Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Convolutional Turbo Code Performance**
Date Submitted	**2001-05-11**
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Re:	Information to TG4 regarding advanced coding techniques.
Abstract	Convolutional Turbo Code Solution for TG4
Purpose	Illustrate the performance improvements that convolutional Turbo Codes bring to a TG4 system.
Notice	
Release	
Patent Policy and Procedures	

Comparison of Convolutional Turbo Codes and Block Turbo Codes

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1.0 Summary

The current TG4 strawman is considering convolutional Turbo Codes and block Turbo Codes. This document demonstrates the superior performance of convolutional turbo codes when compared with block Turbo Codes. Additionally, some of the implementation benefits of convolutional turbo codes are discussed.

2.0 Code Description

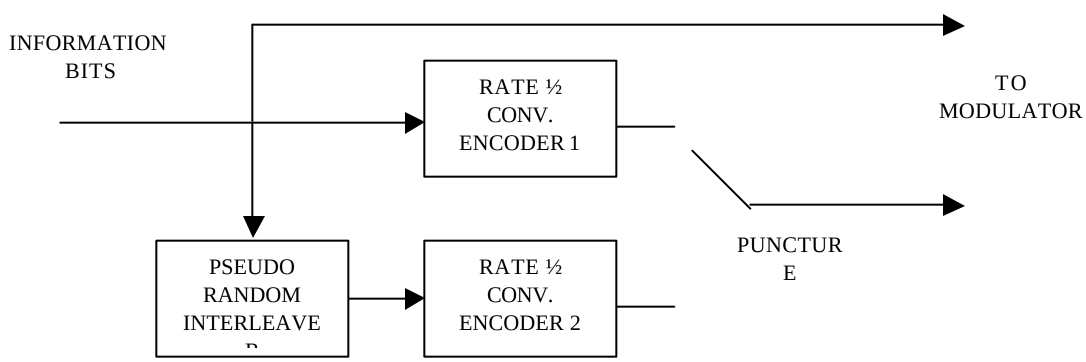

Figure 1.

This figure represents the entire extent of the turbo encoder. Of particular interest is the use of a single encoder for all code rates and frame sizes. This simplifies implementation of the encoder and decoder by having only one configuration. Only the puncture and depuncture circuits need programming to change rates.

3.0 Relation to existing standards.

Convolutional Turbo Codes are the iterative decoding scheme of choice as evidenced by their wide adoption in other standards bodies including 3GPP (W-CDMA), 3GPP2 (CDMA2000) and DVB-RCS. Turbo Codes are also the leading candidate as the advanced coding technique for DSL within the ITU.

These standards bodies have chosen Turbo Codes because they demonstrate materially superior performance when compared with all other FEC coding techniques. The resulting acceptance of turbo codes ensures wide availability of technical expertise, information and intellectual property for building 802.16 systems.

The TCC scheme presented resembles the Turbo Codes used in 3GPP (W-CDMA) and 3GPP2 (CDMA2000) with some enhancements. The enhancements include a generatable interleaver that provides both higher performance and which may be decoded in parallel for very high data rates. Additionally, sixteen state constituent codes have been selected. It is believed that eight state codes will be suitable for the target BER's, however, sufficient testing had not been performed at the time of submission.

4.0 Code Performance

Graph 1-3 provide performance comparisons between the block turbo codes in the TG4 strawman and convolutional turbo codes. The graphs are separated by frame size, and each graph contains performance at two code rates. The simulations demonstrate that convolutional turbo codes perform materially better than block turbo codes at all points of operation. The curves also demonstrated that block codes do not perform better than convolutional turbo codes at *any frame size or code rate combination.* This includes rates as high as .79.

