Error Correction Techniques in Computer Networks

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Outline

- Error?
- Error Detection
- Error Correction
  - Backward Error Correction
  - Forward Error Correction
Error?

• Corruption of data during transmission
  – Bits lost
  – Bits changed
  – Bits added
• Types of errors:
  – Single bit errors
  – Multiple bit errors
  – Burst errors
Error in Network

Transmitter

Encoder

Message

Generator

Message + Redundancy

Unreliable Transmission

Receiver

Decoder

Message

Correct or Discard

Checker

Received Information
Outline

• Error?
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Error Detection

• Error Detection techniques allow the destination to detect errors.
• Sometimes **undetected errors** will still remain but **the goal is to minimize** these errors.
Error Detection

• To detect and correct errors, **enough redundancy bits need to be sent** with data.
• Redundancy bits are the extra bits sent by source to inform destination about the data sent.
Error Detection

- Parity Check
- Cyclic Redundancy Check (based on binary division)
- Checksum
- Hamming Distance Check
Outline

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Backward Error Correction

• Known as *Automatic Repeat Request (ARR)*
• Receiver device sends a request to the source device to re-send the data after detecting the error or errors
• More often used because it requires less bandwidth
• A return channel is needed for backward error correction
Backward Error Correction

• There are two ways to overcome the errors
  – Positive acknowledgement
    Receiver returns confirmation of each block received correctly. The transmitter re-sends the block that is not acknowledged.
  – Negative acknowledgement
    Receiver returns a request to retransmit only the data with error
Outline

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Forward Error Correction

• This technique allows the receiver to detect and correct errors without asking the sender for retransmission
• The bandwidth requirement is higher but return channel is not needed
• Redundant data, sent by transmitter is also called *error correction code*
Forward Error Correction

• Redundancy bits are added to the transmitted information using a predetermined information
• Each redundancy bit can be a function of many parts of original data or also can be nonsystematic
Forward Error Correction

- Example: **Democratic Voting**

<table>
<thead>
<tr>
<th>Received Data</th>
<th>Interpreted as</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>0</td>
</tr>
<tr>
<td>001</td>
<td>0</td>
</tr>
<tr>
<td>010</td>
<td>0</td>
</tr>
<tr>
<td>011</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>101</td>
<td>1</td>
</tr>
<tr>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>111</td>
<td>0 error</td>
</tr>
</tbody>
</table>
Forward Error Correction

• Two main categories
  – Block Coding: Reed-Solomon Coding, Hamming Codes, Binary BCH
  – Convolutional Coding: Viterbi Algorithm
Forward Error Correction

- **Block Coding** works on fixed size packets of bits
- Mostly common used algorithm is *Reed-Solomon*
Forward Error Correction

• A Reed-Solomon code is specified as RS(n,k) with s-bit symbols
• This means that the encoder takes $k$ data symbols of $s$ bits each and adds parity symbols to make an $n$ symbol codeword
• There are $n-k$ parity symbols of $s$ bits each. A Reed-Solomon decoder can correct up to $t$ symbols that contain errors in a codeword, where $2t = n-k$. 
Forward Error Correction

• Example: A popular Reed-Solomon code is RS(255,223) with 8-bit symbols. Each codeword contains 255 code word bytes, of which 223 bytes are data and 32 bytes are parity. For this code:
  • \( n = 255, \ k = 223, \ s = 8 \)
  • \( 2t = 32, \ t = 16 \)
  • The decoder can correct any 16 symbol errors in the code word
Forward Error Correction

- **Convolutional codes** work on bit streams
- If desired a convolutional code can be turned into a block code
- Most widely used algorithm is Viterbi Algorithm if desired
Forward Error Correction

- **Viterbi** decoder examines an entire received data sequence of a given length at a time interval, then computes a metric for each path and makes a decision based on this metric.

- One of the common metric used by Viterbi Algorithm for paths comparison is the Hamming distance metric, which is a bit-wise comparison between the received codeword and the allowable codeword.
Conclusion

- Error Detection
  Parity Check, Cyclic Redundancy Check, Hamming Distance
- Error Correction
  Backward and Forward Error Correction
• Questions?
• Thanks...
ÖNEMLİ

Bu projeler lisansüstü öğrencilerinin hazırladığı çalışmalar olup tüm sorumluluk hazırlayan öğrencilere aittir. Öğrenciler hazırladığı projeye göre not almışlardır.