Project	**IEEE 802.16 Broadband Wireless Access Working Group** **<http://ieee802.org/16>**
Title	**Revision of LDPC to accommodate HARQ**
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Re:	Task Group Review of IEEE P802.16-REVd/D2-2003
Abstract	This contribution proposes text to allow recently defined features such as HARQ and AMC sub channels to operate with LDPC and other coding modes.
Purpose	Adoption
Notice	
Release	
Patent Policy and Procedures	

Introduction

H-ARQ improves performance by allowing the receiver to combine multiple ARQ transmissions. H-ARQ improves the performance of the system in the presence of channel variations due to inaccuracies in channel quality measurements or changes in other cell interference. Support for H-ARQ in the form of Chase Combining can easily be added to all coding modes in the OFDMA PHY without any changes to the physical encoding and with only small changes to the MAC proposed for CTC incremental redundancy.

Contribution IEEE C802.16d-04/74r2 proposes changes to support H-ARQ for incremental redundancy. This contribution recommends that the changes starting on page 20 through the end of the 74r2 contribution be first accepted than amended to support an optional H-ARQ in the form of Chase combining for all channel coding methods defined in the OFDMA PHY.

The contribution is organized as follows. First a description of the basic concept behind the extensions of the signaling in 74r2 is discussed. Next, new text will be proposed for the specific support of Chase combining for all the coding modes other than CTC. Finally, specific revisions to the text in 74r2 will be identified.

Concept of the extension

Three parameters tie the HARQ signaling to the CTC incremental redundancy mode. These parameters are the Subpacket Identified (SPID), the encoder packet size (Nep) and the number of sub channels (Nsch). Alternative definitions for these three parameters will allow Chase combining with the LDPC, BTC and CC mode.

The two-bit SPID is used by the protocol to identify which incremental redundancy encoding format is being used to transmit the current packet. For Chase H-ARQ, all retransmission are identical to the first transmission, therefore, the SPID field is unneeded. When Chase H-ARQ is used, the SPID field should be marked as reserved and encoded “00”.

The Nep and Nsch are each 4-bit fields in the H-ARQ signaling defined in 74r2. These 4-bit fields define the modulation, the number of information bits and number of sub-channels assigned. For the CTC mode, the number of information bits is defined by value of Nep as indexed in table III on page 14 of 74r2. The number of subchannels assigned is dependent on both Nep and Nsch and is addressed in Table KKK on page 10 of 74r2. Finally, the modulation is determined by calculating the Modulation Product Rate (MPR) as defined on page 9 of 74r2 and then making a comparison with a set of threshold levels.

Chase combining requires that alternate definitions of Nep and Nsch be defined for each specific coding mode. In the case of Chase H-ARQ, it is proposed that Nep be mapped to the information payloads currently defined by each respective coding mode. Likewise, it is proposed that Nsch be mapped to the sub-channels currently associated with the defined information payloads and coding rates. The specific encoding of Nep and Nsch will be captured in a set of tables in a new OFDMA PHY subsection called "Chase Combining H-ARQ". See the proposed text for the definition of these tables.

The modulation for Chase H-ARQ will be derived from the encoded values of Nep and Nsch using a similar method that defined in 74r2. A MPR will be calculated and then compared to a set of thresholds. Each of these thresholds would be unique to the particular FEC mode. See the proposed text for the definition of MPR and the modulation thresholds.

The Chase HARQ mode does not define any new modulation levels, coding rates or information bit sizes that were not already defined in the FEC specifications. As a result, not all combinations of Nep and Nsch are valid. The valid Nep and Nsch values are listed for each respective FEC mode.

New text for HARQ support

8.4.9.5 Chase Combining HARQ (optional)

All FEC modes which do not explicitly define incremental redundancy may optionally support H-ARQ using Chase combining. The definition of Nep and Nsch is unique to each of the encoding modes. In addition, the modulation used for a particular transmission is based on Modulation-order Product code Rate (MPR) which is calculated using the following formula.

$$MPR = \frac{N_{EP}}{48 N_{SCH}}$$

Then, the modulation order is specified by the following rule:

i) If $0 < MPR \leq QPSK\_LIMIT$, then a QPSK (modulation order 2) is used
ii) If $QPSK\_LIM < MPR \leq 16QAM\_LIM$, then a 16QAM (modulation order 4) is used
iii) If $16QAM\_LIM < MPR$, then a 64QAM (modulation order 6) is used

The values QPSK_LIMIT, 16QAM_LIMIT are dependent on the particular FEC mode used. They are defined in Table 1.