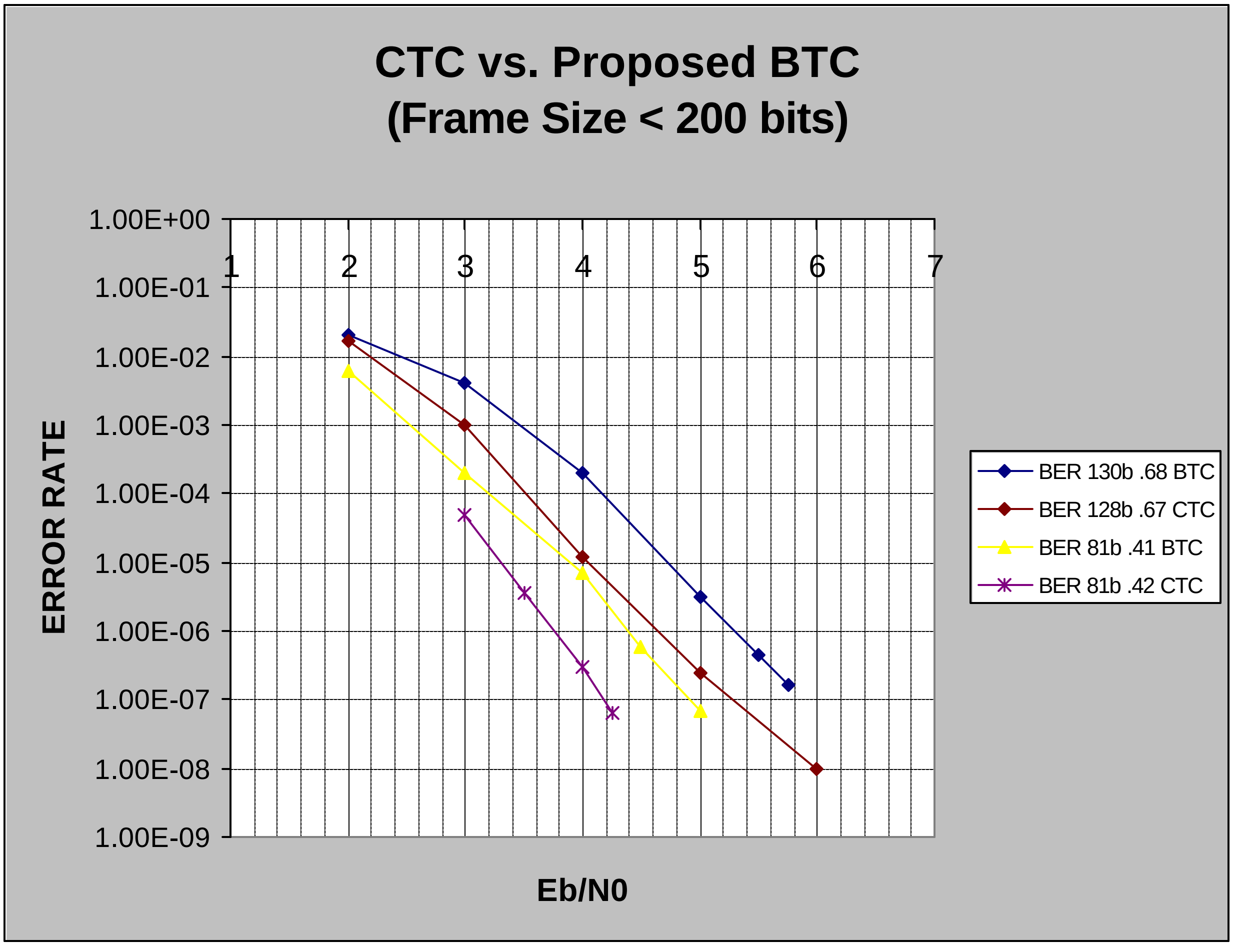

Figure 2. CTC v BTC at small frame sizes.

The block turbo code (BTC) curves are for frame sizes of 130 bits (130b) and 81 bits (81b) as proposed in the TG4 strawman. The convolutional turbo codes are matched closely to frame size and code rate to allow for easy performance comparison. For these small frame sizes, the bit error rate difference is ~.7 dB at both code rates. The CTC curves include implementation loss of .2 dB and the BTC cures use 5 bit samples.

