Reflections on FEC Ad-Hoc group resolutions

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Reflections on ‘FEC Ad-Hoc Group’ Resolutions

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Background

• One of the topics discussed in the FEC ad-hoc: ‘Optimality of the current FEC scheme’

• Current draft (TG3) uses outer RS + inner CC.
  – With very short block lengths. Different from standard practice.

• Comparison with CC only showed that:
  – CC better than RS+CC @ PER >10^{-2}… 10^{-3}
  – RS+CC is better at PER < 10^{-2}… 10^{-3}
  – Cross over points depends on the block length and rate.

• Decision was taken to adopt RS+CC as mandatory mode for TG4.
  – Hence RS+CC is the mandatory scheme for OFDM/OFDMA
Background (cntd).

- Authors feel that this decision is technically wrong.
  - Will increase complexity with no real gain.
  - In this contribution, we shall try to convince the working group on this.

- Please note:
  - A technical debate.
  - Ad hoc procedures were immaculate.

😊 Thnx Garik for chairing the ad-hoc.
Outline

• Summary of simulations results presented
• Discussion points:
  – At what PER to compare ?
  – “It’s unthinkable not to use RS”
  – Can RS erasures be used ?
  – Can the number of RS corrections be used as a redundancy check ?
Simulations results

• Simulation results from 5 individuals
  – Charlie Chan (Who brought up this issue)
  – Einan Regev, Yossi Segal, Brian Edmonston, Tal Kaitz
## Summary of results

<table>
<thead>
<tr>
<th>Source</th>
<th>Conditions</th>
<th>Results</th>
<th>$@ P_{\text{error/byte}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charlie</td>
<td>QPSK $\frac{1}{2}$</td>
<td>CC better by 0.5 dB.</td>
<td>$1.3 \cdot 10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>AWGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brian</td>
<td>QPSK $\frac{1}{2}$</td>
<td>CC better by 0.4 dB</td>
<td>$4 \cdot 10^{-4}$</td>
</tr>
<tr>
<td></td>
<td>AWGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brian</td>
<td>QAM16 $\frac{3}{4}$</td>
<td>CC better by 0.4 dB</td>
<td>$1.2 \cdot 10^{-4}$</td>
</tr>
<tr>
<td></td>
<td>AWGN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Einan</td>
<td>QPSK 1/2-</td>
<td>CC better by ~1dB</td>
<td>$10^{-4}$…$10^{-5}$</td>
</tr>
<tr>
<td></td>
<td>QAM64 $\frac{3}{4}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SUI #1</td>
<td>In all cases</td>
<td></td>
</tr>
</tbody>
</table>
# Summary of results, cntd

<table>
<thead>
<tr>
<th>Source</th>
<th>Conditions</th>
<th>Results</th>
<th>@ P_{error/byte}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tal</td>
<td>QAM16 ½ AWGN</td>
<td>CC better by 0.4 dB.</td>
<td>$1 \cdot 10^{-5}$</td>
</tr>
<tr>
<td>Tal</td>
<td>QAM 64 ¾ AWGN</td>
<td>CC and RSV equal</td>
<td>$2 \cdot 10^{-5}$</td>
</tr>
<tr>
<td>Tal</td>
<td>QAM 64 2/3 AWGN</td>
<td>CC and RSV equal</td>
<td>$10^{-4}$</td>
</tr>
<tr>
<td>Tal</td>
<td>QAM16 ½ SUI #3 4Mhz</td>
<td>CC better by 1.7dB</td>
<td>$10^{-5}$</td>
</tr>
</tbody>
</table>
## Summary of results, cntd

<table>
<thead>
<tr>
<th>Source</th>
<th>Conditions</th>
<th>Results</th>
<th>@ $P_{error}$/byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yossi</td>
<td>QAM16 ½ AWGN</td>
<td>CC and RSV equal. RSV+Erasure better then CC by 0.7dB</td>
<td>$1 \cdot 10^{-5}$</td>
</tr>
<tr>
<td>Yossi</td>
<td>QAM 16 ¾ AWGN</td>
<td>CC better by 0.2dB RSV+Erasure Better by 0.8</td>
<td>$1 \cdot 10^{-5}$</td>
</tr>
<tr>
<td>Yossi</td>
<td>QAM 64 2/3 SUI#1 20MHz</td>
<td>RSV better than CC by 1.5 dB RSV+Erasure better than CC by 1.7dB</td>
<td>$3 \cdot 10^{-4}$</td>
</tr>
<tr>
<td>Yossi</td>
<td>QPSK ½ SUI#1</td>
<td>RSV equal CC</td>
<td>$4 \cdot 10^{-5}$</td>
</tr>
</tbody>
</table>
Results

- Majority of contributors:
  - CC is better at $10^{-5}$ error event /byte.
  - RS+CC is better at lower error probabilities.

- Disagreement with Yossi on Multipath results. (Not same conditions were simulated)
- Yossi showed the advantage of using soft output and erasures.
At what PER to compare

- What code is better depends on required PER.
- ARQ systems can operate well with PER $10^{-2} \ldots 10^{-3}$
- Degradation due to TCP/IP
Degradation due to TCP

Source: Wendy Wang, Aperto Networks
Degradation due to TCP

• Octavian’s point:
  – Our system has 6-8 modes, rates for two consecutive MODES is 1.33…1.5, and the SNR difference is 2-3dB.
  – Suppose we operate at MODE4 with an SNR that provides say PER=10^-2.
  – According to Wendy, this will reduce our throughput to 93%.
  – We panic (TCP ) and switch to mode3 which is 66% data rate.
  – 93%* 100% <> 100% *66 % ?
By requiring very low PER we reduce efficiency
PER working point

• PER is not governed by FEC alone:
  – Fades, interference may govern

• Under fades or interference we experience a temporal loss of SNR.
  – Momentarily we’ll be in high PER region
  – At this point FEC performance will be crucial.
“RS+CC have been around”

- We have nothing against concatenated schemes.
- A properly designed RS+CC with long blocks will perform well even in high PER.
- The common practice is add the outer scheme without reducing the inner CC.
- In our scheme the CC rate is weakened to keep overall rate as is.
- This significantly weakens the code.
Use of erasures

- Performance maybe improved by using Viterbi soft outputs and erasures:
- Literature\(^1\) (Zeoli 1973) shows 0.3 dB in QPSK.
- Yossi showed higher improvements for multipath. Requires further study.

\(^1\)G.W. Zeoli “Coupled Decoding of Block–Convolutional Concatenated Codes”, IEEE Trans on Comm, vol COM–21 1973, M Charlie Cahn provide this reference
Use of erasures

• To use erasures we need to provide soft output from Viterbi decoder.
• Requires changes and additional complexity of Viterbi decoder.
• No longer an off the shelf design block
• If you want to give your product an edge: use turbo codes which are now defined.
Can we use RS as redundancy check?

- Yes but at expense of error correction capability.
- The number of corrections can be used only as a ‘quality indicator’ of received payload.
- This can be done also in CC case, by computing un-coded BER.
Summary

• The current FEC scheme is not optimal
• At packet error rates of interest, this system performs worse than a simpler convolutional code.
• It can be enhanced by using erasure but
  – At major increased complexity
  – With questionable benefits
  – We already have an advanced FEC (Turbo)
• It is different from the standard practice.
Conclusions

• Let’s not use a complicated system instead of a simpler and a better one

• We believe that CC should be the mandatory scheme for 16a (OFDM) and 16b.