Computer Networks (CISC3001)

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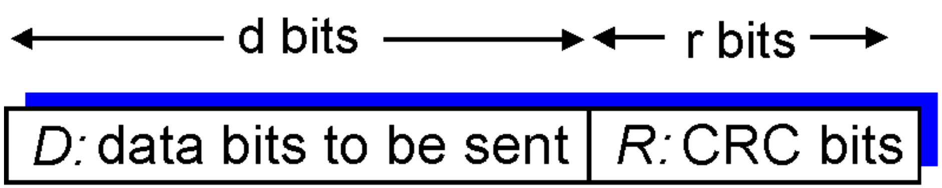
Cyclic redundancy check

- more powerful error-detection coding
- view data bits, D, as a binary number
- choose r+1 bit pattern (generator), G
- goal: choose r CRC bits, R, such that
  - <D,R> exactly divisible by G (modulo 2)
  - receiver knows G, divides <D,R> by G. If non-zero remainder: error detected!
  - can detect all burst errors less than r+1 bits
- widely used in practice (Ethernet, 802.11 WiFi, ATM)



bit pattern

$D * 2^r$ XOR R

mathematical formula

Cyclic redundancy check

- Performance :
  - CRC can detect all single bit errors (G>1)
  - CRC can detect all double-bit errors provided the G contains at least three logic 1's
  - CRC can detect all burst error of length less than r+1 bits
  - CRC can detect most of the larger burst errors with a high probability
  - For example, CRC-12 detects 99.97% of error

- Conditions for G :
  - The highest and lowest bits must be 1
  - When an error occurs in any bit, the remainder should be non-zero
  - When errors occur in different bits, the remainders should be different
  - Balance the number of "1" and the number of "0"

Q1: For D:10110011, G:11001, what are the CRC bits?

Q2: Is G:1001 a "good" generator for D:101110?

CRC example

Q1: For D:10110011, G:11001, what are the CRC bits?

```
  G
1 1 0 0 1 ) 1 0 1 1 0 0 1 1 0 0 0 0
            1 1 0 0 1
            ---------            D
              1 1 1 1 0
              1 1 0 0 1
              ---------
                1 1 1 1 1
                1 1 0 0 1
                ---------
                  1 1 0 0 0
                  1 1 0 0 1
                  ---------
                    0 1 0 0
                      R
```

```
1 1 0 0 1 ) 1 0 1 1 0 0 1 1 0 1 0 0
            1 1 0 0 1
            ---------
              1 1 1 1 0
              1 1 0 0 1
              ---------
                1 1 1 1 1
                1 1 0 0 1
                ---------
                  1 1 0 0 1
                  1 1 0 0 1
                  ---------
                      0 0 0
```

CRC example

Q2: Is G:1001 a "good" generator for D:101110?

```
    G
 _______        1 0 1 0 1 1
|       |     _____________________
 1 0 0 1     ) 1 0 1 1 1 0 0 0 0
               1 0 0 1             D
               -------
                  1 0 1
                  0 0 0
                  -------
                  1 0 1 0
                  1 0 0 1
                  -------
                     1 1 0
                     0 0 0
                     -------
                     1 1 0 0
                     1 0 0 1
                     -------
                        1 0 1 0
                        1 0 0 1
                        -------
                          0 1 1
                          R
```

For the 2nd bit error, the remainder:

```
         ___________________
1 0 0 1 ) 1 1 1 1 1 0 0 1 1
          1 0 0 1
          -------
            1 1 0 1
            1 0 0 1
            -------
              1 0 0 0
              1 0 0 1
              -------
                  1 0 1 1
                  1 0 0 1
                  -------
                    0 1 0
```

For the 5th bit error, the remainder:

```
         ___________________
1 0 0 1 ) 1 0 1 1 0 0 0 1 1
          1 0 0 1
          -------
              1 0 0 0
              1 0 0 1
              -------
                  1 0 1 1
                  1 0 0 1
                  -------
                    0 1 0
```

Bit pattern: 1 0 1 1 1 0 0 1 1

CRC example

Q2: Is G:1001 a "good" generator for D:101110?

When errors occur in different bits, the remainders should be different!

For the second bit and the fifth bit errors,
the remainder:

```
1001 ) 1 1 1 1 0 0 0 1 1
       1 0 0 1
         1 1 0 0
         1 0 0 1
           1 0 1 0
           1 0 0 1
               1 1 0 1
               1 0 0 1
                 1 0 0 1
                 1 0 0 1
                       0
```

No error checked !

The commonly used G

	Polynomial	G
CRC-4	$x^4 + x^3 + x^2 + 1$	11101
	$x^4 + x^2 + x + 1$	10111
	$x^4 + x + 1$	10011

In practical 802.11 protocol, normally CRC-32 with a generator of 33 bits is used

The case of the first bit and fourth bit errors is similar

G:1001 might not be a good generator for D:101110