Error Control
(An Overview)

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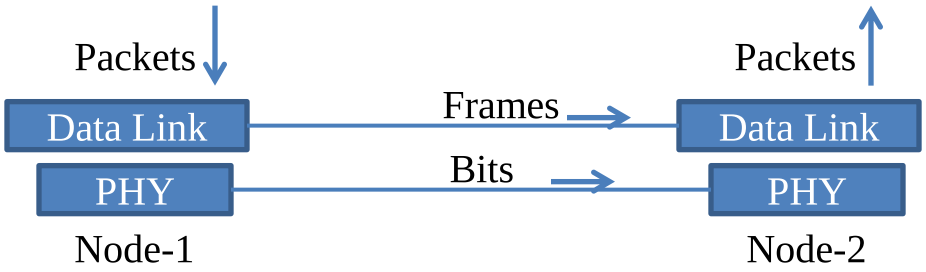
Recap

errors happen due to noise.
sender sends onething and other end recieves other thing.

- Frame-by-Frame next-hop delivery
- Focus on Error Control
  - Error Detection and recovery



Error Detection

- What cause errors?
  - Distortion of signals due to frequency dependant attenuation, noise (PHY layer)
  - Random single-bit vs Bursty errors

single bit sdiff

a bunch of bits are erros

- Why detect errors?

correctness

if error is at 1st hop itself.... then unnecessary to travel many hops

  - Data fidelity, prevent wastage of resources

noise-->1us
data rate : 1Mbps ----> 1 error   single-bit error
100Mbps=----> 100error --> burst errror of 100 bits

What next?

- After Detection:
  - Drop Frame
    - Higher layers (e.g TCP) will recover or few losses dont hurt applications (e.g. audio)
  - Recover Frame
    - Error Correction: Frame carries enough information to correct errors
    - Retransmission: Receiver signals sender on error, sender retransmits the frame

Error correction vs Retransmission

- Error correction requires more redundant bits per frame than error detection
  - Redundancy bits are sent all the time (every frame)
- Retransmission requires another copy to be transmitted
  - Copy sent only on error

Usage

- Error correction useful when
  - Error rate if high (e.g. wireless)
  - Cost (e.g. latency) of retransmission is too high (e.g. satellite link)

Framework

- Add redundant information to a frame to detect or correct errors
- At Sender: Add **k** bits of redundant data to a **m** bit message
  - k derived from original message through some algorithm
- At Receiver: Reapply same algorithm as sender to detect errors; take corrective action if necessary
- Examples:
  - Detection: $k \ll m$; $k = 32$; $m \sim 12{,}000$ for Ethernet
  - Correction: Code Rate: $m/(m+k)$
    - WiFi code rates range from 1/2 to 5/6

Hamming Distance

m message + k redundant = code word

- Code word: n=m+k bits
- Hamming distance between two codewords: Number of bits they differ in
  - XOR the two codewords
- Example:
  - Codewords: 01110110, 00011101
  - Distance is 5

Hamming Distance of a Code

Legal code words are called 'CODE'

- Number of possible code words is 2^n
- Legal code words = 2^m (determined by the algorithm)

  there are m message bits and 2^m possible messages ..... so and each hs a code word which the algorithm determines.. so total 2^m code words

- Among the list of legal code words, find the smallest hamming distance between two code words
  - This is the hamming distance of a code (=d)

Rules

- The error detection/correction capabilities are a function of the code's hamming distance

errror codes are those present in the remaining 2^n - 2^m words

- Error Detection: Can detect up to d-1 errors
  - To change one codeword to another require atleast d bit changes
- Error Correction: Can correct up to (d-1)/2 errors
  - The received codeword (in error) is still closer to the original codeword than any other codeword

Example

- Repetition code
  - 0 → 000; 1 → 111
  - m=1, k=2; n=3
  - Hamming distance is 3, code rate is 1/3
- Can detect up to 2 errors and correct up to 1 error

n = 3; so 8 possible words..
only 2 legal

Design Considerations of a Code

- Reduce k to achieve high code rate
- For given values of n and k, maximize d
- Easy encoding and decoding
  - Minimal memory and processing time

Focus

- Error Detection
- Reliable Transfer (retransmissions)
- ~~Error Correction~~
  - ~~E.g. Reed-Solomon codes, Convolution codes, Turbo codes~~

Summary

- Important to detect errors in frames
- Error Recovery: FEC or Retransmission
  - Inherent tradeoffs
- Framework (Overview)
  - Hamming distance and error detection/correction capabilities
  - Design considerations
- Going forward: Error detection (in detail)