR is the hamming distance between the code words.
- Joh in hamming code-words ki bich ka distance kitana hai ~~two~~ one.
- Aacha apko sets of code words diye hue hai, fahala diya hua hai-

1001, 1010, thisa 1100 now aapse pucha inke bich ka hamming distance kitana.

- Joh kya hum thino ka ek saath XOR karegy-

- Nahi, XOR toh karungy but at a time do ko karungy.

$$\begin{array}{r} 1001 \\ 1010 \\ \hline 0011 \\ \downarrow 2 \end{array}$$

$$\begin{array}{r} 1001 \\ 1100 \\ \hline 0101 \\ \downarrow 2 \end{array}$$

$$\begin{array}{r} 1010 \\ 1100 \\ \hline 0110 \\ \downarrow 2 \end{array}$$

$$\min(2, 2, 2) = 2.$$

- Overall hamming distance kitana kahalayega joh minimum daraha hai. i.e 2.
- So hamming distance between the code word is two (2).
- Yeh hamming distance ka concept important kyo hai, is hamming distance se hum kya conclusion nikal sakte ho??
- Suppose hum communication mein jaise ascii character kitane bits k hote hai 8 bits k.
- * 8 bit k kitane combination ban sakte hai 2^8 i.e 256
8 bit mein 256 different character ban sakte hai.
- * Lekin aap sab words use nahi karte ho, hum kya use karte hai a-z, A-Z, i.e 65-90, a-z, 97-122, bich k joh ascii value hai hum usually use nahi karte hai.
- Joh hamming yeh assume karta hai, ki agar apke code word 8 length k hai, toh 8 length

K. Sabhi code word valid nahi hai.

- Kuch selected valid hai aur kuch invalid hai.
- Valid kisko kaha raha hai jo hum send karrahai hai, aur kon invalid hai jo hum send nahi karrahai hai.
- * Capital A se capital Z tak send karrahai hai, 8 bit ka woh code word jiski value 65 aarhai hai woh valid hai.
- Par 8 bit ka woh code word jiski value kitani aarhai 64 woh kya hojayege invalid.
- Jo hamming yeh assume karta hai ki jitna bhi bada no code word send kar raha hai ^{uske} ~~uske~~ sabhi combination valid nahi hai.
- Some are valid & some are invalid.
- Agar kahi invalid code word receiver end par pahucha gaya, toh definitely receiver ko pata chal jayega ki there is some error.
- Error kab detect nahi hojayege jab ek valid code dusre valid code mein convert hojayege.
- Jaise, chalo dekhte hai, hum assume kar raha hai ki hum four bit k code word send kar raha hai aur sirf do hi send karrahai hai.

- Konse do ek toh 1011 aur dusra 1101.
- Agar yeh do code word hai toh receiver assume karuga ki yeh valid code aaya hai, other than this two agar koi aaya hai, toh receiver definitely assume karuga ki there is some error.
- Aab suppose is code word mein ek bit ki error aayi.
- Aacha in dono code word k bit ka hamming distance kitana 2.
- Now konsi bhi ek bit ki error aagayi, ek code word mein.

~~1011~~ 1011
 ↓
 0 corrupt

- Now hamare bheja tha 1011 par receiver ne ki pass kya facha 0011, toh yeh code word valid hai ki invalid hai.
- Toh yeh code word invalid hai, because do hi code word valid hai ek to 1011 aur dusra 1101.
- Toh receiver k pass jo facha hai usme kuch error hai.
- Agar ek bit ki konsi bhi error hai, result karna hua to invalid code.
- Toh 1 bit ki har error ko receiver detect kar

lega.

