Week 3 – Data Link Layer

COMP90007 Internet Technologies

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Hamming Code

- $n=2^k-k-1$ (n: number of data, k: check bits)

  Example: Data: 0101 - > requires 3 check bits

  $$4 = (2^3) - 3 - 1$$

- Put **check bits in positions *p* that are power of 2**, starting with position 1
- Check bit in **position *p* is parity of positions with a *p* term in their value**

Example

Put check bits in positions p that are power of 2, starting with position 1

- Data: 0101 → requires 3 check bits

111

Position	P1	P2	P3	P4	P5	P6	P7
Data	?	?	0	?	1	0	1

1. Calculate the parity bits for P1, P2, P4 (rule: even parity)

P1 + P3 + P5 + P7 = ?+0+1+1 (even) → P1 = 0
P2 + P3 + P6 + P7 = ?+0+0+1 (odd) → P2 = 1
P4 + P5 + P6 + P7 = ?+1+0+1 (even) → P4 = 0

Data sent: 0100101

error

Example 1: At the receiver: 010010**0**

P1 + P3 + P5 + P7 = 0+0+1+0= 1 ×
P2 + P3 + P6 + P7 = 1+0+0+0= 1 ×
P4 + P5 + P6 + P7 = 0+1+0+0= 1 ×

Error bit = P1+P2+P4 = P7

error

Example 2: At the receiver: 0**0**00101

P1 + P3 + P5 + P7 = 0+0+1+1= 0
P2 + P3 + P6 + P7 = 0+0+0+1= 1 ×
P4 + P5 + P6 + P7 = 0+1+0+1= 0

Error bit = P2

Error Correcting Codes Key Points

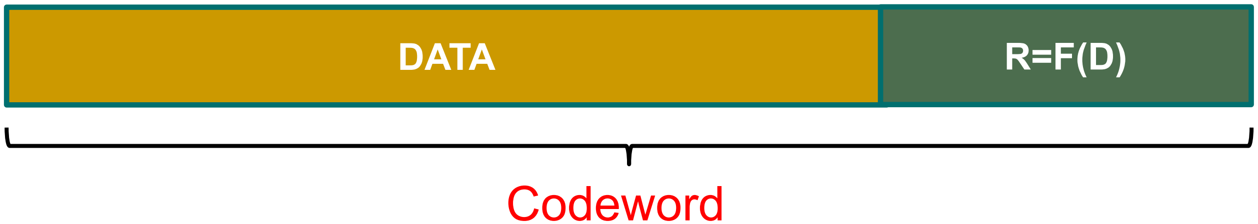
- More efficient in noisy transmission media e.g., wireless
- Challenge is that the error can be in the check bits
- Require assumption on a specific number of errors occurring in transmission

Error Detecting Codes

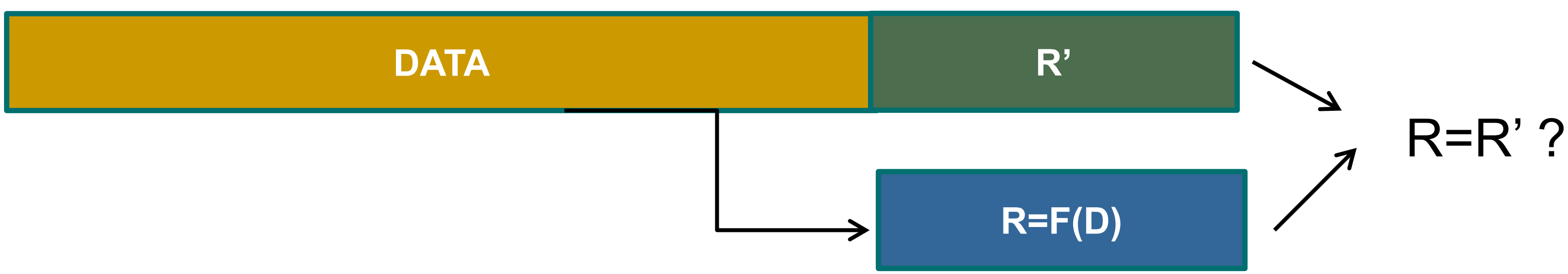
- More efficient in some transmission media – e.g. quality copper, where low error rates occur
- ***Parity*** (1 bit): (Hamming distance=2)
- ***Checksum*** (16 bits): (Hamming distance=2)
- ***Cyclical Redundancy Check*** *(CRC)* (Standard 32-bit CRC: Hamming distance=4)

How it works?

- Sender: calculates R check bits using a function of data bits:



- Receiver: receives the codeword and calculates the same function on the data and match the results with received check bits:



Parity Bit

Given data 10001110, count the number of 1s

Sender: Add parity bit → 10001110**0** (for even parity)

10001110**1** (for odd parity)

Receiver: Check the transferred data for errors on arrival.

Hamming distance is 2 for Parity Bit…

2 – 1 = **1 error bit can be detected** and

(2 – 1) / 2 = ½ not even 1 bit error can be corrected

Internet Checksum

- There are different variations of checksum
- Internet Checksum (16-bit word):

Sum modulo 2^{16} and add any overflow of high order bits back into low-order bits

Example of Checksum

Calculate checksum (5-bit word) for data

00110 10001 11001 01011

1. 00110
   +10001 = $\boxed{10111}$

2. 11001
   +10111 = 10000 +1 = $\boxed{10001}$

3. 01011
   +10001 = $\boxed{11100}$

4. The checksum is *one's complement* of 11100 which is 00011

Data sent: 00110 10001 11001 01011 00011

Cyclic Redundancy Check

- Based on a generator polynomial G(x)
  - e.g. $G(x) = x^4+x+1$ (10011)
  - Let r be the degree of $G(x)$ (r=4). **Append *r* zero bits to the low-order end of the frame** so it now contains $m + r$ bits and corresponds to the polynomial $x^rM(x)$.
  - **Divide the bit string corresponding to $G(x)$** into the bit string corresponding to $x^rM(x)$, using modulo 2 division.
  - **Subtract the remainder** (which is always r or fewer bits) from the bit string corresponding to $x^rM(x)$ using modulo 2 subtraction.
  - The result is the checksummed frame to be transmitted. Call its polynomial $T(x)$.

Example

Data: **1101001** and G(x) = x^4+x+1 (**10011**)

5 bits polynomial add **4** bits as the checksum – so add 0000

```
10011 | 11010010000
        10011
        ------
        010010
          10011
          ------
          000011000
                10011
                ------
                010110
                  10011
                  ------
                  00101
```

Data sent:
11010010101