Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Block Turbo Codes for 802.16 optional coding**
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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	
Release	
Patent Policy and Procedures	

Optional Coding Schemes for 802.16

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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 iCODINGs 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.

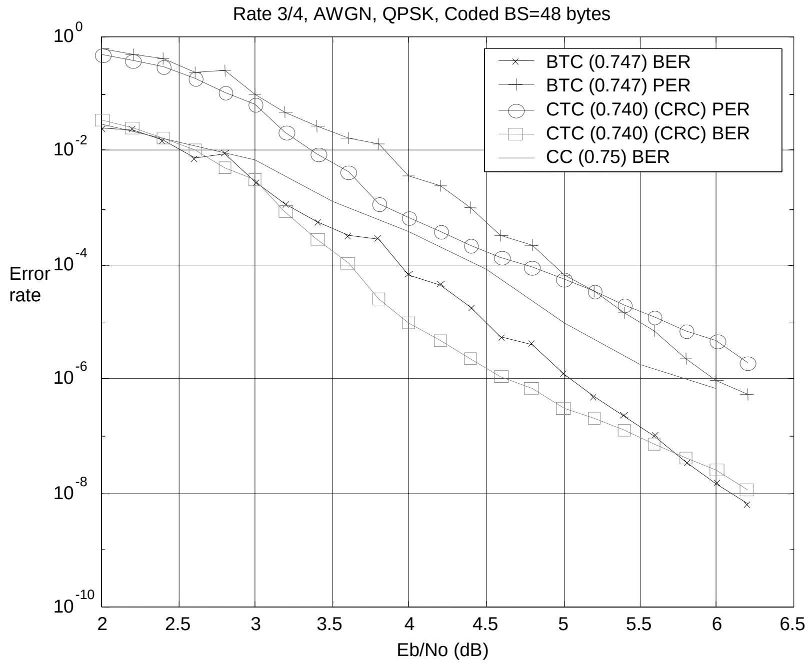

Figure 1, Optional channel coding for rate 3/4 QPSK OFDM mode in AWGN.

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.

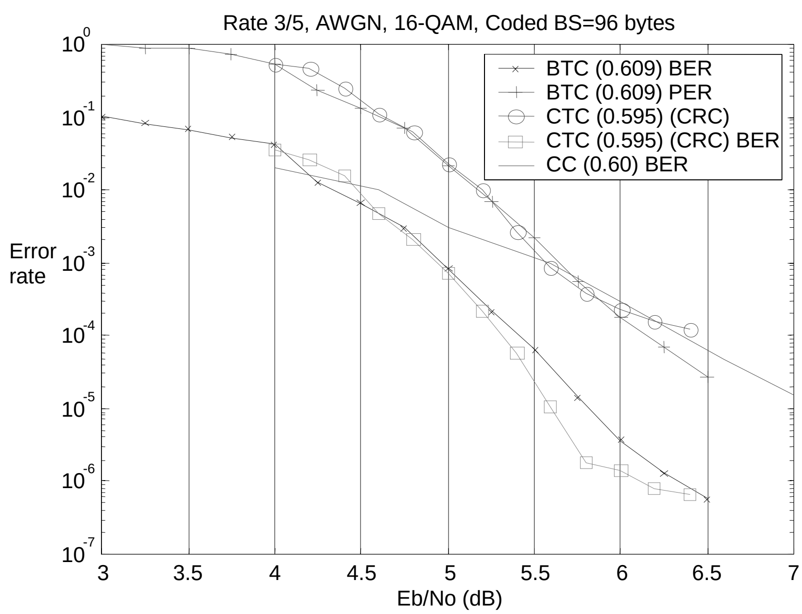

Figure 2, Optional channel coding for rate 3/5 16-QAM OFDM mode in AWGN.

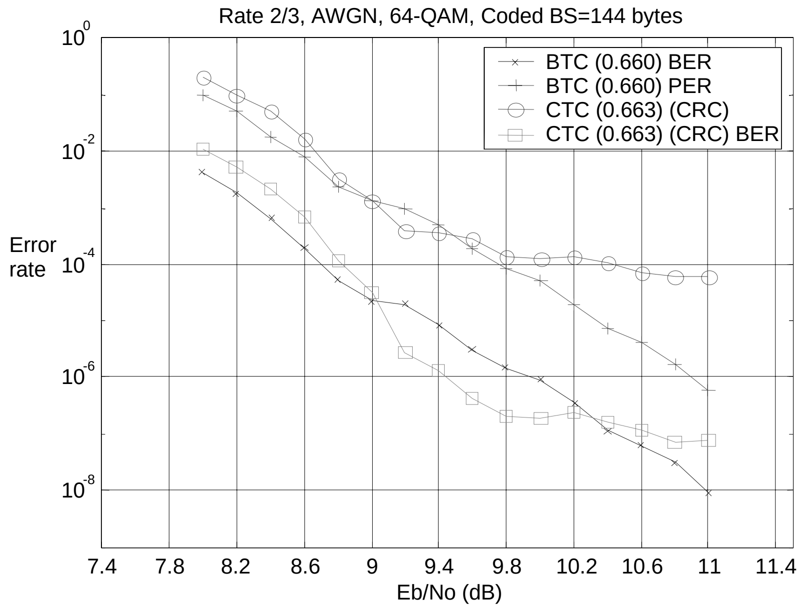

Figure 3, Optional channel coding for rate 2/3 64-QAM OFDM mode in AWGN.

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 Eb/No 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 looses 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 Eb/No 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.