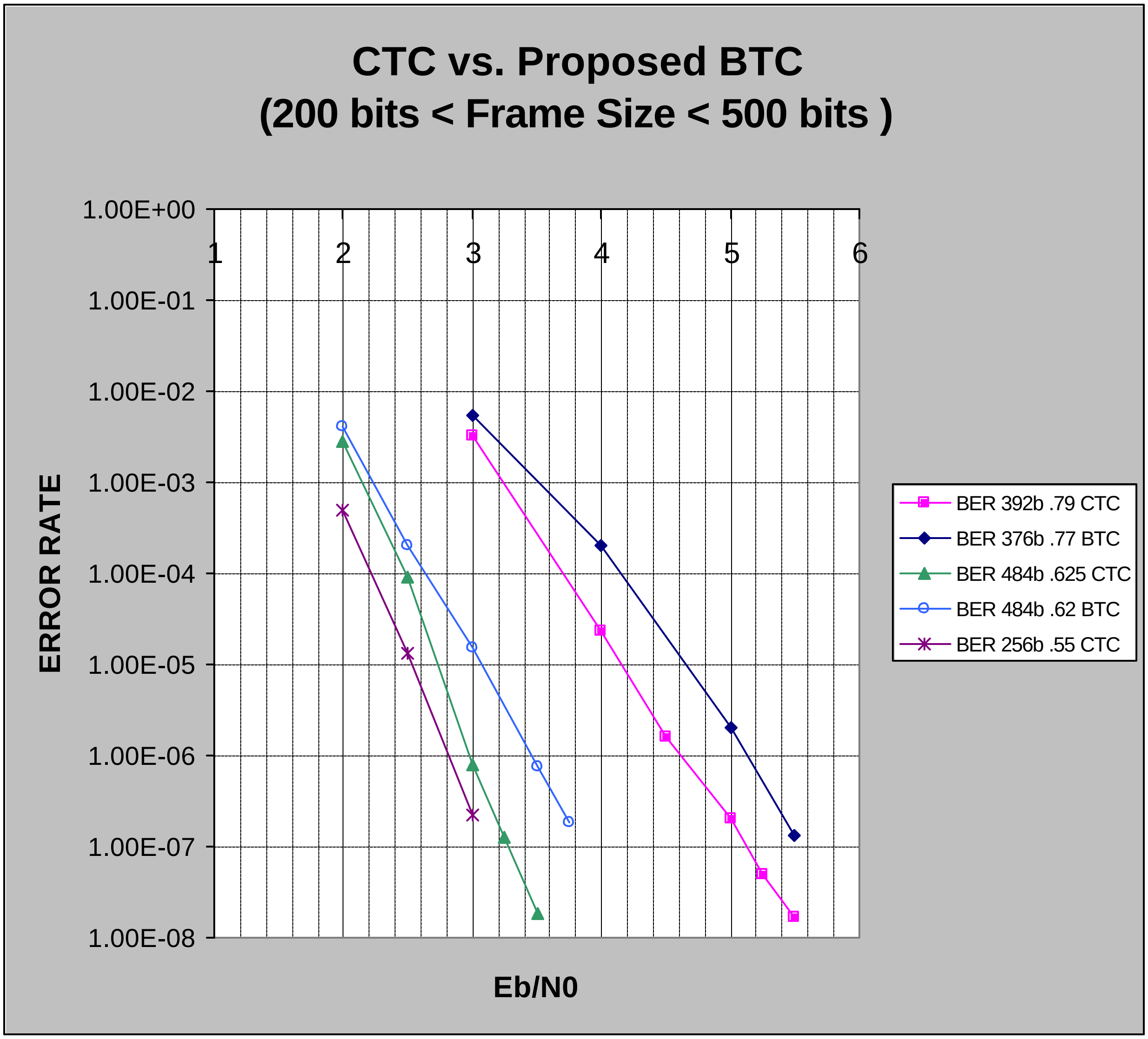

Figure 2. CTC v BTC at medium frame sizes.

