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| Project | **IEEE 802.16 Broadband Wireless Access Working Group** <**http://ieee802.org/16**> |
| Title | **Chase H-ARQ support for all FEC schemes** |
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| Re: | Ballot #14a |
| Abstract | This contribution proposes text to allow recently defined features such as H-ARQ and AMC sub channels to operate with all FEC schemes. |
| 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 be added to all coding modes in the OFDMA PHY without any changes to the physical encoding and with only small backwards-compatible changes to the MAC adopted for CTC incremental redundancy. The contribution proposes that Chase Combining techniques be adopted for the all FEC schemes in the specification. It is further anticipated that the extensions defined in this contribution will also be applicable to LDPC once a harmonized proposal has been accepted.

The contribution is organized as follows. First a description of the basic concept behind the extensions of the signaling 802.16RevD/D5 is discussed. Next, new text will be proposed for the specific support of Chase combining for all the coding modes. Finally, specific revisions to the text in 802.16e/D3 will be identified.

## Concept of the extension

In general, HARQ requires that the ARQ control information be transmitted independently from the user data. The ARQ control information identifies retransmissions for the receiver and allows the receiver to decide which blocks should be combined with previous failed transmission attempts and which blocks represent new data. It is convenient to transmit the ARQ control information with the allocation of resources to a subscriber station. Therefore, one option would be to embed the ARQ control information within the DL_MAP IE. However, compatibility with non-HARQ operation would require that an extended DIUC be used making this option too cumbersome. This was the conclusion reached by the CTC IR proponents as is evident in their revision of contribution C802.16d-04/74r3 and the subsequent definition of an independent HARQ_MAP. A second option might be to define a new CHASE_HARQ_MAP, however, the functionality in the CHASE_HARQ_MAP would be largely similar to that in the HARQ_MAP. Considering the commonality between Chase and IR, the most promising option is to modify the existing HARQ_MAP.

One challenge to modifying the HARQ_MAP signaling is maintaining compatibility with the RevD version of the HARQ_MAP. Requirements for backward compatibility and specific construction of the HARQ_MAP put the following unique constraints on the extensions of the HARQ_MAP:

1) Ordering of allocations is important for backwards compatibility. Allocations using the HARQ_MAP are cumulative. Each HARQ Compact DL_MAP IE within the HARQ_MAP specifies only the number of sub channels assigned to the SS, not the precise location within the frame as in the conventional DL_MAP. It

is implied that the allocation of the first Compact DL_MAP begins at the first sub channel in the allocation region and that allocation of the second Compact DL_MAP begins in the next unallocated sub channel. Therefore, an SS must decode each preceding Compact DL_MAP in order to determine the location of its own allocation. As a result, RevD-style allocations intended for RevD compliant SS must occur before 16e-style allocations to ensure that all preceding allocations are decodable by the legacy SS.

2) The length of a HARQ Compact DL_MAP IE may not be modified. None of the Compact DL_MAP IEs contain a length field. Therefore, any modifications to the length of these messages would violate the parsing rules employed by RevD SSs. A RevD SS having lost its place may read an erroneous allocation forcing a protocol error. To prevent RevD SSs from misinterpreting HARQ_MAP, the length must be preserved for all HARQ Compact DL_MAP_IEs within HARQ_MAP.

Three parameters currently link the HARQ signaling to the CTC incremental redundancy mode. These parameters are the Subpacket Identifier (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 CC, CTC and BTC modes. In addition, they will potentially allow extension to future coding modes such as LDPC.

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 802.16RevD/D5. 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 330 on page 613 of 802.16RevD/D5. The number of subchannels assigned is dependent on both Nep and Nsch and is addressed for the downlink in Table 329 on page 609 of 802.16RevD/D5. Finally, the modulation is determined by calculating the Modulation Product Rate (MPR) as defined on page 608 of 802.16RevD/D5 and then making a comparison with a set of threshold levels. Alternatively, the modulation, coding rate and number of sub channels assigned may be represented in a 16x16 table of Nep and Nsch values. Table A.1 and A.2 in the Appendix show the modulation and subchannels allocated for the DL CTC IR mode. Table A.3, A.4 and A.5 show the modulation and subchannels allocated for the UL CTC IR mode.