- Now aab two bit ki error detect ho payegi ki nahi ho payegi.
- Jo hamare bheja tha 1011 aur mila kya 0111, toh yeh invalid code hai yeh receiver detect karlega.
- Now suppose 1011 ko bheja ki do bit corrupt hogayi toh kya milega 1101
- Now suppose hamare 1011 hi bheja but receiver ko kya mila hamare bina middle ki do bit corrupt kar di toh receiver ko kya mila 1101. Now yeh 1101 kya hai, ek valid code word.
- Jo yeh error receiver detect nahi kar payega
- * One bit ki sabhi error ko detect kar payega par two bit ki sabhi error ko detect nahi kar payega.
- Aaisa kyo because unka hamming distance kitana tha two.
- * Jo to detect 'd' bit errors, toh code word ke bich mein kitana hamming distance jaruri hai $d+1$ distance.

to detect d bit $\Rightarrow d+1$
to correct d bit $\Rightarrow 2d+1$

code word
CLASSMATE
Date
Page
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- To detect d bit error, code word should $d+1$ distance apart.
- Agar two bit ka hamming distance hai toh one bit ki sabhi error detect ho jayegi.

* Isli tarika se hamming kahata hai to correct k d bits error, code words mein kitara hamming distance hona chahiye $2d+1$ distance hona chahiye.

Ques: If distance between code word is nine, then how many bits of error can be corrected??

Sol/-

$$\lfloor \frac{2d+1}{2} \rfloor = 9$$

$$2d = 8$$

$$d = 4$$

इतनी bit correct kr sakte

Ques: If distance between code word is 8, then how many bits of error can be corrected??

Ans

$$2d+1 = 8$$

$$2d = 7$$

$$d = 3.5$$

$$\lfloor d \rfloor = \lfloor 3.5 \rfloor = 3$$

Ans = Three bits can be corrected.

- Now yeh toh hamare theory discuss ki, actual mein hamming k code kaise implement hote hai,
- Joh joh practically implemented hamming code hai, it can correct only single bit error.

- Joh hamming ne apni scheme introduce ki thi, usme sirf ek bit k error correct hosakta hai,
 - Joh aab hum dekhte hai woh practically implement kaise hua hai.
 - Joh VRC mein kitani redundant bit one, CRC mein kitani redundant bit equal to highest power of the polynomial.
 - Joh hamming mein kitani redundant bits, -
If d is the length of data bits -
Joh Number of redundant bits n is equal to minimum value of n .
- Joh ek equation hoti hai -

$$d + n + 1 \leq 2^n$$

What is d → d is the length of data bit,
 n is redundant bit.

- Joh Minimum value of n , which is satisfied by this equation should be the number of redundant bits.
- Now suppose apki data bit 4 hai, toh kitani redundant bit hone chahiye -

$$d + n + 1 \leq 2^n$$

$$4 + n + 1 \leq 2^n$$

$$5 + n \leq 2^n$$

Minimum value of $n = 3$

- Toh agar data bit four hai toh redundant bit kitane hongi three hongi.

- If eight is the length of data bits, then how many redundant bits are there??

Ans 2

$$d = 8$$

$$d + n + 1 \leq 2^n$$

$$8 + n + 1 \leq 2^n$$

$$9 + n \leq 2^n$$

$$9 + 4 \leq 2^4$$

Minimum value of $n = 4$
which satisfy by this equation.

→ Number of redundant bit = 4.

- Now suppose hamara data hai eight bit ka, toh kitane redundant bit add karne hai four. Toh $8 + 4$, toh kitane bit ka data hogaya hamara 12 bits ka.

- Now ab redundant bit kaha add karne hai, beginning mein end mein, kaha??

- Toh ab hum dekhte hai, hamare kaha redundant bit add karne hai.

- Now hamko data ki numbering karne hai from 1 to 12.

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

- Now inme se konsi position 2 ki power ki hai,

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

- Jo position number 1, 2, 4, 8 yeh two ki power ki hai.

- Jo Jo yeh 2 ki power wali position hai waha kya aayegi redundant bits aayegi.

- Aur remaining position par kya aayega data bit aayega.

- Jo hum ek data bit hai $d = 100$

$$d = 10011010$$

- Jo sabse pahle position par kya aayega redundant bit aayega.

1	2	3	4	5	6	7	8	9	10
1	0	1	0	0	0	1	1	1	0
↓	↓		↓				↓		
2^0	2^1		2^2				2^3		