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Re:	Response to the call for contributions to IEEE Standard 802.16-2004, IEEE 802.16maint-04/01, 2004-08-04. Header error fix to IEEE 802.16maint-04/29.
Abstract	This contribution presents modifications to coding parameters of Block Turbo Codes for OFDMA in IEEE Standards Draft 5. With these modifications the code rate of every redesigned encoding patterns based on BTC will be exactly 1/2 or 3/4 and the information bits will have an exact multiple relations, not approximate as previous encoding patterns specified previously have.
Purpose	To incorporate the text modification proposed in this contribution into IEEE 802.16REVd standard.
Notice	
Release	
Patent Policy and Procedures	

On Concatenation of Block Turbo Codes for OFDMA

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1. Introduction

As an optional FEC scheme, BTC (Block Turbo Code), or TPC (Turbo Product Code) possesses many advantages over other FEC proposals in IEEE Standards Draft 5[1], such as high code rate applications and superior BER Vs Eb/N0 performance, which have been pointed out in previous contributions on BTC, for example [2-4]. And in [1], ten optional encoding patterns based on BTC for OFDMA are provided, as listed in Table 320 and Table 321, on page 596-597 of Draft 5. However most of these coding patterns are not exactly 1/2 or 3/4 code rate, but approximately 1/2 or 3/4. This will impair effects of concatenation dramatically, and sometimes even make it impossible. While Concatenating, exact useful data payload and encoded data bytes are needed, and in fact we can obtain encoding patterns with exact code rate 1/2 and 3/4, not approximate. In the next section this will be detailed and an encoding scheme to replace those listed in Table 320 and Table 321 of [1] will be presented.

Table 320—Useful data payload for a subchannel

	QPSK		**16-QAM**		**64-QAM**		**Coded Bytes**
Encoding Rate	R=1/2	R=3/4	R=1/2	R=3/4	R=1/2	R=3/4	
Allowed Data (Bytes)	6	9					12
	16	20	16	20			24
	16	25			16	25	36
	23	35	23	35			48
	31						60
	40		40		40		72

Table 321—Optional channel coding per modulation

Data Bytes	**Coded Bytes**	**Constituent**	**Code Parameters**
6	12	(8,7)(32,26)	Ix=4,Iy=8,B=0,Q=6
9	12	(16,15)(16,15)	Ix=6,Iy=6,B=4,Q=5
16	24	(8,7)(32,26)	Ix=2,Iy=0,B=0,Q=2
20	24	(16,15)(16,15)	Ix=2,Iy=2,B=4,Q=5
16	36	(32,26)(16,11)	Ix=11,Iy=2,B=6,Q=7
25	36	(8,7) (64,57)	Ix=2,Iy=16,B=0,Q=5
23	48	(32,26)(16,11)	Ix=4,Iy=2,B=8,Q=6
35	48	(32,26)(16,15)	Ix=0,Iy=4,B=0,Q=6
31	60	(32, 26)(32,26)	Ix=10,Iy=10,B=4,Q=4
40	72	(32,26)(32,26)	Ix=8,Iy=8,B=0,Q=4

2. The Solution

Concatenation scheme of Block Turbo Codes for OFDMA PHY layer are stated on page 592 in [1], as follows:

Concatenation of a number of subchannels shall be performed in order to make larger blocks of coding where it is possible, with the limitation of not passing the largest block under the same coding rate (the block defined by 64-QAM modulation). Table 316 specifies the concatenation of subchannels for different allocations and modulations. The parameters in Table 315 and Table 316 shall apply to the CC encoding scheme (see 8.4.9.2.1) and the BTC encoding scheme (see 8.4.9.2.2), for the CTC encoding scheme (see 8.4.9.2.3), the concatenation rule is defined in 8.4.9.2.3.3.

