Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Extension of OFDMA Physical layer mode to support 256 & 1024 point QAM constellations for high capacity back-haul applications**
Date Submitted	**2013-03-07**
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Re:	IEEE 802.16-13-0032-01-Gdoc
Abstract	Changes required to extend 802.16 OFDMA physical layer in order to support 256-QAM and 1024-QAM constellations, along with necessary extensions to the block sizes and control codes.
Purpose	For acceptance as part of the 802.16r amendment.
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Extension of OFDMA Physical layer mode to support 256 & 1024 point QAM constellations for high capacity back-haul applications

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13/03/2013

Scope

This document is in response to the call for contributions to the 802.16r PAR. It specifies changes required to the "IEEE Std 802.16-2012" [1] standard to implement the 256- and 1024-QAM modulation using Convolutional Turbo Codes (CTCs), together with the introduction of a new block size to allow efficient use of the increased spectral efficiency.

References

[1] 802.16-2012, IEEE Standard for Air Interface for Broadband Wireless Access Systems, May 2012.
[2] 802.16.1-2012, IEEE Standard for WirelessMAN-Advanced Air Interface for Broadband Wireless Access Systems, September 2012.

Background

The 802.16r PAR calls for contributions to support high-order modulations, and specifically mentions 256, 512 and 1024 point QAM. The increase in spectral efficiency is required to support applications such as small cell backhaul.

It should be noted that the 256 and 1024 point QAM are conventional "square" constellations that result from being of the form $2^{(2n)}$, that is not the case for 512-point QAM. It is the opinion of the authors of this contribution that system gains associated with the non-square 512-point QAM constellation are questionable and do not justify the increased complexity. Equivalent gains can be obtained using the 1024-point constellation along with stronger forward error correction. As a result this contribution does not consider 512-point QAM any further.

This contribution addresses changes in the OFMDA physical layer mode only.

In addition to PHY changes, we introduce a new MAC message to support signaling of both CQI and HARQ ACK/NACK from MS, as an alternative to using HARQ ACK/NACK signaling regions. Although similar to the HARQ messages used for Relay, there is no single message that allows an MS to report both CQI and HARQ ACK/NACK.

Requirements

Mac Message

We propose to enhance the capacity of the system by eliminating the need to allocate a fixed region for CQI and HARQ ACK/NACK signals. This is appropriate for systems with very few MS and when the operating SNR for all links is high, as is envisaged for the use of the standard in Small Cell Backhaul (SCB) applications. To allow signaling of the same information, we introduce a Channel state information message (SCB_CHN_INFO).

Replace the following line from Table 6-51:

Type	**Message Name**	**Message Description**	**Connection**
110–255		*Reserved*	

With

Type	**Message Name**	**Message Description**	**Connection**
110	SCB_CHN_INFO	CQI and HARQ ACK/NACK of received message	
111–255		*Reserved*	

After section 6.3.2.3.98 introduce the following text:

6.3.2.3.99 SCB_CHN_INFO

If the BS does not schedule a PUSC region in a frame and therefore not include a HARQ ACK/NACK or CQI feedback channel and makes an allocation for the MS , then an MS supporting SCB shall transmit an SCB_CHN_INFO management message in the first allocated slot. Each MS may be required to supply at most 2 CQI reports. It is the BS responsibility to schedule appropriate slots and modulation/coding to allow the MS to transmit this information.

Table 6-227A – SCB_CHN_INFO

Syntax	Size (bit)	Notes
SCB_CHN_INFO_Message_format() {		
Management Message Type = 111	8	
Number of CQI Reports (-1)	1	0: 1 report, 1: 2 reports
Frame Number	3	Least significant 3 bits of frame number that this message refers to.
CQI Report 1	6	CQI feedback, see section 8.4.11.6 and table 8-336
CQI Report 2	6	CQI feedback, see section 8.4.11.6 and table 8-336
HARQ ACK bitmap	16	DL HARQ limited to 16 per MS.

Channel Coding

Channel coding procedures include randomization (see 8.4.9.1 of [1]), FEC encoding (see 8.4.9.2 of [1]), bit interleaving (see 8.4.9.3 of [1]), repetition (see 8.4.9.5 of [1]), and modulation (see 8.4.9.4 of [1]). Repetition is only applied to QPSK modulation.

Based on Table 8-317 of [1], the valid FEC block sizes N_{EP} (measured in bits prior to encoding) are: 48, 72, 96, 144, 192, 216, 240, 288, 360, 384, 432, and 480. The N_{EP} have been chosen in such a way that for any of the predefined modulation and coding scheme, a slot's worth of data is mapped to one of the FEC blocks. Here, a new FEC block size of 320 bits is introduce for the two highest modulations. This is done to support the 5/6 rate for 256-QAM and 2/3 rate for 1024-QAM. We also introduce three new rates: 5/8 for 256-QAM, and 3/5 and 4/5 for 1024-QAM. This was done in order to support the pre-existing FEC block sizes.

For **CTC**, the valid coding rates for 256-QAM are:

- **1/2** = 0.500, (N_{EP} = 192)
- **5/8** = 0.625, (N_{EP} = 240)

- **3/4** = 0.755, (N_{EP} = 288)
- **5/6** = 0.833, (N_{EP} = 320)

For **CTC**, the valid coding rates for 1024-QAM are:

- **3/5** = 0.600, (N_{EP} = 288)
- **2/3** = 0.667, (N_{EP} = 320)
- **3/4** = 0.750, (N_{EP} = 360)
- **4/5** = 0.800, (N_{EP} = 384)

Interleaving: To support higher performance in systems where we expect large packets to be encoded, we propose increasing the number of different CTC interleaver options. These are included in the changes to the tables below. The interleaver parameters have been chosen to be, as far as possible, compatible with those described in IEEE 802.16-2012 [1], either Table 8-304 or 8-305, or using values already accepted for IEEE 802.16.1-2012, table 6-309 [2].

UCD management message encoding

The FEC code type and modulation type field of the UCD burst profile encodings, of Tables 11-18 of the standard [1], shall be augmented with new values:

Editorial Instruction:
In Table 11-18, replace

FEC Code type and modulation type	150	1	53..255=*Reserved*

With the following

FEC Code type and modulation type	150	1	53 = 256-QAM (CTC) 1/2
			54 = 256-QAM (CTC) 5/8
			55 = 256-QAM (CTC) 3/4
			56 = 256-QAM (CTC) 5/6
			57 = 1024-QAM (CTC) 3/5
			58 = 1024-QAM (CTC) 2/3
			59 = 1024-QAM (CTC) 3/4
			60 = 1024-QAM (CTC) 4/5
			61..255=*Reserved*

DCD management message encoding

The FEC code type and modulation type field of the DCD burst profile encodings, of Tables 11-25 of the standard [1], shall be augmented with new values:

Editorial Instruction:
In Table 11-25, replace

FEC Code type and modulation type	150	1	53..255=*Reserved*

With the following

FEC Code type and modulation type	150	1	53 = 256-QAM (CTC) 1/2
			54 = 256-QAM (CTC) 5/8
			55 = 256-QAM (CTC) 3/4
			56 = 256-QAM (CTC) 5/6
			57 = 1024-QAM (CTC) 3/5
			58 = 1024-QAM (CTC) 2/3
			59 = 1024-QAM (CTC) 3/4
			60 = 1024-QAM (CTC) 4/5
			61..255=*Reserved*

CTC encoder

The “Encoding slot concatenation for different rates in CTC” Table 8-313, Sec. 8.4.9.2.3.1 of [1], shall be augmented with the 256- and 1024-QAM coding rate parameter j as shown in Table 1 below:

Modulation and rate	j
256-QAM-1/2	2
256-QAM-5/8	2
256-QAM-3/4	1
256-QAM-5/6	1
1024-QAM-3/5	1
1024-QAM-2/3	1
1024-QAM-3/4	1
1024-QAM-4/5	1

Table 1. Encoding slot concatenation for 1024-QAM and various rates in CTC.

The “Parameters for the subblock interleavers” Table 8-317, Sec. 8.4.9.2.3.4.2 of [1], shall be augmented with the new block size as shown in Table 2 below:

Block size (bits) N_{EP}	N	Subblock interleaver parameters	
		m	J
320	110	6	3

Table 2. Parameters for the subblock interleavers

Augment Table 8-314 “CTC channel coding per modulation”, Sec. 8.4.9.2.3.1 of [1], with the contents of Table 3 below:

Modulation	Data block size (bytes)	Encoding data block size (bytes)	Code rate	N	P0	P1	P2	P3
256-QAM	24	48	1/2	96	7	48	24	72
256-QAM	48	96	1/2	192	11	96	48	144
256-QAM	120	240	1/2	480	53	62	12	2
256-QAM	240	480	1/2	960	43	64	300	824
256-QAM	360	720	1/2	1440	43	720	360	540
256-QAM	480	960	1/2	1920	31	8	24	16
256-QAM	600	1200	1/2	2400	53	66	24	2
256-QAM	30	48	5/8	120	13	60	0	60
256-QAM	60	96	5/8	240	13	120	60	180
256-QAM	120	192	5/8	480	53	62	12	2
256-QAM	240	384	5/8	960	43	64	300	824
256-QAM	360	576	5/8	1440	43	720	360	540
256-QAM	480	768	5/8	1920	31	8	24	16
256-QAM	600	960	5/8	2400	53	66	24	2
256-QAM	36	48	3/4	144	17	74	72	2
256-QAM	360	480	3/4	1440	43	720	360	540
256-QAM	40	48	5/6	160	17	84	108	132
256-QAM	120	144	5/6	480	53	62	12	2
256-QAM	240	288	5/6	960	43	64	300	824
256-QAM	360	432	5/6	1440	43	720	360	540
256-QAM	480	576	5/6	1920	31	8	24	16
256-QAM	600	720	5/6	2400	53	66	24	2
1024-QAM	36	60	3/5	144	17	74	72	2
1024-QAM	360	600	3/5	1440	43	720	360	540
1024-QAM	40	60	2/3	160	17	84	108	132
1024-QAM	120	180	2/3	480	53	62	12	2
1024-QAM	240	360	2/3	960	43	64	300	824
1024-QAM	360	540	2/3	1440	43	720	360	540

Modulation	Data block size (bytes)	Encoding data block size (bytes)	Code rate	N	P0	P1	P2	P3
1024-QAM	480	720	2/3	1920	31	8	24	16
1024-QAM	600	900	2/3	2400	53	66	24	2
1024-QAM	45	60	3/4	180	11	90	0	90
1024-QAM	360	480	3/4	1440	43	720	360	540
1024-QAM	48	60	4/5	192	11	96	48	144
1024-QAM	240	300	4/5	960	43	64	300	824
1024-QAM	480	600	4/5	1920	31	8	24	16

Table 3. CTC channel coding for increased block sizes and for 256- and 1024-QAM

Data Modulation

Modify the following text from section

8.4.9.4.2 Data modulation:
After the repetition block, the data bits are entered serially to the constellation mapper. Gray-mapped QPSK and 16-QAM (as shown in Figure 8-128) shall be supported, whereas the support of 64-QAM, 256-QAM and 1024-QAM is optional.
The constellations (as shown in Figure 8-128 and Figures 8-128A and 8-128B) shall be normalized by multiplying the constellation point with the indicated factor *c* to achieve equal average power.

And add the following text and figures:

The Gray-mapped 256-QAM is shown in FigureFigure 8-128A The constellation shall be normalised by multiplying the constellation point by the factor $c = 1/\sqrt{170}$ to achieve equal average power.

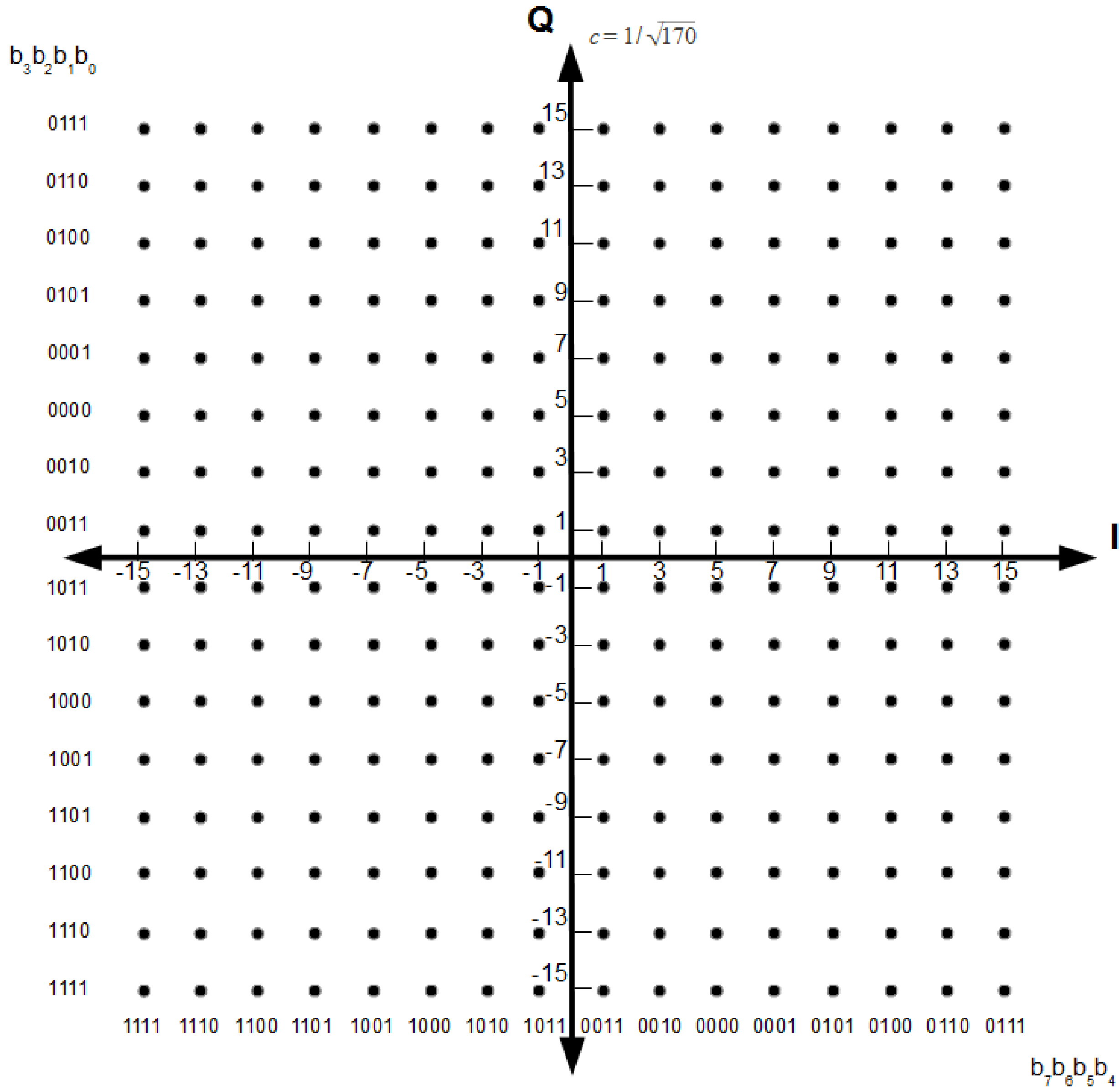

Figure 8-128A. 256-QAM constellation

The Gray-mapped 1024-QAM is shown in Figure 8-128B. The constellation shall be normalised by multiplying the constellation point by the factor $c = 1/\sqrt{682}$ to achieve equal average power.

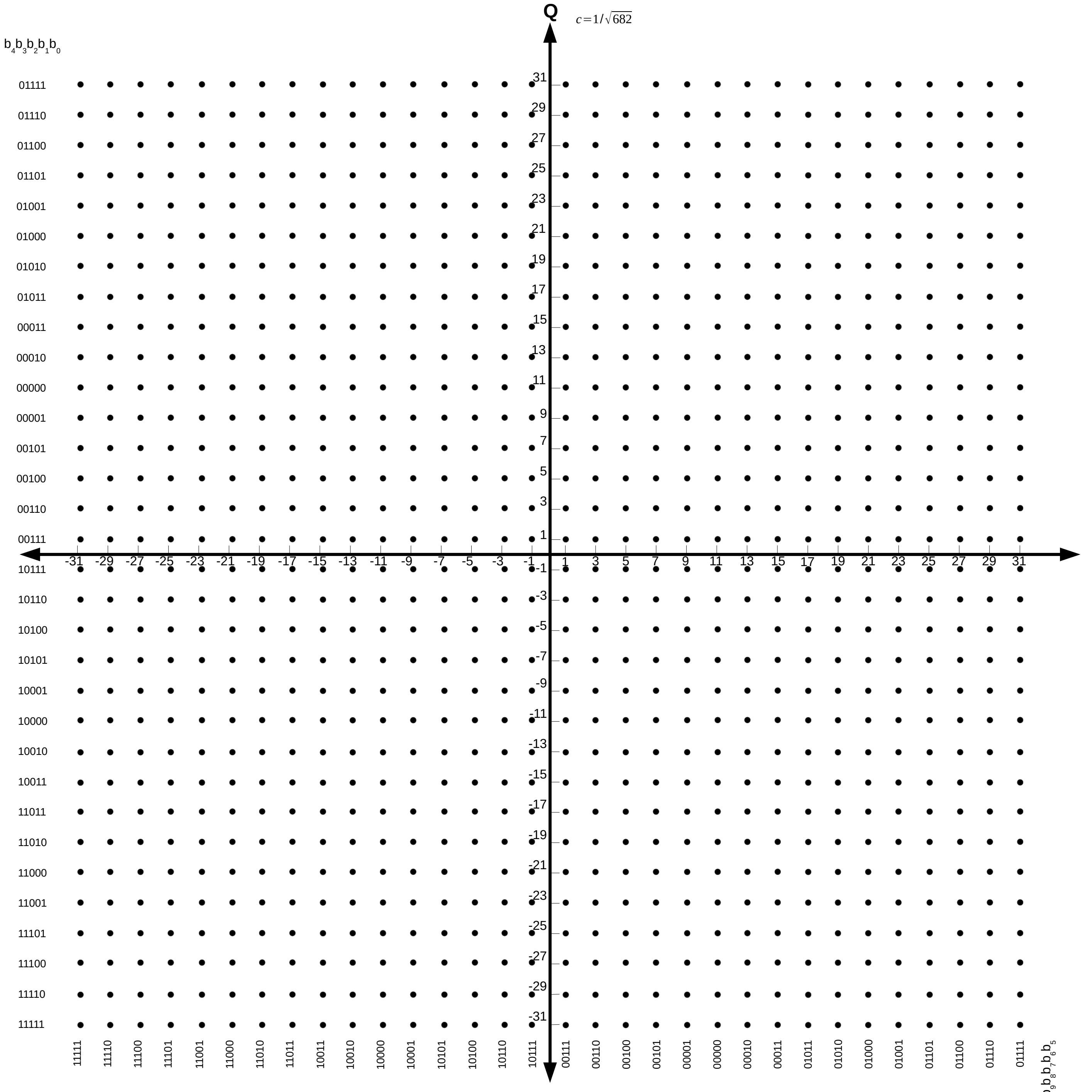

Figure 8-128B. 1024-QAM constellation