Chase combining requires alternate definitions of Nep and Nsch. It is proposed that the 8 bits used for Nep and Nsch be redefined as two fields: a shortened DIUC/UIUC field and a companded sub channel allocation when a generic Chase HARQ allocation is signalled. The shortened DIUC field would be 3-bits, which is 1-bit smaller the DIUC field in the conventional DL_MAP. The shortened DIUC would be mapped to the lower eight values in the conventional DIUC. The companded sub channel allocation would identify the number of sub channels based on a pre-defined look-up table, as illustrated in the proposed text.

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New block lengths have not been defined for any of the coding modes. Unlike the CTC IR mode, Chase HARQ is defined for all existing modulation and coding pairs. Chase HARQ will employ the same block concatenation rules as defined for the CC, CTC, and BTC non-HARQ modes.

# New text for HARQ support

## 8.4.9.5 Chase Combining HARQ (optional)

Chase Combining HARQ may be enabled for any of the existing FEC modes. A change in the H-ARQ mode is signaled using the "H-ARQ Compact_DL-MAP IE format for Switch H-ARQ Mode" (see section 6.3.2.3.43.6.7). The definitions of the H-ARQ modes are defined in Table AAA.

**Table AAA HARQ Companded Sub Channel Definitions**

| H-ARQ Mode | Description |
|---|---|
| 0 | CTC Incremental Redundancy |
| 1 | Generic Chase |
| 2…5 | Reserved |

When Chase Combining HARQ is enabled for a particular SS, the HARQ_MAP will used to signal the allocation and the HARQ Control IE will use the "Generic Chase" allocation format. The encoding of the companded sub channel field is defined in Table BBB below. Concatenation rules for each respective coding mode are applied as defined for non-HARQ transmissions.

**Table BBB HARQ Companded Sub Channel Definitions**

| Companded Sub Channels | Assigned Sub Channels | | Companded Sub Channels | Assigned Sub Channels |
|---|---|---|---|---|
| 0 | 1 | | 16 | 40 |
| 1 | 2 | | 17 | 48 |
| 2 | 3 | | 18 | 56 |
| 3 | 4 | | 19 | 64 |
| 4 | 5 | | 20 | 80 |
| 5 | 6 | | 21 | 96 |
| 6 | 7 | | 22 | 112 |
| 7 | 8 | | 23 | 128 |
| 8 | 10 | | 24 | 160 |
| 9 | 12 | | 25 | 192 |
| 10 | 14 | | 26 | 224 |
| 11 | 16 | | 27 | 256 |
| 12 | 20 | | 28 | 320 |
| 13 | 24 | | 29 | 384 |
| 14 | 28 | | 30 | 448 |
| 15 | 32 | | 31 | 512 |

# Modifications from text in 802.16RevD/D5

*Section 6.3.17 "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 6.3.17.1 through 6.3.7.1 are all applicable to generic HARQ.*

*The changes are as follows:*

*Modify Section 6.3.17 "MAC support for HARQ" after figure 130*

### 6.3.17 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 a H-ARQ packet formed by adding a CRC to the PHY burst. Figure 130 shows how the H-ARQ encoder packet is constructed.

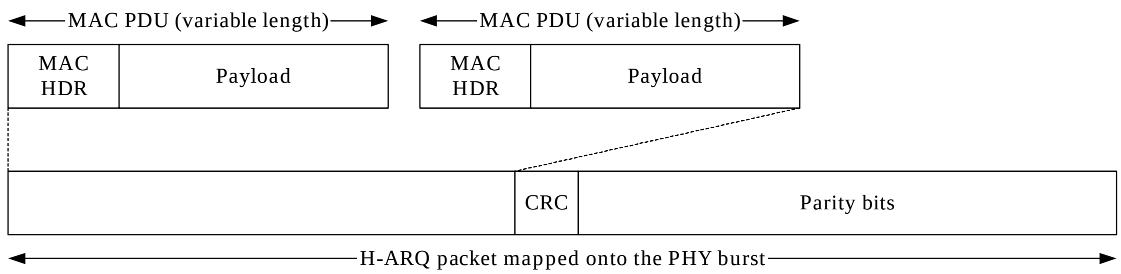


**Figure 130—Construction of H-ARQ encoder packet**

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.

*Add the following text to section 6.3.2.43.1 "H-ARQ Map Message format" after table 88*

Table 89 represents the extended types of compact DL MAP.