So the concatenation of BTC for OFDMA PHY layer should comply with Table 315 and Table 316 on page 592-593 in [1]:

Table 315—Subchannel concatenation rule

Number of subchannels	Subchannels concatenated
$n<j$	1 block of n subchannels
$n>j$	$(k-1)$ blocks of j subcahnnels 1 block of ceil $((m+j)/2)$ subchannels 1 block of floor $((m+j)/2)$ subchannels

Table 316—Encoding Subchannel concatenation for different allocations and modulations

Modulation and rate	j
QPSK 1/2	j=6
QPSK 3/4	j=4
16-QAM 1/2	j =3
16-QAM 3/4	j =2
64-QAM 1/2	j =2
64-QAM 2/3	j =1
64-QAM 3/4	j =1

And in Table 315 and 316, the parameters j, n, k and m are defined as follows:

j: parameter dependent on the modulation and FEC rate

n: number of allocated subchannels

k: floor (n/j)

m: n modulo j

In order to meet the demands of concatenation rule specified in Table 315 and 316, 10 encoding patterns are given in Table 320 and 321 of [1], on page 596-597. Unfortunately, only the first two rows are exactly 1/2 and 3/4 code rate, and the others are approximately 1/2 or 3/4, not exactly. This will result in inexact concatenation, or even make it impossible to implement. Therefore in this contribution, a new designed encoding scheme for BTC is provided to replace those listed in Table 320 and Table 321, and it will exactly matches the concatenation rule specified in Table 315 and Table 316.

First, in order to comply with the concatenation rule specified in Table 315 and 316, the Table 320 in [1] should be replaced by Table 320' given in this contribution, as follows:

Table 320'—Useful data payload for a subchannel

	QPSK		16-QAM		64-QAM		Coded Bytes
Encoding Rate	R=1/2	R=3/4	R=1/2	R=3/4	R=1/2	R=3/4	
Allowed Data (Bytes)	6	9					12
	12	18	12	18			24
	18	27			18	27	36
	24	36	24	36			48
	30						60
	36		36		36		72

And then we can obtain the following encoding parameters by searching from encoding patterns listed in Table 214 of [1], with code rates are exactly 1/2 or 3/4, as listed in Table 1.

Table 1: **Optional channel coding patterns**

Data Bytes	Coded Bytes	Constituent	Code Parameters
6	12	(8,7)(16,11)	Ix=0,Iy=3,B=8,Q=0
6	12	(8,7)(16,11)	Ix=0,Iy=4,B=0,Q=1
6	12	(8,7)(16,11)	Ix=1,Iy=1,B=9,Q=3
6	12	(8,7)(16,11)	Ix=1,Iy=2,B=2,Q=4
6	12	(8,7)(32,26)	Ix=4,Iy=8,B=0,Q=6
6	12	(8,7)(32,26)	Ix=2,Iy=15,B=6,Q=1
6	12	(8,7)(32,26)	Ix=2,Iy=16,B=0,Q=2
9	12	(8,7)(16,15)	Ix=0,Iy=3,B=8,Q=4
9	12	(8,7)(16,15)	Ix=0,Iy=4,B=0,Q=5
9	12	(8,7)(16,15)	Ix=1,Iy=1,B=9,Q=3
9	12	(8,7)(16,15)	Ix=1,Iy=2,B=2,Q=4
9	12	(8,7)(16,15)	Ix=2,Iy=0,B=0,Q=3
9	12	(16,15)(16,15)	Ix=6,Iy=6,B=4,Q=5
9	12	(16,15)(16,15)	Ix=10,Iy=0,B=0,Q=3
9	12	(16,15)(16,15)	Ix=9,Iy=2,B=2,Q=4
9	12	(16,15)(16,15)	Ix=4,Iy=8,B=0,Q=5
12	24	(16,11)(32,31)	Ix=5,Iy=14,B=6,Q=0
12	24	(16,15)(32,26)	Ix=2,Iy=18,B=4,Q=4
12	24	(16,15)(64,57)	Ix=4,Iy=48,B=0,Q=3
12	24	(32,26)(32,31)	Ix=18,Iy=18,B=4,Q=4
18	24	(8,7)(64,63)	Ix=3,Iy=24,B=8,Q=4
18	24	(8,7)(64,63)	Ix=3,Iy=25,B=3,Q=5
18	24	(16,15)(64,63)	Ix=11,Iy=24,B=8,Q=4
18	24	(16,15)(64,63)	Ix=11,Iy=25,B=3,Q=5
18	36	(16,11)(32,31)	Ix=5,Iy=5,B=9,Q=3
18	36	(16,11)(64,63)	Ix=5,Iy=37,B=9,Q=3
27	36	(64,63) (8,7)	Ix=3,Iy=3,B=17,Q=7
27	36	(64,63) (16,15)	Ix=3,Iy=11,B=17,Q=7
24	48	(16, 11)(32,26)	Ix=1,Iy=6,B=6,Q=2
24	48	(16, 11)(32,26)	Ix=0,Iy=8,B=0,Q=6
24	48	(32, 31)(32,26)	Ix=2,Iy=19,B=6,Q=5
36	48	(128,127)(8,7)	Ix=42,Iy=3,B=46,Q=6

