

| | | |
|------------------------------|---|--|
| Project | IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 > | |
| Title | Block Turbo Codes for 802.16 optional coding | |
| Date Submitted | 2002-07-09 | |
| Source(s) | Brian A. Banister Advanced Hardware Architectures 2345 NE Hopkins Court Pullman WA 99163-5601 | Voice: 509-336-7108 Fax: 509-334-9000 bbaniste@aha.com |
| Re: | | |
| Abstract | Demonstrates that the current optional coding scheme does provide material gains, correcting comparisons made in C802.16a-02/59. | |
| Purpose | Defend BTCs from claims made in C802.16a-02/59 | |
| 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 | <p>The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard."</p> <p>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:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.</p> | |

Optional Coding Schemes for 802.16

Brian A. Banister

Advanced Hardware Architectures

Optional Coding

This contribution demonstrates that the current optional coding scheme provides material gains over the mandatory coding scheme. The mandatory coding scheme performance is modeled using convolutional codes, using simulation points read off of the graphs in [1]. This paper further demonstrates that the claimed additional gains in [1] beyond the current optional coding scheme are immaterial.

The results presented below are for the AWGN channel. We regret that insufficient time was available to verify or compare to the fading channel simulations presented in [1]. We only mention in passing that the SUI results presented in [2], and by implication, in [1], assume a static channel model, failing to accommodate the channel model's time varying statistics.

As the thrust of this paper is to respond to [1], there is no new text or modification necessary for the standard.

Performance of Optional FEC Schemes

In this section, we compare the performance of the current optional coding scheme, block turbo codes (BTCs), with convolutional turbo codes (CTCs). As the author of [1] (iCODING) is unwilling to release reference software, the CTCs used for reference are supplied by Communications Research Centre, Canada (CRC). iCODING indicates improved results beyond that obtained by CRC, particularly in regards to where the CTC error floor begins. However, there are no means available to independently verify iCODING's claimed results, as iCODING offers no software, and appears to have not published the claimed modifications to the CTC.

Optimal log likelihood ratios (LLRs) are used by both the BTC and CTC. The CTC LLRs were computed in floating point precision and then quantized internally to the CRC software to 8 bits [3]. The remainder of the processing occurs in 16 bit precision [3]. The one exception to this is for the 64QAM example, where the I and Q values are quantized to 6 bits each, prior to the LLR computation. The BTC simulations assume 7 soft bits for each I and Q value. Early stopping detection was enabled for both systems, and showed similar average number of iterations, typically on the order of 1.5 to 2 iterations for BER at or below $1e-6$. The coding rates shown in the figures are the actual coding rates, accounting for all shortening or puncturing, and for termination of the convolutional codes for the CTC (4 uncoded bits).

For the optional mode of rate $3/4$, QPSK OFDM mode in AWGN, it is observed and conceded that the CTC offers an improvement on the order of 0.5 dB at a BER of $1e-6$. However, shortly below $1e-6$, the performance of the CTC begins to degrade as it hits its error floor. By a BER of $1e-8$, it is observed that the BTC offers gain beyond that of the CTC. The BER advantage of the BTC increases for increasing SNR. It is also noted that the packet error rate (PER) of the BTC is superior to the CTC for PER below about $5e-5$.

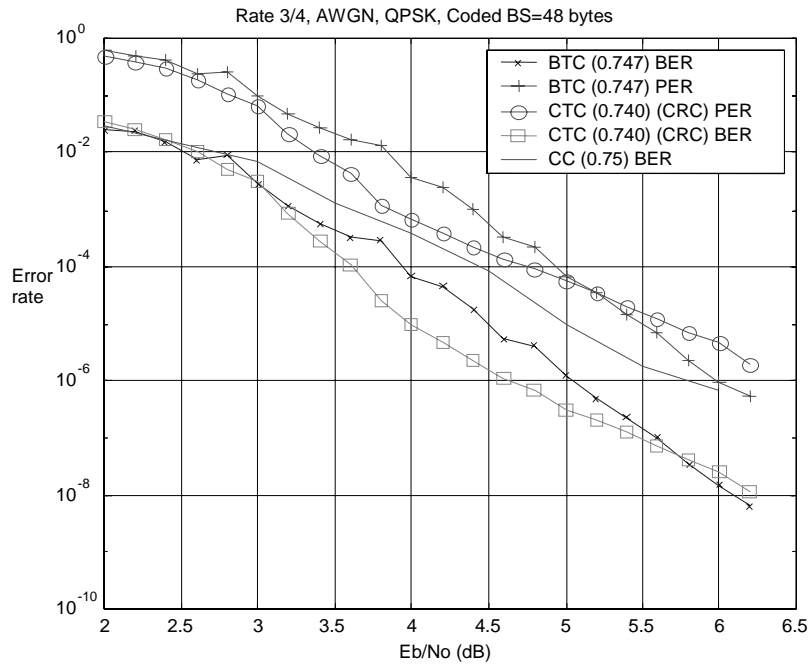


Figure 1, Optional channel coding for rate 3/4 QPSK OFDM mode in AWGN.

For the optional mode of rate 3/5, 16-QAM OFDM mode in AWGN, very similar BER and PER rates are observed for BER above 1e-4 and PER above 1e-4. Below 1e-4, and prior to the CTC reaching the error floor, the CTC gains up to an additional 0.3 dB. The error floor is seen in the figure to begin around a BER of 1e-6, with the BTC expected to have the advantage below a BER of 1e-8. For the PER, the BTC begins to have an advantage at 1e-4.

