Project	IEEE 802.16 Broadband Wireless Access Working Group <**http://ieee802.org/16**>
Title	Improved CTC Performance
Date Submitted	2005-01-10
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Re:	IEEE P802.16-REVe/D5a, BRC recirc
Abstract	This contribution demonstrates that the convolutional turbo code (CTC) interleavers for block sizes 120 bytes and above have performance deficiencies. By selecting different interleaver parameters for these block sizes, the deficiencies can be corrected. The performance improvement in AWGN at 10^{-4} FER with the new parameters is at least 0.5 dB and in some cases up to 1.3 dB.
Purpose	To provide improved CTC channel coding interleaver parameters when supporting H-ARQ with 802.16e units.
Notice	
Release	
Patent Policy and Procedures	

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-REVd/D5. 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],

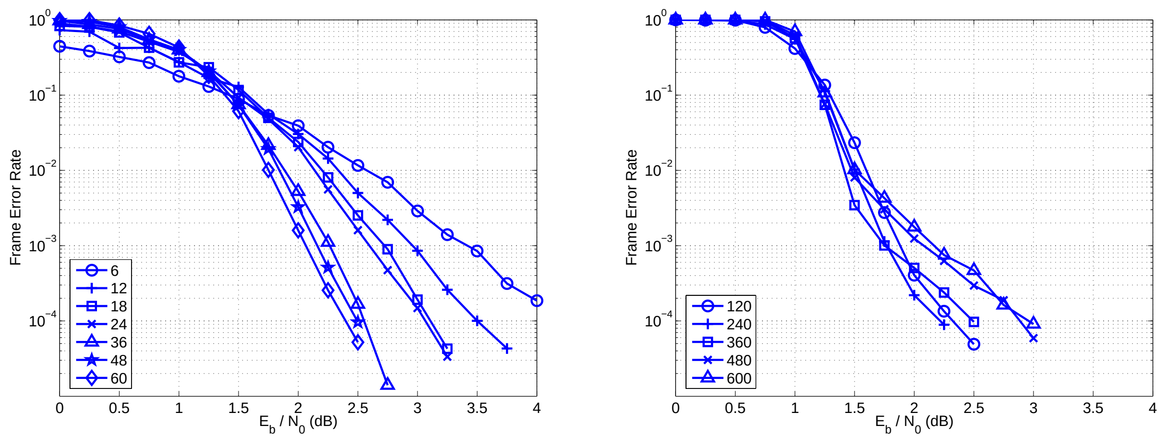
$$\pi(i) = (iP_0 + d(i)) \bmod N \qquad (1)$$

where $0 \le i \le N-1$ 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

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

for $0 \le i \le N-1$. The values of P_0, P_1, P_2, and P_3 depend on N, and are listed in Tables 324 and 325. 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 6*n*-byte data block sizes (n = 1, 2, 3, 4, 6, 8, 10), and sub-figure (b) plots results for the larger 120*n*-byte data block sizes (n = 1, 2, 3, 4, 5).



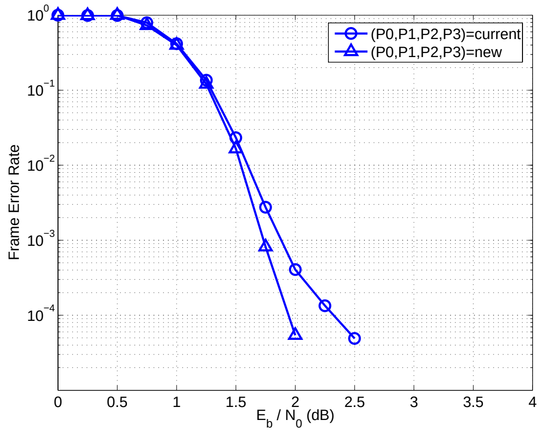
(a) 6*n*-byte block sizes, n = 1, 2, 3, 4, 6, 8, 10 (b) 120*n*-byte block sizes, n = 1, 2, 3, 4, 5

Figure 1. FER performance for currently specified CTC interleavers.