The block turbo code (BTC) curves for Figure 2 are for frame sizes of 376 bits (376b) and 484 its (484b) as proposed in the TG4 strawman. The convolutional turbo codes are matched closely to frame size and code rate to allow for easy performance comparison. For these medium frame sizes, the bit error rate difference is between .5-.6 dB at both code rates. The CTC curves include implementation loss of .2 dB and the BTC cures use 5 bit samples.

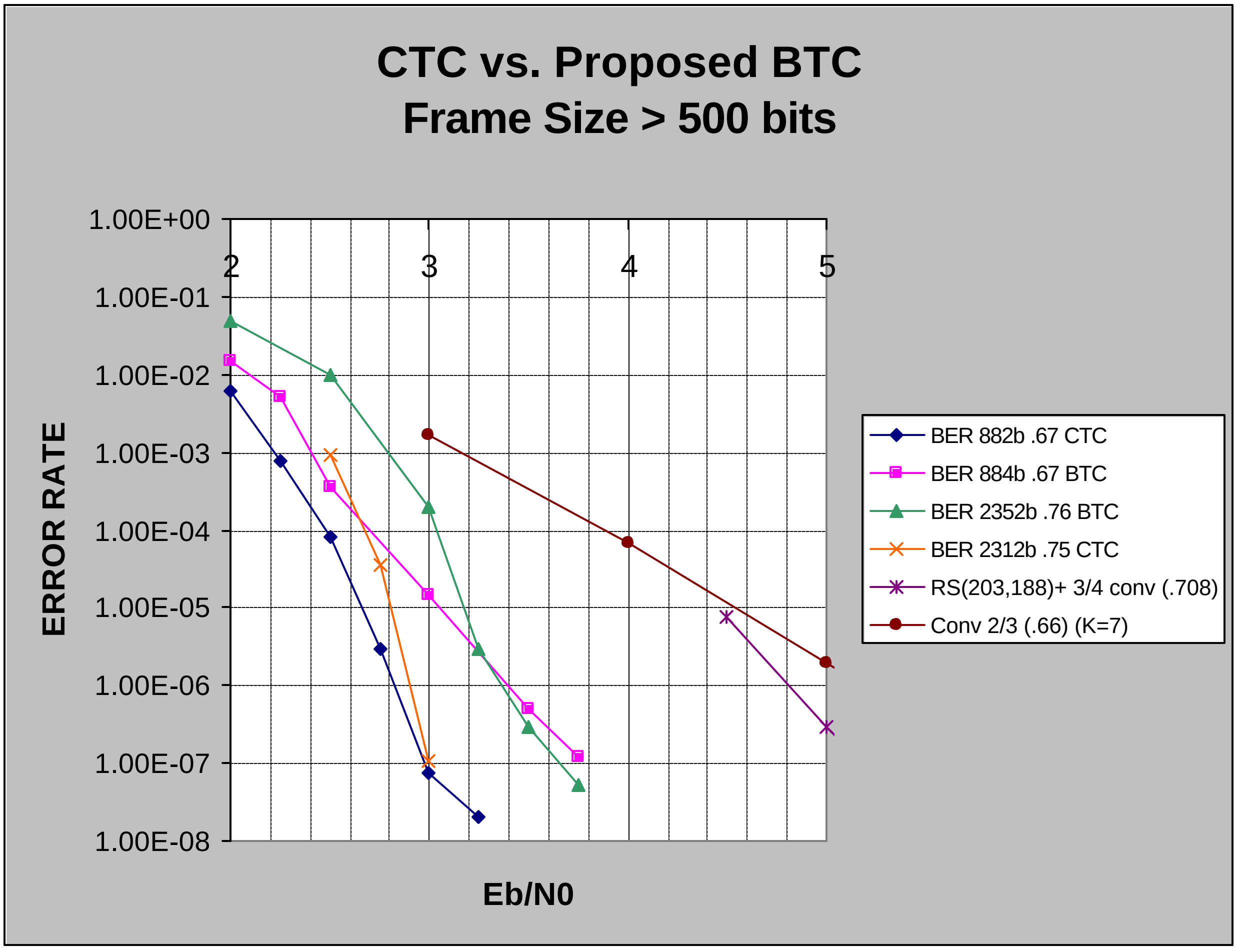

Figure 3. CTC v BTC at larger frame sizes.