**Table 89—Extended Compact_DL-MAP IE types**

| **Compact DL-MAP Type** | **Description** |
|---|---|
| 0 | Switch H-ARQ Mode |
| 1..7 | *reserved* |

*Section 6.3.2.43.4 "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 6.3.2.3.43.4 are as follows:*

**6.3.2.3.43.4 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 92. This IE shall be located after CID in the DL/UL MAP_IE.

Table 92 H-ARQ_Control_IE format

| **Syntax** | **Size** | **Notes** |
|---|---|---|
| H-ARQ_Control_IE () { | | In DL/UL-MAP |
| Prefix | 1 bit | 0 = Temporary disable H-ARQ<br>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 each encoder 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.

*Add section 6.3.2.43.6.7 "H-ARQ Compact_DL_MAP IE format for Switch H-ARQ Mode"*

### 6.3.2.3.43.6.7 H-ARQ Compact_DL-MAP IE format for Switch H-ARQ Mode

In the HARQ-MAP, a BS may transmit DL-MAP Type=7 with the Switch H-ARQ mode IE. Allocations subsequent to this IE shall be for the H-ARQ mode identified.

**Table BBB—H-ARQ Compact_DL-MAP IE format for Switch H-ARQ Mode**

| Syntax | Size | Notes |
|---|---|---|
| Compact_DL-MAP_IE () { | | |
| **DL-MAP Type =7** | 3 bits | |
| **DL-MAP sub-type** | 5 bits | Extension sub type |
| **Length** | 4 bits | Length of the IE in Bytes |
| **H-ARQ mode** | 4 bits | Sub-type dependent payload |
| } | | |

**DL-MAP Type**
This value specifies the type of the compact DL-MAP IE. A value of 7 indicates the extension type.

**DL-MAP Sub-Type**
This value specifies the extended map type as H-ARQ mode switch

**Length**
This indicates the length of this IE in Bytes. This is encoded as 2

**H-ARQ mode**
This is a 4-bit value specifies the H-ARQ mode for all subsequent Compact DL-MAP IEs to the end of the current H-ARQ map. See section 8.4.9.5 for encoding of this value.

*Section 6.3.2.43 "H-ARQ MAP message" requires the Nep and Nsch table entries to be replaced depending on the type of H-ARQ mode.*

*In sections 6.3.2.3.43.6.1, 6.3.2.3.43.6.2, and 6.3.2.3.43.6.3, replace the table entries for Nep and Nsch:*

| | | |
|---|---|---|
| **$N_{EP}$ code** | 4 bits | Code of encoder packet bits (see 8.4.9.2.3.5) |
| **$N_{SCH}$ code** | 4 bits | Code of allocated subchannels (see 8.4.9.2.3.5) |

*With:*

| | | |
|---|---|---|
| if (H-ARQ mode = “CTC IR”) { | | |
| **$N_{EP}$ code** | 4 bits | Code of encoder packet bits (see 8.4.9.2.3.5) |
| **$N_{SCH}$ code** | 4 bits | Code of allocated subchannels (see 8.4.9.2.3.5) |
| } elsif (H-ARQ mode = Generic) { | | |
| ***Shortened DIUC*** | 3 bits | Shortened DIUC |
| ***Companded SC*** | 5 bits | Code of allocated subchannels (see 8.4.9.5) |
| } | | |

*Also, replace the text describing Nep and Nsch as:*

**NEP code, NSCH code**

The combination of *NEP* code and *NSCH* code indicates the number of allocated subchannels and scheme of coding and modulation for the DL burst.

*With the following text:*

**NEP code, NSCH code**

The combination of *NEP* code and *NSCH* code indicates the number of allocated subchannels and scheme of coding and modulation for the DL burst.

**Shortened DIUC**

A shortened version of the DIUC. The shortened DIUC takes on values 0..7 of the DIUC as defined in the DCD. See section 8.4.5.3.1.

**Companded SC**

The compand SC indicates the number of allocated subchannels.