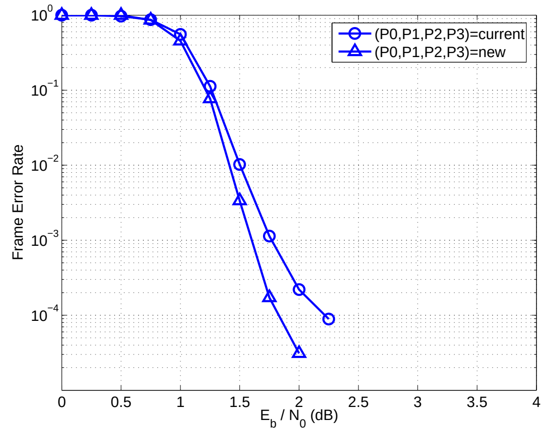
The performance of the 6*n*-byte block sizes displays the expected turbo code behavior of improving performance with increasing block size. Furthermore, no error floor is discernable down to a FER of 10^{-4}. However, the performance of the 120*n*-byte block sizes displays the opposite. Here, the performance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

CTC Performance with New Interleaver Parameters

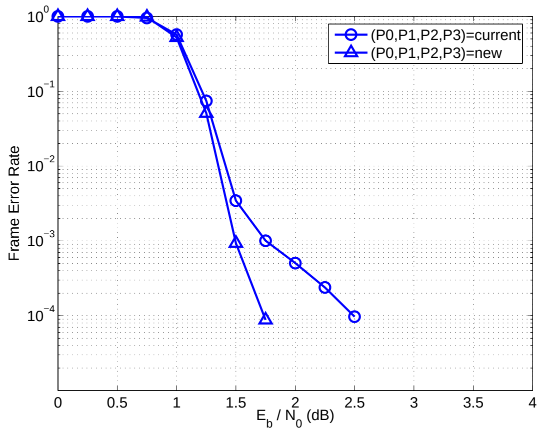
A new set of CTC interleaver parameters was designed to correct the performance deficiencies of the 120*n*-byte block sizes. The new parameters were selected according to guidelines prescribed in [1]. The FER performance (rate-1/2, binary modulation, static AWGN channel, 7.5 decoding iterations, and “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.



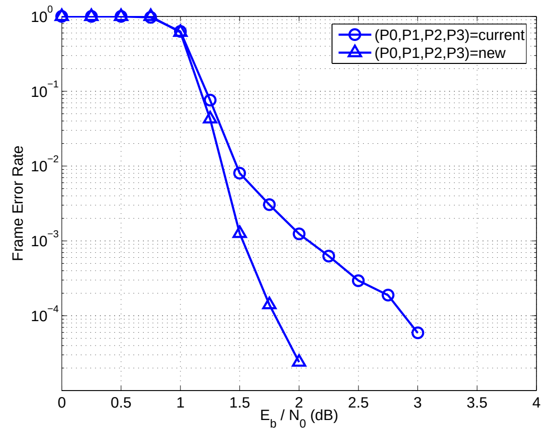
(a) 120-byte block



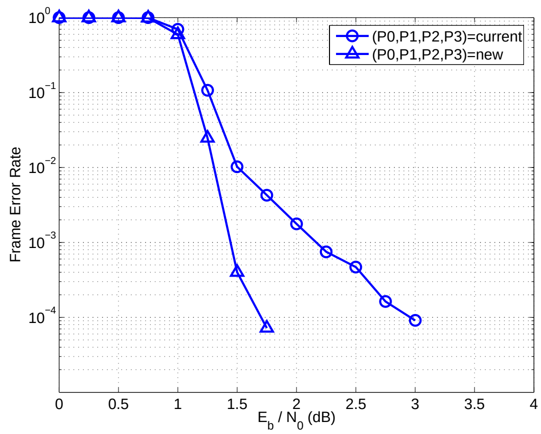
(b) 240-byte block



(c) 360-byte block



(d) 480-byte block



(e) 600-byte block

Figure 2. Performance with new CTC interleaver parameters.

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:

Add the following text and table to 802.16e_D5a, adjusting the numbering as required.

<Insert new section 8.4.9.2.3.1 on p. 330>

<Add the following text and Table 325a to new section 8.4.9.2.3.1 on p. 330. The text precedes Table 324 (p. 600 of 802.16-REVd/D5), and Table 325a immediately follows Table 325 (p. 601 of 802.16-REVd/D5). In Table 325a do not include the strikethrough marks – these are included to show the difference between Table 325 and 325a.>

Table 325a shows the code parameters for HARQ for any CTC coded unicast transmission to or from an 802.16e-compliant unit.

Table 325a – 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