36	48	(128,127)(8,7)	Ix=43,Iy=3,B=41,Q=7
36	48	(128,127)(16,15)	Ix=42,Iy=11,B=46,Q=6
36	48	(128,127)(16,15)	Ix=43,Iy=11,B=41,Q=7
30	60	(32, 26)(32,26)	Ix=2,Iy=16,B=0,Q=0
30	60	(32, 26)(32,26)	Ix=5,Iy=14,B=6,Q=6
36	72	(64, 57)(64,57)	Ix=40,Iy=40,B=0,Q=1
36	72	(32,26)(64,57)	Ix=16,Iy=28,B=0,Q=2
36	72	(32, 26)(64,57)	Ix=3,Iy=44,B=4,Q=7
36	72	(32, 26)(64,57)	Ix=15,Iy=30,B=2,Q=7

All of the component codes (extended Hamming codes or Parity-check only codes) of them are those listed in Table 214 of [1]. And as mentioned above, all of these encoding patterns are designed according to requirements of concatenation scheme specified in Table 315 and Table 316 of [1]. However for every coding scheme with the same code rate, data bytes and coded bytes, there are more than one coding pattern available. For every coding scheme we will select the optimal one by way of performance test (BER Vs Eb/N0), and others listed here only for reference. Through numerous simulations, the optimal coding patterns we obtained from the sense of BER vs E_b/N_0 performance are listed in Table 321', which attempt to replace the Table 321 of [1]. Encoding patterns listed in Table 321' possess the following two advantages:

1) They exactly match the required packet size of information bits and all code rates of them are exactly equal to those specified in Table 316 of [1], which makes the implementation of concatenation rule possible. Such as for 64QAM 1/2 rate coding pattern specified in Table 316, we adopt (64,57)(64,57) as the component codes and Ix=40,Iy=40,B=0,Q=1 as the shorten parameters, the information bytes is exact 36 and the coded bytes is 72, and this results in an exact 1/2 rate. However, for encoding pattern listed in Table 321 of [1], corresponding to 64QAM 1/2 rate, the information bytes is 40 and the coded bytes is 72, which will result a code rate 5/9, only approximate to 1/2, not exactly. While concatenating, 40-36=4 data bytes will be wasted. In addition, the code rate 5/9 is lager than 1/2, which will result in performance degradation.
2) Each encoding pattern in Table 321', attempting to replace their counterparts, those listed in the corresponding row of Table 321 of [1], either is simpler to encode or is better in performance. This will be demonstrated in the next section.

Table 321'—Optional channel coding per modulation

Data Bytes	Coded Bytes	Constituent	Code Parameters
6	12	(8,7)(16,11)	Ix=0,Iy=4,B=0,Q=1
9	12	(8,7)(16,15)	Ix=0,Iy=4,B=0,Q=5
12	24	(32,31) (16,11)	Ix=14,Iy=5,B=6,Q=0
18	24	(64,63) (8,7)	Ix=24,Iy=3,B=8,Q=4
18	36	(32,31) (16,11)	Ix=5,Iy=5,B=9,Q=3
27	36	(64,63) (8,7)	Ix=3,Iy=3,B=17,Q=7
24	48	(32,26) (16, 11)	Ix=6,Iy=1,B=6,Q=2
36	48	(128,127)(8,7)	Ix=42,Iy=3,B=46,Q=6
30	60	(32, 26)(32,26)	Ix=2,Iy=16,B=0,Q=0
36	72	(64, 57)(64,57)	Ix=40,Iy=40,B=0,Q=1