*In sections 6.3.2.3.43.6.1 and, 6.3.2.3.43.6.3 replace the table entries for Nep and Nsch for uplink:*

| | | |
|---|---|---|
| ***$N_{EP}$* code for UL** | 4 bits | Code of encoder packet bits (see 8.4.9.2.3.5) |
| ***$N_{SCH}$* code for UL** | 4 bits | Code of allocated subchannels (see 8.4.9.2.3.5) |

*With:*

| | | |
|---|---|---|
| if (H-ARQ mode = “CTC IR”) { | | |
| ***$N_{EP}$* code for UL** | 4 bits | Code of encoder packet bits (see 8.4.9.2.3.5) |
| ***$N_{SCH}$* code for UL** | 4 bits | Code of allocated subchannels (see 8.4.9.2.3.5) |
| } elsif (H-ARQ mode = Generic) { | | |
| ***Shortened UIUC*** | 3 bits | Shortend UIUC |
| ***Companded SC*** | 5 bits | Code of allocated subchannels |
| } | | |

*Also, replace the text describing Nep and Nsch for uplink as:*

**NEP code for UL, NSCH code for UL**
The combination of *NEP* code and *NSCH* code indicates the number of allocated subchannels and scheme of coding and modulation for the UL burst.

*With the following text:*

**NEP code for UL, NSCH code for UL**
The combination of *NEP* code and *NSCH* code indicates the number of allocated subchannels and scheme of coding and modulation for the UL burst.

**Shortened UIUC**
A shortened version of the UIUC. The shortened UIUC takes on values 1..8 of the UIUC as defined in the DCD. See section 8.4.5.4.1

**Companded SC**
The compand SC indicates the number of allocated subchannels.

*In sections 6.3.2.3.43.7.1, 6.3.2.3.43.7.2, and 6.3.2.3.43.7.3, replace the table entries for Nep and Nsch:*

| | | |
|---|---|---|
| ***$N_{EP}$* code** | 4 bits | Code of encoder packet bits (see 8.4.9.2.3.5) |
| ***$N_{SCH}$* code** | 4 bits | Code of allocated subchannels (see 8.4.9.2.3.5) |

*With:*

| | | |
|---|---|---|
| if (H-ARQ mode = “CTC IR”) { | | |
| ***$N_{EP}$* code** | 4 bits | Code of encoder packet bits (see 8.4.9.2.3.5) |
| ***$N_{SCH}$* code** | 4 bits | Code of allocated subchannels (see 8.4.9.2.3.5) |
| } elsif (H-ARQ mode = Generic) { | | |
| ***Shortened DIUC*** | 3 bits | Shortend DIUC (see 8.4.9.2.3.5) |
| ***Companded SC*** | 5 bits | Code of allocated subchannels (see 8.4.9.5) |
| } | | |

*Also, replace the text describing Nep and Nsch as:*

**NEP code, NSCH code**

The combination of *NEP* code and *NSCH* code indicates the number of allocated subchannels and scheme of coding and modulation for the UL burst.

*With the following text:*

**NEP code, NSCH code**

The combination of *NEP* code and *NSCH* code indicates the number of allocated subchannels and scheme of coding and modulation for the UL burst.

**Shortened UIUC**

A shortened version of the UIUC. The shortened UIUC takes on values 1..8 of the UIUC as defined in the DCD. See section 8.4.5.4.1

**Companded SC**

The compand SC indicates the number of allocated subchannels.

# Appendix A: Sub-channel, Modulation, and Coding Rate Allocation for CTC IR

This section provides tables illustrating the current sub-channel, modulation and coding rate allocation for the CTC IR mode in the standard. These tables are informational and do not propose any changes to the standard. Tables A.1 and A.2 are for downlink allocations. Tables A.3, A.4, and A.5 are for uplink allocations.

