

| | | |
|------------------------------|---|--|
| Project | IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 > | |
| Title | Improved CTC Performance | |
| Date Submitted | 2005-03-11 | |
| Source(s) | T. Keith Blankenship Yufei Blankenship Brian Classon Motorola | keith.blankenship@motorola.com yufei.blankenship@motorola.com brian.classon@motorola.com |
| | Alek Purkovic Nortel Networks | apurkovi@nortelnetworks.com |
| | John Benko Marie-Helene Hamon France Telecom Research & Development | John.Benko@francetelecom.com mhelene.hamon@francetelecom.com |
| Re: | IEEE P802.16-2004/Cor1-D1 (2005-02-11) | |
| Abstract | This contribution demonstrates that the convolutional turbo code (CTC) interleavers for block sizes 120 bytes and above were selected incorrectly. By selecting different interleaver parameters for these block sizes, the errors can be corrected without implementation impact. The difference between the proposed parameters and the existing parameters is at least 0.5 dB and in some cases up to 1.3 dB in AWGN at 10^{-4} FER. | |
| Purpose | To correct CTC channel coding interleaver parameters when supporting H-ARQ. | |
| Notice | This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein. | |
| Release | The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16. | |
| Patent Policy and Procedures | The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures < http://ieee802.org/16/ipr/patents/policy.html >, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair < mailto:chair@wirelessman.org > as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site < http://ieee802.org/16/ipr/patents/notices >. | |

Current CTC Performance

The convolutional turbo code (CTC), a parallel concatenation of two duo-binary tail-biting recursive systematic codes, is an optional error control coding mode in 802.16-2004. The CTC interleaver, defined in 8.4.9.2.3.1 and 8.4.9.2.3.2, uses an “almost regular” permutation (ARP) [1],

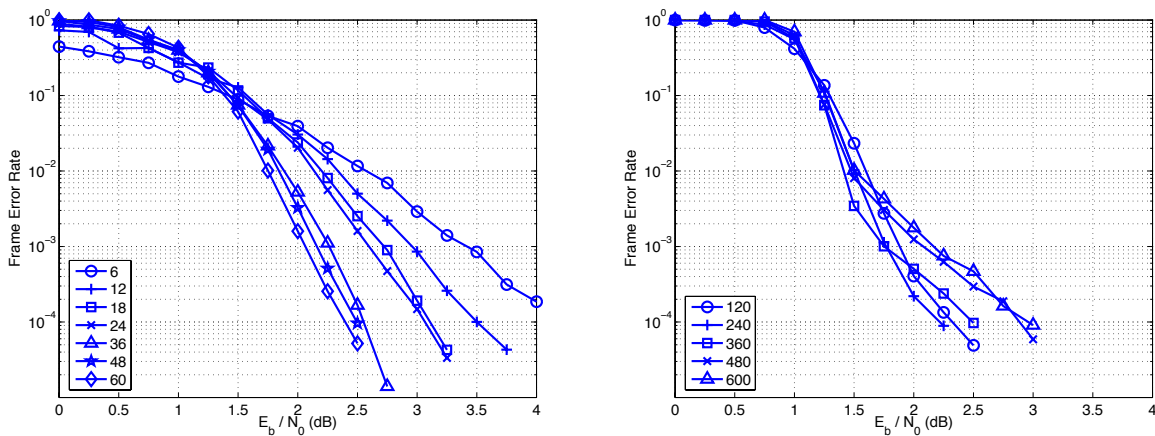
$$\pi(i) = (iP_0 + d(i)) \bmod N \tag{1}$$

where $0 \leq i \leq N-1$ is the sequential index, $\pi(i)$ is the permuted index, N is the information block size in bit couples, P_0 is a number that is relatively prime to N , and $d(i)$ is a “dither” vector. For all 802.16 block sizes, $d(i)$ assumes the form

$$d(i) = \begin{cases} 1, & i \bmod 4 = 0 \\ 1 + N/2 + P_1 & i \bmod 4 = 1 \\ 1 + P_2 & i \bmod 4 = 2 \\ 1 + N/2 + P_3 & i \bmod 4 = 3 \end{cases} \tag{2}$$

for $0 \leq i \leq N-1$. The values of $P_0, P_1, P_2,$ and P_3 depend on N , and are listed in Tables 326 and 327. Henceforth, this document only considers block sizes contained in Table 325.

Figure 1 plots the simulated frame error rate (FER) versus E_b/N_0 using the current 802.16 CTC interleaver specification. The results assume a rate-1/2 code, binary modulation over a static additive white Gaussian noise (AWGN) channel, 7.5 decoding iterations, and perfect “genie” knowledge by the decoder of the encoder circulation states. Sub-figure (a) plots results for $6n$ -byte data block sizes ($n = 1, 2, 3, 4, 6, 8, 10$), and sub-figure (b) plots results for the larger $120n$ -byte data block sizes ($n = 1, 2, 3, 4, 5$).