3. Performance

We have replaced the encoding parameters listed in Table 320 and Table 321 with the new encoding parameters. And the new designed encoding patterns have either better performance, or exact 1/2 or 3/4 code rates, which are required by concatenation rule specified in [1]. Such as for the encoding pattern of the first row of Table 320, we adopted (8,7) (16,11) as the component codes and the shorten parameters are Ix=0,Iy=3,B=8,Q=0, not the corresponding encoding pattern in [1], which adopts (8,7) (32,26) as component codes and the shorten parameters are Ix=4,Iy=8,B=0,Q=6. Both of these two patterns have an exact code rate 1/2, and the reasons for adopting the former are as follows:

1, Encoding of the extended Hamming component code (16,11) will be simpler than that of (32,26).

2, Simulation shows that the performance of BTC adopting (8,7)(16,11) as its component codes is superior to that of adopting (8,7)(32,26) as component codes, as illustrated in Fig. 1.

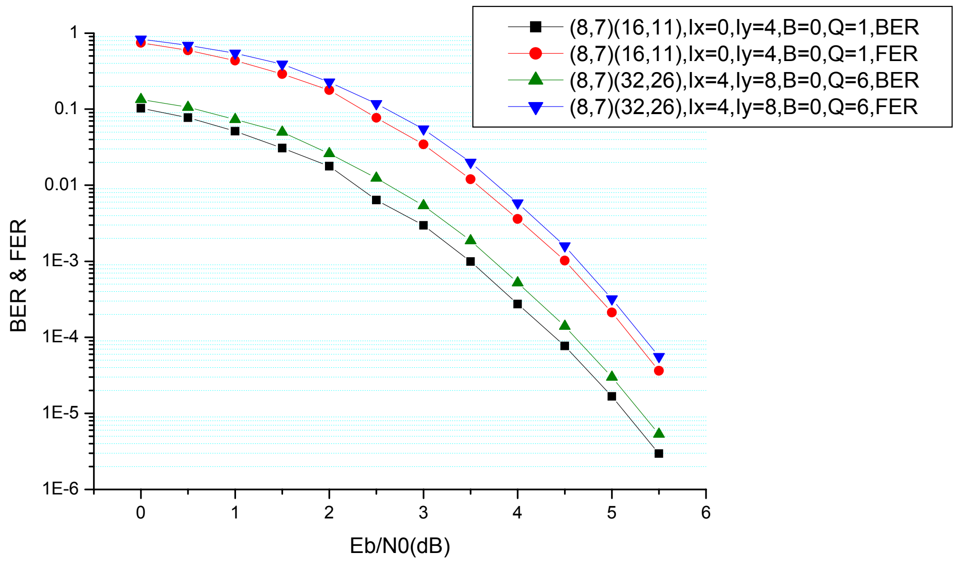

Figure 1 Performance comparison between the proposed coding parameters and those specified in the first row of table 321 in Draft 5

Similarly we can show that the performance of coding patterns listed in Table 321' will either be superior to those listed in Table 321, or at least be the same as them. Besides this, the code rates of the proposed coding patterns are exactly 1/2 or 3/4, which enable the concatenation of BTC and improve performance of short frames.