**Table A.1 DL Modulation and coding for Nep/Nsch encoding**

| Nsch \ Nep | 144<br>0000 | 192<br>0001 | 288<br>0010 | 384<br>0011 | 480<br>0100 | 960<br>0101 | 1920<br>0110 | 2880<br>0111 | 3840<br>1000 | 4800<br>1001 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000 | 64QAM R= 1/2 | 64QAM R= 2/3 | 64QAM R= 1/2 | 64QAM R= 2/3 | 64QAM R= 5/6 | 64QAM R= 5/6 | 64QAM R= 5/6 | 64QAM R= 5/6 | 64QAM R= 5/6 | 64QAM R= 5/6 |
| 0001 | 16QAM R= 3/8 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 2/3 | 64QAM R= 5/9 | 64QAM R= 2/3 | 64QAM R= 20/27 | 64QAM R= 10/13 | 64QAM R= 20/27 | 64QAM R= 25/33 |
| 0010 | QPSK R= 1/2 | QPSK R= 2/3 | 16QAM R= 3/8 | 16QAM R= 1/2 | 16QAM R= 5/8 | 64QAM R= 5/9 | 64QAM R= 2/3 | 64QAM R= 2/3 | 64QAM R= 2/3 | 64QAM R= 25/39 |
| 0011 | QPSK R= 3/10 | QPSK R= 1/2 | QPSK R= 3/5 | 16QAM R= 2/5 | 16QAM R= 1/2 | 16QAM R= 5/8 | 64QAM R= 20/39 | 64QAM R= 1/2 | 64QAM R= 20/39 | 64QAM R= 25/48 |
| 0100 | QPSK R= 1/4 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 2/3 | 16QAM R= 5/12 | 16QAM R= 1/2 | 16QAM R= 2/3 | 16QAM R= 15/22 | 16QAM R= 2/3 | 16QAM R= 25/38 |
| 0101 | QPSK R= 1/6 | QPSK R= 1/4 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 5/8 | 16QAM R= 5/13 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 1/2 |
| 0110 | QPSK R= 1/8 | QPSK R= 1/6 | QPSK R= 1/4 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 2/3 | 16QAM R= 5/13 | 16QAM R= 3/8 | 16QAM R= 5/13 | 16QAM R= 25/64 |
| 0111 | QPSK R= 1/12 | QPSK R= 1/8 | QPSK R= 1/6 | QPSK R= 1/4 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 2/3 | QPSK R= 15/22 | QPSK R= 2/3 | QPSK R= 25/38 |
| 1000 | X | QPSK R= 1/12 | QPSK R= 1/8 | QPSK R= 1/6 | QPSK R= 1/6 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 1/2 | QPSK R= 1/2 | QPSK R= 1/2 |
| 1001 | X | X | X | QPSK R= 1/8 | QPSK R= 1/8 | QPSK R= 1/4 | QPSK R= 1/3 | QPSK R= 1/3 | QPSK R= 1/3 | QPSK R= 1/3 |
| 1010 | X | X | X | QPSK R= 1/12 | QPSK R= 1/12 | QPSK R= 1/6 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/4 |
| 1011 | X | X | X | X | X | QPSK R= 1/8 | QPSK R= 1/6 | QPSK R= 1/6 | QPSK R= 1/6 | QPSK R= 1/6 |
| 1100 | X | X | X | X | X | QPSK R= 1/12 | QPSK R= 1/8 | QPSK R= 1/8 | QPSK R= 1/8 | X |
| 1101 | X | X | X | X | X | X | QPSK R= 1/12 | X | X | X |
| 1110 | X | X | X | X | X | X | X | X | X | X |
| 1111 | X | X | X | X | X | X | X | X | X | X |

**Table A.2 DL Nsch values for Nep/Nsch encoding**

| Nsch \ Nep | 144<br>0000 | 192<br>0001 | 288<br>0010 | 384<br>0011 | 480<br>0100 | 960<br>0101 | 1920<br>0110 | 2880<br>0111 | 3840<br>1000 | 4800<br>1001 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0000 | 1 | 1 | 2 | 2 | 2 | 4 | 8 | 12 | 16 | 20 |
| 0001 | 2 | 2 | 3 | 3 | 3 | 5 | 9 | 13 | 18 | 22 |
| 0010 | 3 | 3 | 4 | 4 | 4 | 6 | 10 | 15 | 20 | 26 |
| 0011 | 5 | 4 | 5 | 5 | 5 | 8 | 13 | 20 | 26 | 32 |
| 0100 | 6 | 6 | 6 | 6 | 6 | 10 | 15 | 22 | 30 | 38 |
| 0101 | 9 | 8 | 9 | 8 | 8 | 13 | 20 | 30 | 40 | 50 |
| 0110 | 12 | 12 | 12 | 12 | 10 | 15 | 26 | 40 | 52 | 64 |
| 0111 | 18 | 16 | 18 | 16 | 15 | 20 | 30 | 44 | 60 | 76 |
| 1000 | X | 24 | 24 | 24 | 30 | 30 | 40 | 60 | 80 | 100 |
| 1001 | X | X | X | 32 | 40 | 40 | 60 | 90 | 120 | 150 |
| 1010 | X | X | X | 48 | 60 | 60 | 80 | 120 | 160 | 200 |
| 1011 | X | X | X | X | X | 80 | 120 | 180 | 240 | 300 |
| 1100 | X | X | X | X | X | 120 | 160 | 240 | 320 | X |
| 1101 | X | X | X | X | X | X | 240 | X | X | X |
| 1110 | X | X | X | X | X | X | X | X | X | X |
| 1111 | X | X | X | X | X | X | X | X | X | X |