(a) $6n$ -byte block sizes, $n = 1, 2, 3, 4, 6, 8, 10$ (b) $120n$ -byte block sizes, $n = 1, 2, 3, 4, 5$

Figure 1. FER performance for currently specified CTC interleavers.

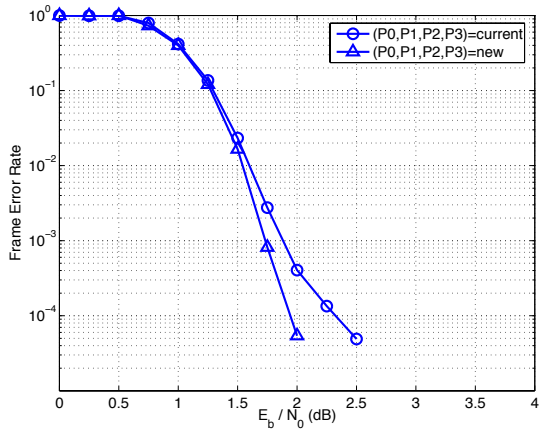
The performance of the $6n$ -byte block sizes displays the expected turbo code behavior of improving performance with increasing block size. Furthermore, no error floor is discernable down to a FER of 10^{-4} . However, the performance of the $120n$ -byte block sizes displays the opposite. Here, the performance degrades with increasing block size (above 240-byte) and a distinct error floor is present.

CTC Performance with New Interleaver Parameters

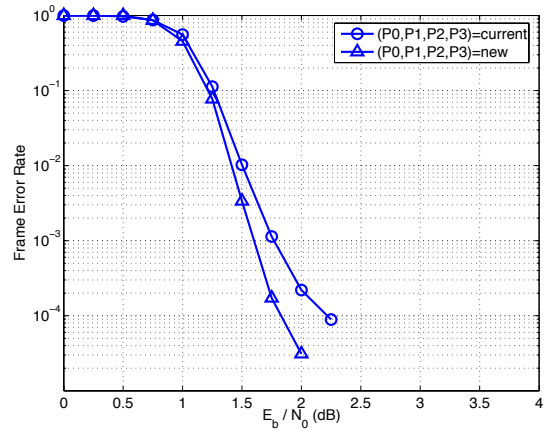
A new set of CTC interleaver parameters was designed to correct the performance deficiencies of the $120n$ -byte block sizes. The new parameters were selected according to guidelines prescribed in [1]. The FER performance (rate-1/2, binary modulation, static AWGN channel, 7.5 decoding iterations, and “genie” circulation state knowledge) with the new parameters is plotted in Figure 2. The figure shows that the new parameters correct the performance deficiencies of the current parameters. At FER = 10^{-4} the performance with the new parameters is at least 0.5 dB and in some cases up to 1.3 dB better than with the current parameters.

The proposed interleaver parameters have been independently tested by Nortel in comparison to the existing parameters. Their results in Figure 3 further support the significant improvement achieved by the proposed parameters.

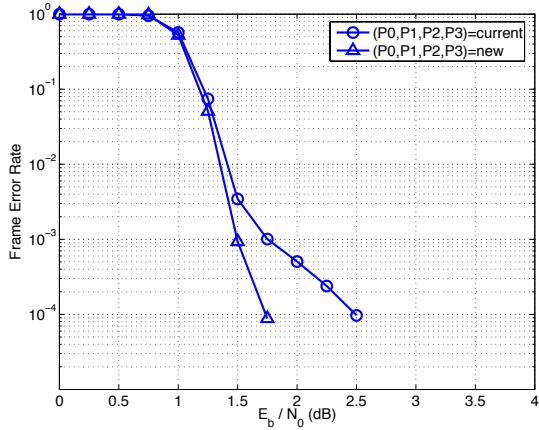
In addition, a search conducted by France Telecom showed that the proposed parameters are among the best that could be found.