4. Proposed Text

As a result of the above analysis, the following substitutions are suggested:

1) Table 320 and Table 321 on page 596-597 should be replaced by Table 320' and Table 321', respectively:

Table 320—Useful data payload for a subchannel

	QPSK		16-QAM		64-QAM		Coded Bytes
Encoding Rate	R=1/2	R=3/4	R=1/2	R=3/4	R=1/2	R=3/4	
Allowed Data (Bytes)	6	9					12
	~~16~~	~~20~~	~~16~~	~~20~~			24
	~~16~~	~~25~~			~~16~~	~~25~~	36
	~~23~~	~~35~~	~~23~~	~~35~~			48
	~~31~~						60
	~~40~~		~~40~~		~~40~~		72

Substituted by →

Table 320'—**Useful data payload for a subchannel**

	QPSK		16-QAM		64-QAM		Coded Bytes
Encoding Rate	R=1/2	R=3/4	R=1/2	R=3/4	R=1/2	R=3/4	
Allowed Data (Bytes)	6	9					12
	12	18	12	18			24
	18	27			18	27	36
	24	36	24	36			48
	30						60
	36		36		36		72

Table 321—Optional channel coding per modulation

Data Bytes	Coded Bytes	Constituent	Code Parameters
6	12	~~(8,7)(32,26)~~	~~Ix=4,Iy=8,B=0,Q=6~~
9	12	~~(16,15)(16,15)~~	~~Ix=6,Iy=6,B=4,Q=5~~
~~16~~	~~24~~	~~(8,7)(32,26)~~	~~Ix=2,Iy=0,B=0,Q=2~~
~~20~~	~~24~~	~~(16,15)(16,15)~~	~~Ix=2,Iy=2,B=4,Q=5~~
~~16~~	~~36~~	~~(32,26)(16,11)~~	~~Ix=11,Iy=2,B=6,Q=7~~
~~25~~	~~36~~	~~(8,7) (64,57)~~	~~Ix=2,Iy=16,B=0,Q=5~~
~~23~~	~~48~~	~~(32,26)(16,11)~~	~~Ix=4,Iy=2,B=8,Q=6~~
~~35~~	~~48~~	~~(32,26)(16,15)~~	~~Ix=0,Iy=4,B=0,Q=6~~
~~31~~	~~60~~	~~(32, 26)(32,26)~~	~~Ix=10,Iy=10,B=4,Q=4~~
~~40~~	~~72~~	~~(32,26)(32,26)~~	~~Ix=8,Iy=8,B=0,Q=4~~

Substituted by →

Table 321'—Optional channel coding per modulation

Data Bytes	Coded Bytes	Constituent	Code Parameters
6	12	(8,7)(16,11)	Ix=0,Iy=4,B=0,Q=1
9	12	(8,7)(16,15)	Ix=0,Iy=4,B=0,Q=5
12	24	(32,31) (16,11)	Ix=14,Iy=5,B=6,Q=0
18	24	(64,63) (8,7)	Ix=24,Iy=3,B=8,Q=4
18	36	(32,31) (16,11)	Ix=5,Iy=5,B=9,Q=3
27	36	(64,63) (8,7)	Ix=3,Iy=3,B=17,Q=7
24	48	(32,26) (16, 11)	Ix=6,Iy=1,B=6,Q=2
36	48	(128,127)(8,7)	Ix=42,Iy=3,B=46,Q=6
30	60	(32, 26)(32,26)	Ix=2,Iy=16,B=0,Q=0
36	72	(64, 57)(64,57)	Ix=40,Iy=40,B=0,Q=1

Data Bytes	Coded Bytes	Constituent	Code Parameters
6	12	(8,7)(16,11)	Ix=0,Iy=4,B=0,Q=1
12	24	(32,31) (16,11)	Ix=14,Iy=5,B=6,Q=0
18	36	(32,31) (16,11)	Ix=5,Iy=5,B=9,Q=3
24	48	(32,26) (16, 11)	Ix=6,Iy=1,B=6,Q=2
30	60	(32, 26)(32,26)	Ix=2,Iy=16,B=0,Q=0
36	72	(64, 57)(64,57)	Ix=40,Iy=40,B=0,Q=1
9	12	(8,7)(16,15)	Ix=0,Iy=4,B=0,Q=5
18	24	(64,63) (8,7)	Ix=24,Iy=3,B=8,Q=4
27	36	(64,63) (8,7)	Ix=3,Iy=3,B=17,Q=7
36	48	(128,127)(8,7)	Ix=42,Iy=3,B=46,Q=6

2) **UCD burst profile encodings of BTC** in Table 355, on page 663 of [1] should also be modified correspondingly, namely:

Table 355—UCD burst profile encodings—WirelessMAN-OFDMA

Name	Type (1 byte)	Length	Value (variable length)
FEC Code type and modulation type	150	1	**0 = QPSK (CC) 1/2 1 = QPSK (CC) 3/4 2 = 16-QAM (CC) 1/2 3 = 16-QAM (CC) 3/4 4 = 64-QAM (CC) 2/3 5 = 64-QAM (CC) 3/4 6 = QPSK (BTC) 1/2 ~~7 = QPSK (BTC) 2/3~~ ~~8 = 16-QAM (BTC) 3/5~~ ~~9 = 16-QAM (BTC) 4/5~~ ~~10 = 64-QAM (BTC) 5/8~~ ~~11 = 64-QAM (BTC) 4/5~~ 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19 = 64-QAM (CTC) 5/6 20 = QPSK (ZT CC) 1/2 21 = QPSK (ZT CC) 3/4 22= 16-QAM (ZT CC) 1/2 23= 16-QAM (ZT CC) 3/4 24= 64-QAM (ZT CC) 2/3 25= 64-QAM (ZT CC) 3/4 26..255 = *Reserved***
Ranging data ratio	151	1	**Reducing factor in units of 1 dB, between the power used for this burst and power should be used for CDMA Ranging.**

Substituted by →

Normalized C/N override	152	5	**This is a list of numbers, where each number is encoded by one nibble, and interpreted as a signed integer. The nibbles correspond in order to the list define by Table 332, starting from the second line, such that the LS nibble of the first byte corresponds to the second line in the table. The number encoded by each nibble represents the difference in normalized C/N relative to the previous line in the table.**

Table 355'—UCD burst profile encodings—WirelessMAN-OFDMA

Name	**Type (1 byte)**	**Length**	**Value (variable length)**
FEC Code type and modulation type	150	1	**0 = QPSK (CC) 1/2 1 = QPSK (CC) 3/4 2 = 16-QAM (CC) 1/2 3 = 16-QAM (CC) 3/4 4 = 64-QAM (CC) 2/3 5 = 64-QAM (CC) 3/4 6 = QPSK (BTC) 1/2 7 = QPSK (BTC) 3/4 8 = 16-QAM (BTC) 1/2 9 = 16-QAM (BTC) 3/4 10 = 64-QAM (BTC) 1/2 11 = 64-QAM (BTC) 3/4 12 = QPSK (CTC) 1/2 13 = QPSK (CTC) 2/3 14 = QPSK (CTC) 3/4 15 = 16-QAM (CTC) 1/2 16 = 16-QAM (CTC) 3/4 17 = 64-QAM (CTC) 2/3 18 = 64-QAM (CTC) 3/4 19 = 64-QAM (CTC) 5/6 20 = QPSK (ZT CC) 1/2 21 = QPSK (ZT CC) 3/4 22= 16-QAM (ZT CC) 1/2 23= 16-QAM (ZT CC) 3/4 24= 64-QAM (ZT CC) 2/3 25= 64-QAM (ZT CC) 3/4 26..255 = *Reserved***
Ranging data ratio	151	1	**Reducing factor in units of 1 dB, between the power used for this burst and power should be used for CDMA Ranging.**
Normalized C/N override	152	5	**This is a list of numbers, where each number is encoded by one nibble, and interpreted as a signed integer. The nibbles correspond in order to the list define by Table 332, starting from the second line, such that the LS nibble of the first byte corresponds to the second line in the table. The number encoded by each nibble represents the difference in normalized C/N relative to the previous line in the table.**

References:

1, IEEE 802.16.1pc-00/35, “Turbo Product Code FEC Contribution”
2, IEEE 802.16.1pc-00/43, “FEC proposal: use of Block Turbo Code (BTC) for IEEE 802.16.1 Air Interface Standard”
3, IEEE 802.16.3p-01/05, “IEEE 802.16.3 PHY Utilizing Turbo Product Codes”
4, IEEE P802.16-REVd/D5-2004, Draft IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed Broadband Wireless Access Systems