**Table A.3 UL Modulation and coding for Nep/Nsch encoding (Part 1 of 2)**

| Nsch \ Nep | 48<br>0000 | 96<br>0001 | 144<br>0010 | 192<br>0011 | 288<br>0100 | 384<br>0101 | 480<br>0110 | 960<br>0111 |
|---|---|---|---|---|---|---|---|---|
| 0000 | QPSK R= 1/2 | 16QAM R= 1/2 | 16QAM R= 3/4 | 16QAM R= 1/2 | 16QAM R= 3/4 | 16QAM R= 2/3 | 16QAM R= 5/6 | 16QAM R= 5/6 |
| 0001 | QPSK R= 1/4 | QPSK R= 1/2 | 16QAM R= 3/8 | QPSK R= 2/3 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 5/8 | 16QAM R= 5/7 |
| 0010 | QPSK R= 1/6 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 1/2 | 16QAM R= 3/8 | 16QAM R= 2/5 | 16QAM R= 1/2 | 16QAM R= 5/8 |
| 0011 | QPSK R= 1/8 | QPSK R= 1/4 | QPSK R= 3/10 | QPSK R= 1/3 | QPSK R= 3/5 | QPSK R= 2/3 | 16QAM R= 5/12 | 16QAM R= 1/2 |
| 0100 | QPSK R= 1/12 | QPSK R= 1/6 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/2 | QPSK R= 1/2 | QPSK R= 5/8 | QPSK R= 2/3 |
| 0101 | X | QPSK R= 1/8 | QPSK R= 1/6 | QPSK R= 1/6 | QPSK R= 1/3 | QPSK R= 1/3 | QPSK R= 1/2 | QPSK R= 1/2 |
| 0110 | X | QPSK R= 1/12 | QPSK R= 1/8 | QPSK R= 1/8 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/3 | QPSK R= 1/3 |
| 0111 | X | X | QPSK R= 1/12 | QPSK R= 1/12 | QPSK R= 1/6 | QPSK R= 1/6 | QPSK R= 1/6 | QPSK R= 1/4 |
| 1000 | X | X | X | X | QPSK R= 1/8 | QPSK R= 1/8 | QPSK R= 1/8 | QPSK R= 1/6 |
| 1001 | X | X | X | X | QPSK R= 1/12 | QPSK R= 1/12 | QPSK R= 1/12 | QPSK R= 1/8 |
| 1010 | X | X | X | X | X | X | X | QPSK R= 1/12 |
| 1011 | X | X | X | X | X | X | X | X |
| 1100 | X | X | X | X | X | X | X | X |
| 1101 | X | X | X | X | X | X | X | X |
| 1110 | X | X | X | X | X | X | X | X |
| 1111 | X | X | X | X | X | X | X | X |