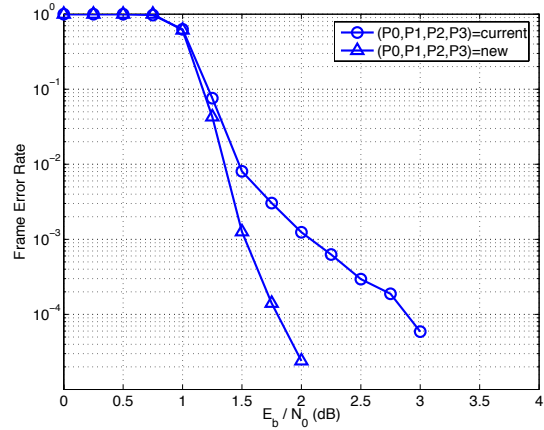
(a) 120-byte block



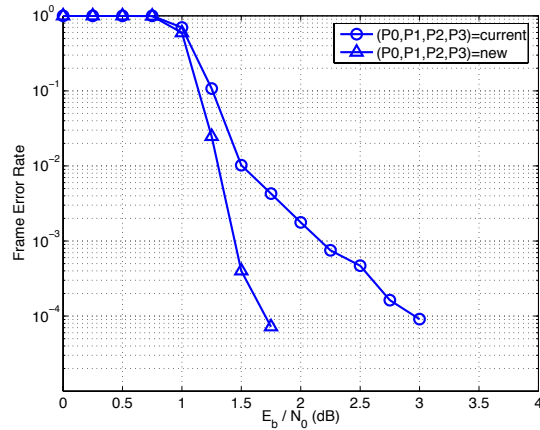
(b) 240-byte block



(c) 360-byte block



(d) 480-byte block



(e) 600-byte block

Figure 2. Performance with new CTC interleaver parameters.

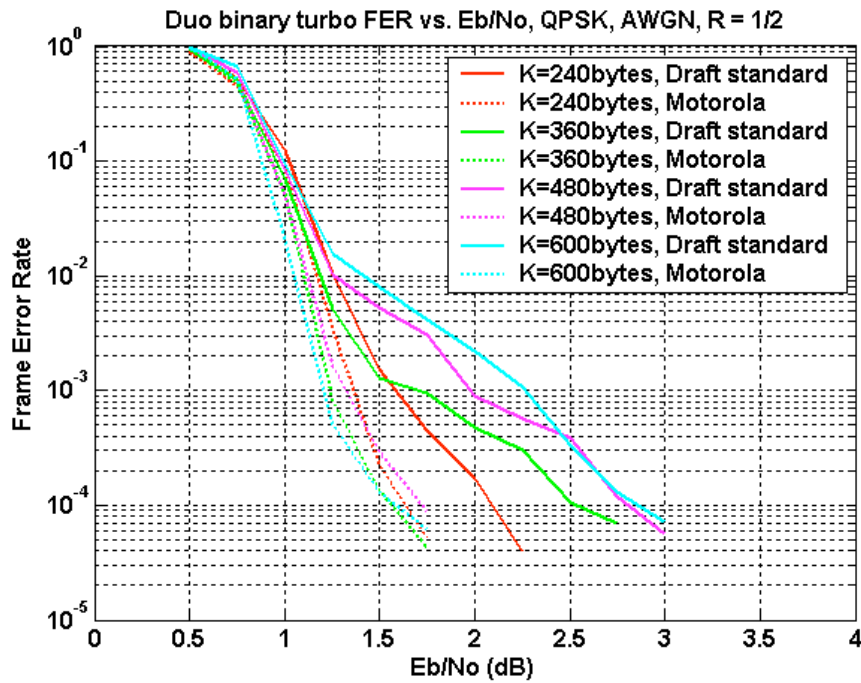


Figure 3. Cross simulation provided by Nortel on the existing and new CTC interleaver parameters.

References

[1] C. Berrou *et al.*, “Designing good permutations for turbo codes: towards a single model,” in *Proceedings of the 2004 IEEE International Conference on Communications*, vol. 1, pp. 341-345.

Recommended Text Changes:

<Insert the following to IEEE P802.16-2004/Cor1-D1 (2005-02-11) section 8.4.9.2.3.1 p.110 line 59>
 Change the entries of Table 327 as indicated.

Table 327 – Optimal CTC channel coding per modulation when supporting H-ARQ

| Data block size (bytes) | N | P0 | P1 | P2 | P3 |
|-------------------------|------|------------------|--------------------|--------------------|--------------------|
| 6 | 24 | 5 | 0 | 0 | 0 |
| 12 | 48 | 13 | 24 | 0 | 24 |
| 18 | 72 | 11 | 6 | 0 | 6 |
| 24 | 96 | 7 | 48 | 24 | 72 |
| 36 | 144 | 17 | 74 | 72 | 2 |
| 48 | 192 | 11 | 96 | 48 | 144 |
| 60 | 240 | 13 | 120 | 160 | 180 |
| 120 | 480 | 13 53 | 240 62 | 120 12 | 360 2 |
| 240 | 960 | 13 43 | 480 64 | 240 300 | 720 824 |
| 360 | 1440 | 17 43 | 720 | 360 | 540 |
| 480 | 1920 | 17 31 | 960 8 | 480 24 | 1440 16 |
| 600 | 2400 | 17 53 | 1200 66 | 600 24 | 1800 2 |