The block turbo code (BTC) curves for Figure 3 are for frame sizes of 884 bits (884b) and 2352 bits (2352b) as proposed in the TG4 strawman. The convolutional turbo codes are matched closely to frame size and code rate to allow for easy performance comparison. For these medium frame sizes, the bit error rate difference is between .5-.7 dB at both code rates. The CTC curves include implementation loss of .2 dB and the BTC cures use 5 bit samples. Also included for reference are curves for a K=7 rate 2/3 convolutional code and a concatenated RS-Convolutional code.

Two additional points are worth mentioning. It is a common, but incorrect, belief that block turbo codes perform better than convolutional turbo codes at higher codes rates. The above graphs demonstrate that in fact convolutional codes continue to perform materially at these rates.

Another common, but also mistaken, belief is that convolutional Turbo Codes experience error floors and block Turbo Codes do not experience error floors. Both code experience some type of curve flaring, but performance gains continue to be made by both as signal strength increases.

5.0 Other Benefits of Convolutional Turbo Codes

Simple implementation.

In addition to better performance, Convolutional Turbo Codes have distinct implementation advantages over block Turbo Codes in a multi-rate variable frame size system. This is because convolutional Turbo Codes use a single constituent code for all frame sizes and all code rates. Simply changing the interleaver parameters supports different frame sizes. Changing the puncturing changes the code rate.

Block Turbo codes require multiple constituent codes to provide a reasonable variety of code rates and frame sizes. Thus one has to implement multiple encoders and configure them in multiple combinations in order to achieve a range of coding options. Similarly, the decoder must by highly configurable in order to conduct decoding on all the code combinations it may encounter.

Compatibility with 802.11 Rates

Convolutional Codes can operate at virtually any code rate, but the most natural are rates such as 1/2, 2/3 and 3/4. These rates are the same as the rates used in 802.11, so framing change will be kept to a minimum. As evidenced by the proposed block Turbo Codes rates and frame sizes, the natural rates of Turbo Block Codes are substantially different from those of 802.11.

Reduced Memory

All the Convolutional Turbo Codes proposed are 2D codes. That is, they use only two constituent codes. Several of the Turbo block codes are 3D codes. It is necessary to use 3D block code to achieve the desired code rates, because the set of constituent codes available is limited. 3D turbo codes require 3 subiterations per iteration, and are therefore slower and require twice as much extrinsic information as 2D codes. Memory makes up the largest portion of a turbo decoder circuit.

Greater use, more technical literature and more sources for IP

Convolutional Turbo Codes were the original form of Turbo Codes, and have therefore had the greatest time for development and accumulation of technical literature. Convolutional Turbo Codes continue to demonstrate the best overall performance of all iterative decoding schemes and therefore the focus on convolutional Turbo Codes will continue. Convolutional Turbo Codes have been adopted by the most widely used standards in the world including W-CDMA and CDMA2000. This wide use of Turbo Codes will ensure that talent and intellectual property are widely available for development of 802.16 systems including this technology.

6.0 Conclusion

Bandwidth, infrastructure and time to market are the most critical elements of a successful wireless network. Convolutional Turbo Codes will allow service providers to make use of these assets better than any other FEC coding scheme under consideration. The wide use of Convolutional Turbo Codes by other digital communication standards demonstrates this, and also ensures timely availability of the technology to ASIC and system developers.