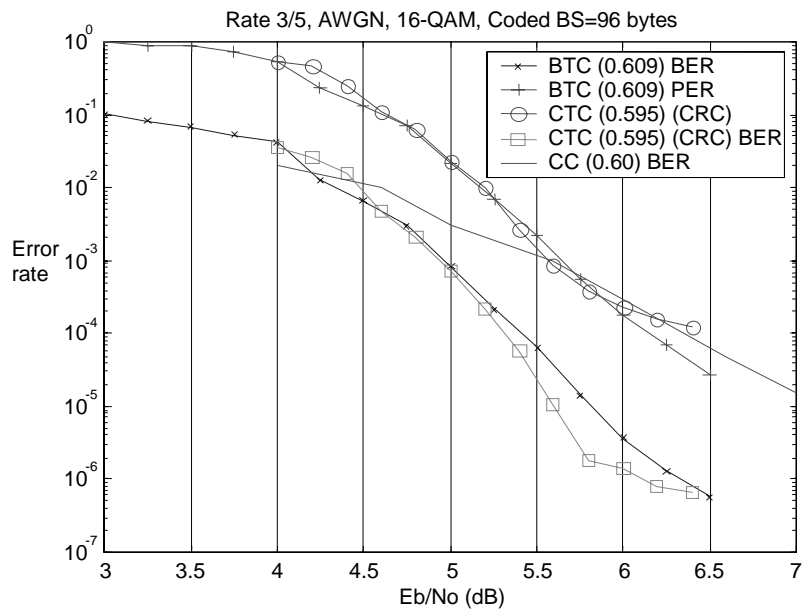


Figure 2, Optional channel coding for rate 3/5 16-QAM OFDM mode in AWGN.

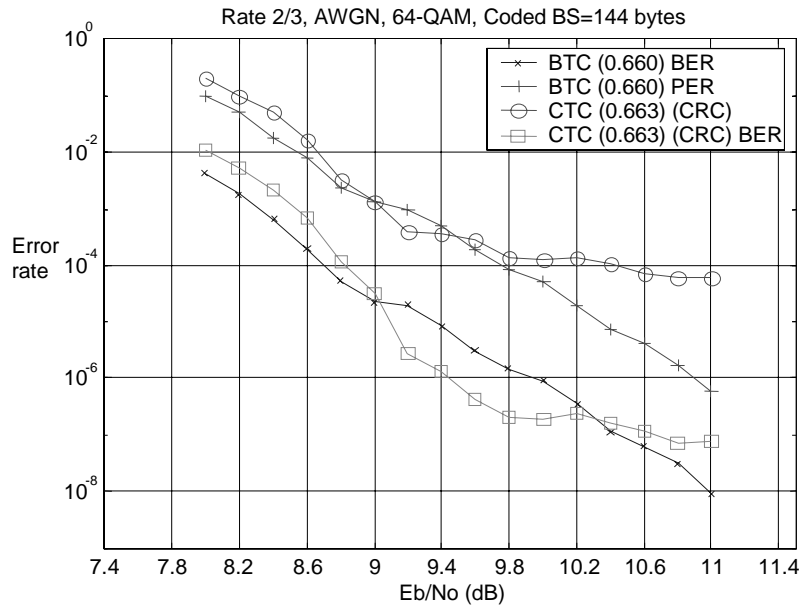


Figure 3, Optional channel coding for rate 2/3 64-QAM OFDM mode in AWGN.

At higher throughput rates, obtained by higher order modulation schemes and accompanied by larger block sizes, the CTC error floor becomes even more of a detriment. As seen in Figure 3, the PER for the CTC is significantly impacted by the error floor, with a factor of 100 difference in packet error probabilities between the BTC and CTC at E_b/N_0 of 11 dB. As observed in the earlier figures, we note that the CTC does provide an additional gain over the BTC at a BER of $1e-6$, but loses this advantage at lower BERs.

Conclusion

The significant coding gains claimed in [1] are only applicable over a small region on the performance curves. From a BER/PER performance, the results above indicate the CTC/BTC debate is 6 of one, and half a dozen of the other. To claim that either the BTC or the CTC offers no material gains over the mandatory mode is strictly a marketing ploy. Other concerns, such as latency and low cost parts availability, may be of greater concern than the small performances differences at a particular E_b/N_0 operating point. The BTC technology is currently in production from multiple vendors. Since the block codes are based upon standard constituents with no randomized components (interleavers for example), interoperability already exists. The CTC community is not yet as stabilized and settled upon a common interleaver or even constituent codes. With the number of patents filed, it may be difficult for more than a single provider to generate a standards compliant part, should the CTC be included. Naturally, this jeopardizes the cost constraints. Given the short time remaining for the standardization process, we recommend that the BTC be retained as the optional coding method.

References

- [1] Brian Edmonston, "Convolutional turbo codes for 802.16," IEEE C802.16a-02/59, May 15, 2002.
- [2] B. Bougard, and J. David, "Comparison between a new convolutional turbo coding scheme and the current block turbo coding scheme for HiperMAN," BRAN29d050, June 27, 2002.
- [3] Paul Guinand, *Personal correspondence*, Communications Research Center Canada, June 25, 2002.