**Table A.4 UL Modulation and coding for Nep/Nsch encoding (Part 2 of 2)**

| Nsch \ Nep | 1920<br>1000 | 2880<br>1001 | 3840<br>1010 | 4800<br>1011 | 9600<br>1100 | 14400<br>1101 | 19200<br>1110 | 24000<br>1111 |
|---|---|---|---|---|---|---|---|---|
| 0000 | 16QAM R= 5/6 | 16QAM R= 3/4 | 16QAM R= 10/9 | 16QAM R= 5/6 | 16QAM R= 5/6 | 16QAM R= 5/6 | 16QAM R= 5/6 | 16QAM R= 5/6 |
| 0001 | 16QAM R= 10/13 | 16QAM R= 5/8 | 16QAM R= 1/1 | 16QAM R= 25/34 | 16QAM R= 25/34 | 16QAM R= 25/34 | 16QAM R= 25/34 | 16QAM R= 25/34 |
| 0010 | 16QAM R= 2/3 | 16QAM R= 1/2 | 16QAM R= 5/6 | 16QAM R= 25/38 | 16QAM R= 25/38 | 16QAM R= 25/38 | 16QAM R= 25/38 | 16QAM R= 25/38 |
| 0011 | 16QAM R= 1/2 | 16QAM R= 3/8 | 16QAM R= 10/13 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 1/2 | 16QAM R= 1/2 |
| 0100 | 16QAM R= 5/13 | QPSK R= 2/3 | 16QAM R= 2/3 | 16QAM R= 25/66 | 16QAM R= 25/66 | 16QAM R= 25/66 | 16QAM R= 25/66 | 16QAM R= 25/66 |
| 0101 | QPSK R= 2/3 | QPSK R= 1/2 | 16QAM R= 1/2 | QPSK R= 25/38 | QPSK R= 25/38 | QPSK R= 25/38 | QPSK R= 25/38 | QPSK R= 25/38 |
| 0110 | QPSK R= 1/2 | QPSK R= 1/3 | 16QAM R= 5/13 | QPSK R= 1/2 | QPSK R= 1/2 | QPSK R= 1/2 | QPSK R= 1/2 | QPSK R= 1/2 |
| 0111 | QPSK R= 1/3 | QPSK R= 1/4 | QPSK R= 2/3 | QPSK R= 1/3 | QPSK R= 1/3 | QPSK R= 1/3 | QPSK R= 1/3 | QPSK R= 1/3 |
| 1000 | QPSK R= 1/4 | QPSK R= 1/6 | QPSK R= 1/2 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/4 | QPSK R= 1/4 |
| 1001 | QPSK R= 1/6 | QPSK R= 1/8 | QPSK R= 1/3 | X | X | X | X | X |
| 1010 | QPSK R= 1/8 | X | QPSK R= 1/4 | X | X | X | X | X |
| 1011 | QPSK R= 1/12 | X | QPSK R= 1/6 | X | X | X | X | X |
| 1100 | X | X | X | X | X | X | X | X |
| 1101 | X | X | X | X | X | X | X | X |
| 1110 | X | X | X | X | X | X | X | X |
| 1111 | X | X | X | X | X | X | X | X |

**Table A.5 UL Nsch values for Nep/Nsch encoding**

| Nsch \ Nep | 48<br>0000 | 96<br>0001 | 144<br>0010 | 192<br>0011 | 288<br>0100 | 384<br>0101 | 480<br>0110 | 960<br>0111 | 1920<br>1000 | 2880<br>1000 | 3840<br>1001 | 4800<br>1010 | 9600<br>1011 | 14400<br>1100 | 19200<br>1101 | 24000<br>1110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0000 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 6 | 12 | 20 | 18 | 30 | 60 | 90 | 120 | 150 |
| 0001 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 7 | 13 | 24 | 20 | 34 | 68 | 102 | 136 | 170 |
| 0010 | 3 | 3 | 3 | 4 | 4 | 5 | 5 | 8 | 15 | 30 | 24 | 38 | 76 | 114 | 152 | 190 |
| 0011 | 4 | 4 | 5 | 6 | 5 | 6 | 6 | 10 | 20 | 40 | 26 | 50 | 100 | 150 | 200 | 250 |
| 0100 | 6 | 6 | 6 | 8 | 6 | 8 | 8 | 15 | 26 | 45 | 30 | 66 | 132 | 198 | 264 | 330 |
| 0101 | X | 8 | 9 | 12 | 9 | 12 | 10 | 20 | 30 | 60 | 40 | 76 | 152 | 228 | 304 | 380 |
| 0110 | X | 12 | 12 | 16 | 12 | 16 | 15 | 30 | 40 | 90 | 52 | 100 | 200 | 300 | 400 | 500 |
| 0111 | X | X | 18 | 24 | 18 | 24 | 30 | 40 | 60 | 120 | 60 | 150 | 300 | 450 | 600 | 750 |
| 1000 | X | X | X | X | 24 | 32 | 40 | 60 | 80 | 180 | 80 | 200 | 400 | 600 | 800 | 1000 |
| 1001 | X | X | X | X | 36 | 48 | 60 | 80 | 120 | 240 | 120 | X | X | X | X | X |
| 1010 | X | X | X | X | X | X | X | 120 | 160 | X | 160 | X | X | X | X | X |
| 1011 | X | X | X | X | X | X | X | X | 240 | X | 240 | X | X | X | X | X |
| 1100 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 1101 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 1110 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 1111 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |