IEEE 802.3bp RTPGE FEC Contribution

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Definitions

Assumptions

Code Candidates

Code Selection based on assumptions

Performance
  - Coding Gain
  - Burst Error Performance

Flexibility of Selection

Summary
Definitions

- **Concatenated Codes**
  - Product of two subcodes, where overall rate is a product of the independent rates and the code size is also a product of the constituent codes.

- **LDPC**
  - Low density parity check codes, invented by Gallagher in 1960’s, a class of soft iterative decodable codes

- **Waterfall and Error Floor Regions** of the BER performance curves
  - Red area is the waterfall region, (low SNR)
  - Blue lines are the error floor region, (high SNR)

- **Puncturing and shortening** – techniques applied to a code, to produce a new codeword set that is smaller and custom tuned to an application.
Assumptions

- An energy efficient modulation scheme is chosen such under our channel model agreements a target FEC coding gain on the order of ~5dB is required to meet our BER objectives.

- A high rate code is desired, overhead <10%, implying code rates >90%

- Burst Error correcting code would be desirable

- Low latency is desired

- Good performance in the “error floor” region
  - Wireline-like performance vs Wireless-like performance

- Allows puncturing or shortening to adjust the code to our application
Code Candidates

Based on the assumptions of High Rate Codes, 90%

<table>
<thead>
<tr>
<th>Code Type</th>
<th>High Rate Codes, &gt;90%</th>
<th>Candidate Code?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic Algebraic Codes</td>
<td>Selected members of the BCH, Reed Solomon, family of codes achieve high rates and low error floors</td>
<td>Yes</td>
</tr>
<tr>
<td>LDPC</td>
<td>A few, specified in 802.15.3c for example, but poor performance in the error floor region</td>
<td>No</td>
</tr>
<tr>
<td>Concatenated Codes, TPC</td>
<td>Tough to find at 90% code rate unless component codes are very large, then latency is a concern. Accumulator codes might meet the code rate requirements but tend to perform poorly in the error floor region.</td>
<td>No</td>
</tr>
<tr>
<td>Turbo Codes</td>
<td>Not high enough rate, poor error floor performance</td>
<td>No</td>
</tr>
</tbody>
</table>

* If code rate is relaxed (>80%) then this opens the door for LDPC, Concatenated Codes
Code Selection

- **RS (255,239,17)**
  - Reed Solomon non-binary cyclic code
  - S=8 size of symbol
  - N=255 symbols per codeword
  - K=239 information symbols per codeword
  - D=17 minimum Hamming distance between any two codewords
  - Distance = 17, implies t=8 error correcting capability
  - Particularly useful for burst error correction
  - Flexibility, can be easily shortened (some performance penalty will result)
Erasure decoding Performance

- The Erasure decoding performance of a RS code is:
  - \( R = d_{\text{min}} - 1 = n-k \) in this case 16, twice as many symbols can be corrected if we know where the symbol errors are.

- Simultaneous Erasure capability and error correction is related by:
  - \( 2a + b < d_{\text{min}} < n-k \)
  - Where \( a \) = unknown error locations
  - Where \( b \) = known erasures
Performance

- Assume Hard Decoding
- Coding Gain*
  - ~5dB at BER = $10^{-10}$
  - ~6.2dB at BER = $10^{-15}$

* Not the Net effective coding gain
Flexibility of Code Selection

- Flexibility of Selection
  - Shortening, puncturing (size adaptability)
    - Example DVB standard uses a RS(204,188), a shortened code RS(255,239)
  - Improved burst protection through multi block interleaving is possible, at the expense of decoding latency
  - Very good erasure performance
  - Works with most modulation schemes
Summary

- RS(255,239) has been an industry work horse code for good reasons
  - Particularly in wireline, optical where low errors floors are desirable
    - G.709, DVB standards

- An overhead of 6.3% redundancy, achieves ~5dB coding gain at BER=10^{-10}
  - (theoretical performance in AWGN)

- Excellent Burst Error Correction capability
  - Important in an environment known to have impulse noise sources

- Flexible
  - Code can be shortened to match to framing protocols and improve latency
  - Good erasure performance

- Low latency
Next Steps

- Validate the assumptions

- After a first round of looking at modulation and coding, it would be nice to have targets for coding gain, latency, burst correction criteria, and overhead, to iterate to a more refined FEC selection.