Table 1 Chase H-ARQ Modulation Selection Thresholds

coding mode	QPSK_LIM	16QAM_LIM
conv	1.5	3
BTC	1.67	3.35
LDPC	1.6	3.2

The values for Nep, Nsch are defined in the following subsections. Note, that not all combinations of Nep and Nsch are valid. Only the combinations as defined in the specific FEC modes are allowed.

8.4.9.5.1 Convolutional H-ARQ parameters

Table 2 defines the encoding of Nep and Nsch for the Convolutional H-ARQ mode. Table 3 lists the valid Nep and Nsch combinations along with the associated modulation level.

Table 2 Nep and Nsch for Convolutional H-ARQ

Nep code	Nep value	Nsch code	Nsch value
0	48	0	1
1	72	1	2
2	96	2	3
3	144	3	4
4	192	4	5
5	216	5	6
6	240	6	Reserved
7	288	7	Reserved
8	Reserved	8	Reserved
9	Reserved	9	Reserved
10	Reserved	10	Reserved
11	Reserved	11	Reserved
12	Reserved	12	Reserved
13	Reserved	13	Reserved
14	Reserved	14	Reserved
15	Reserved	15	Reserved

Table 3 Valid Nep and Nsch combinations for Convolutional H-ARQ

Nep value	Nsch value	coded bits	modulation	code rate	MPR
48	1	96	2	0.50	1.00
96	2	192	2	0.50	1.00
144	3	288	2	0.50	1.00
192	4	384	2	0.50	1.00
240	5	480	2	0.50	1.00
288	6	576	2	0.50	1.00
72	1	96	2	0.75	1.50
144	2	192	2	0.75	1.50
216	3	288	2	0.75	1.50
288	4	384	2	0.75	1.50
96	1	192	4	0.50	2.00
192	2	384	4	0.50	2.00
288	3	576	4	0.50	2.00
144	1	192	4	0.75	3.00
288	2	384	4	0.75	3.00
192	1	288	6	0.67	4.00
216	1	288	6	0.75	4.50

8.4.9.5.2 Block Turbo H-ARQ parameters

Table 4 defines the encoding of Nep and Nsch for the Block Turbo H-ARQ mode. Table 5 lists the valid Nep and Nsch combinations along with the associated modulation level.

Table 4 Nep and Nsch encoding for Block Turbo H-ARQ

Nep code	Nep value	Nsch code	Nsch value
0	48	0	1
1	72	1	2
2	128	2	3
3	160	3	4
4	184	4	5
5	200	5	6
6	248	6	Reserved
7	280	7	Reserved
8	320	8	Reserved
9	Reserved	9	Reserved
10	Reserved	10	Reserved
11	Reserved	11	Reserved
12	Reserved	12	Reserved
13	Reserved	13	Reserved
14	Reserved	14	Reserved
15	Reserved	15	Reserved

Table 5 Valid Nep and Nsch combination for Block Turbo H-ARQ

Nep value	Nsch value	coded bits	modulation	code rate	MPR
128	3	288	2	0.44	0.89
184	4	384	2	0.48	0.96
48	1	96	2	0.50	1.00
248	5	480	2	0.52	1.03
320	6	576	2	0.56	1.11
128	2	192	2	0.67	1.33
200	3	288	2	0.69	1.39
280	4	384	2	0.73	1.46
72	1	96	2	0.75	1.50
160	2	192	2	0.83	1.67
184	2	384	4	0.48	1.92
320	3	576	4	0.56	2.22
128	1	192	4	0.67	2.67
280	2	384	4	0.73	2.92
160	1	192	4	0.83	3.33
200	1	288	6	0.69	4.17

8.4.9.5.3 Low-Density Parity Check HARQ parameters

Table 4 defines the encoding of Nep and Nsch for the Low-Density Parity Check H-ARQ mode. Table 5 lists the valid Nep and Nsch combinations along with the associated modulation level.

Table 6 Nep and Nsch encoding for Low-Density Parity Check H-ARQ

Nep code	Nep value	Nsch code	Nsch value
0	176	0	3
1	368	1	4
2	464	2	5
3	752	3	6
4	1040	4	8
5	1136	5	10
6	1328	6	12
7	1520	7	16
8	Reserved	8	20
9	Reserved	9	Reserved
10	Reserved	10	Reserved
11	Reserved	11	Reserved
12	Reserved	12	Reserved
13	Reserved	13	Reserved
14	Reserved	14	Reserved
15	Reserved	15	Reserved

Table 7 Valid Nep and Nsch combinations for Low-Density Parity Check H-ARQ

Nep value	Nsch value	coded bits	modulation	code rate	MPR
176	6	576	2	0.31	0.61
368	8	768	2	0.48	0.96
752	12	1152	2	0.65	1.31
1136	16	1536	2	0.74	1.48
1520	20	1920	2	0.79	1.58
368	4	768	4	0.48	1.92
752	6	1152	4	0.65	2.61
1136	8	1536	4	0.74	2.96
1520	10	1920	4	0.79	3.17
464	3	864	6	0.54	3.22
752	4	1152	6	0.65	3.92
1040	5	1440	6	0.72	4.33
1328	6	1728	6	0.77	4.61

Changes to 74r2

Section 6.4.17 "MAC support for HARQ" contains a brief discussion of Chase Combining and Incremental Redundancy. In addition, the discussion of packet transmissions and sub-packet procedures is clarified. Sections 6.4.17.1 through 6.4.7.1 are all applicable to generic HARQ.

The changes are as follows:

Modify Section 6.4.17 "MAC support for HARQ" after figure 125

6.4.17 MAC support for HARQ

Hybrid automatic repeat request (H-ARQ) scheme is an optional part of the MAC and can be enabled on a per-terminal basis. The per-terminal H-ARQ and associated parameters shall be specified and negotiated during initialization procedure. A terminal cannot have a mixture of H-ARQ and non-H-ARQ traffic. One or more MAC PDUs can be concatenated and an H-ARQ packet formed by adding a CRC to the PHY burst. Figure eee shows how the H-ARQ encoder packet is constructed.

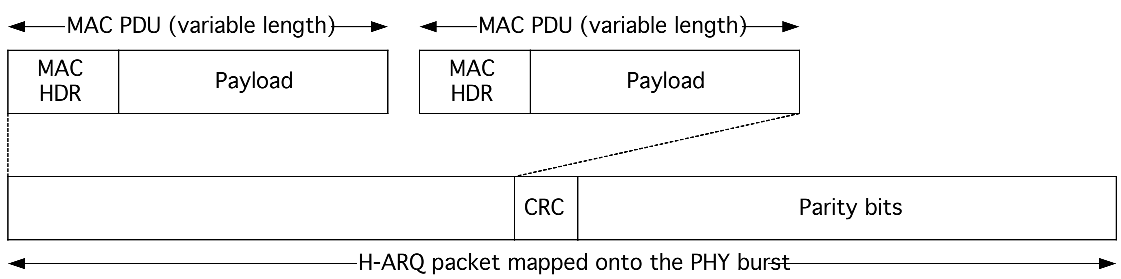

Figure eee—Construction of H-ARQ encoder packet

The two main variants of H-ARQ are supported, Chase Combining or Incremental Redundancy (IR). For IR, the PHY layer will encode the H-ARQ packet generating several versions of encoded subpackets. Each subpacket will be uniquely identified using a subpacket identifier (SPID). For Chase Combining, the PHY layer will encode the H-ARQ packet generating only one version of the encoded packet. As a result, no SPID is required for Chase Combining.

~~Each H-ARQ packet is encoded according to the PHY specification, and four subpackets are generated from the encoded result. A subpacket identifier (SPID) is used to distinguish the four subpackets. In case of downlink communication, a BS can send one of the subpackets in a burst transmission. Because of the redundancy among the subpackets, SS can correctly decode the original encoder packet even before it receives all four subpackets. Whenever receiving the first subpacket, the SS attempts to decode the original encoder packet from it. If it succeeds, the SS sends an ACK to the BS, so that the BS stops sending additional subpackets of the encoder packet. Otherwise, the SS sends a NAK, which causes the BS to transmit one subpacket selected from the four. These procedures go on until the SS successfully decodes the encoder packet. When the SS receives more than one subpacket, it tries to decode the encoder packet from ever-received subpackets.~~

For downlink H-ARQ operation, the BS will send a version of the encoded H-ARQ packet. The SS will attempt to decode the encoded packet on this first H-ARQ attempt. If the decoding succeeds, the SS will send an ACK to the BS. If the decoding fails, the SS will send a NAK to the BS. In response, the BS will send another H-ARQ attempt. The BS may continue to send H-ARQ attempts until the SS successfully decodes the packet and sends an acknowledgement.

For IR, each H-ARQ attempt may have a uniquely encoded subpacket. The rule of subpacket transmission is as follows,

1. At the first transmission, BS shall send the subpacket labeled '00'.
2. BS may send one among subpackets labeled '00', '01', '10', or '11' in any order
3. BS can send more than one copy of any subpacket, and can omit any subpacket except the subpacket labeled '00' .

In order to specify the start of a new transmission, one-bit H-ARQ identifier sequence number (AI_SN) is toggled on every ~~successful transmission of an encoder packet~~ HARQ Attempt on the same H-ARQ channel. If the AI_SN changes, the receiver treats the corresponding HARQ Attempt as belonging ~~subpacket as a subpacket belongs~~ to a new encoder packet, and discards ~~ever-received subpackets~~ previous HARQ Attempt with the same ARQ identifier.

The H-ARQ scheme is basically a stop-and-wait protocol. The ACK is sent by the SS after a fixed delay (synchronous ACK) defined by H-ARQ DL ACK delay offset which is specified in DCD message. Timing of retransmission is, however, flexible and corresponds to the asynchronous part of the H-ARQ. The ACK/NAK is sent by the BS using the H-ARQ Bitmap IE, and sent by a SS using the fast feedback UL subchannel.

The H-ARQ scheme supports multiple H-ARQ channels per a connection, each of which may have an encoder packet transaction pending. The number of H-ARQ channels in use is determined by BS. These ARQ channels are distinguished by an H-ARQ channel identifier (ACID). The ACID for any subpackets can be uniquely identified by the control information carried in the MAPs.

H-ARQ (Hybrid Automatic Repeat reQuest) can be used to mitigate the effect of channel and interference fluctuation. H-ARQ renders performance improvement due to SNR gain and time diversity achieved by combining previously erroneously decoded packet and retransmitted packet~~, and due to additional coding gain by IR (Incremental Redundancy)~~.

6.4.17.1 Subpacket generation

H-ARQ operates at the FEC block level. When IR is defined, the FEC encoder is responsible for generating the H-ARQ subpackets, as defined in the relevant PHY section. The subpackets are combined by the receiver FEC decoder as part of the decoding process.

6.4.16.2 DL/UL ACK/NAK signaling

For DL/UL H-ARQ, fast ACK/NAK signaling is necessary. For the fast ACK/NAK signaling of DL H-ARQ channel, a dedicated PHY layer ACK/NAK channel is designed in UL. For the fast ACK/NAK signaling of UL H-ARQ channel, H-ARQ ACK message is designed.

Section 6.3.2.44.4 "H-ARQ Control IE" the SPID field should only be sent when incremental redundancy is defined for the FEC mode. Otherwise, the field is reserved.

The changes to section 6.3.2.3.44.4 are as follows:

6.3.2.3.44.4 H-ARQ Control IE

The format of H-ARQ_Control_IE , which includes encoding/decoding information for H-ARQ enabled DL/UL bursts, is presented in Table 7. This IE shall be located after CID in the DL/UL MAP_IE.

Table 7 H-ARQ_Control_IE format

Syntax	**Size**	**Notes**
H-ARQ_Control_IE () {		In DL/UL-MAP
Prefix	1 bit	0 = Temporary disable H-ARQ 1 = enable H-ARQ
if (Prefix ==1){		
AI_SN	1 bits	H-ARQ ID Seq. No
SPID/Reserved	2 bits	Subpacket ID when IR is defined by the FEC mode, otherwise reserved (encoded 00)
ACID	4 bits	H-ARQ CH ID
} else{		
Reserved	3 bits	
}		
}		

Prefix

Indicates whether H-ARQ is enabled or not.

AI_SN

Defines ARQ Identifier Sequence Number. This is toggled between ‘0’ and ‘1’ on successfully transmitting eache ncoder packet with the same ARQ channel.

SPID

Defines SubPacket ID, which is used to identify the four subpackets generated from an encoder packet. This field only applies to FEC modes supporting incremental redundancy.

ACID

Defines H-ARQ Channel ID, which is used to identify H-ARQ channels. Each connection can have multiple HARQ channels, each of which may have an encoder packet transaction pending.