Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Normal MAP Extension for H-ARQ**
Date Submitted	**2005-01-25**

Source(s)	Yigal Eliaspur, Yuval Lomnitz, Zivan Ori **Intel Corp**.	yigal.eliapsur@intel.com, yuval.lomnitz@intel.com, zivan.ori@intel.com
	Geunhwi Lim, Jiho Jang, Wonil Roh, Yong Chang, Seungju Maeng **Samsung Electronics Co. Ltd**.	geunhwi.lim@samsung.com, yongchang@samsung.com
	Ran Yaniv **Alvarion Ltd**.	ran.yaniv@alvarion.com
	Mo-Han Fong, Wen Tong **Nortel Networks**	mhfong@nortelnetworks.com
	Bin-Chul Ihm **LG Electronics, Inc.**	bcihm@lge.com
	Mary Chion, Irving Wang **ZTE San Diego Inc.**	mchion@ztesandiego.com
	Sungcheol Chang, Chulsik Yoon **ETRI**	scchang@etri.re.kr
	Kamran Etemad Greg Schumaker **Nextel Communications**	kamran.etemad@nextel.com
	John J. Humbert IV **Sprint**	jhumbe01@sprintspectrrum.com
	Radu Selea, Bogdan Franovici **Redline Communications**	radu@redlinecommunications.com
	Kamlesh Rath, Trever Pearman, Brett Schein, Erik Lindskog **Beceem Communications, Ltd**	

Re:	IEEE P802.16e/D5a

Abstract	The document contains suggestions for extending the Normal MAP for H-ARQ support. Additionally, certain MAC fixes are described for H-ARQ support.
Purpose	Adoption of proposed changes into P802.16e /D5a-2004
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

Table of Contents

1 Motivation

In 802.16e there are two sets of maps: the normal maps and optional H-ARQ maps. However none of the maps supports a complete set of features. For example, the mandatory PUSC/FUSC permutations, two dimentional allocations, boosting and AAS are supported only by the normal maps, whereas is H-ARQ, as well as the ability to define multiple downlink maps are supported only by the H-ARQ map.

The purpose of this contribution is to define a single map that supports both feature sets. For this purpose we add the most important functionalities of the H-ARQ map to the normal map. The functionalities are:
- Incremental redundancy H-ARQ for CTC
- Chase combining H-ARQ for all coding schemes.
- Multiple map support.

H-ARQ enables to improve the performance of ARQ based links. Multiple maps enable to use maps at different burst profiles instead of one map at the most robust burst profile, and thus reduce the map overhead (see contribution C80216e-04/468).

H-ARQ also has various effects on the 802.16 MAC. These include MAC PDU reordering, sequencing and encryption implications. Section 2.2 of this document describes these problems and proposes solutions that will allow the current MAC to operate with H-ARQ.

2 Overview of the proposed solution

2.1 Support H-ARQ and multiple maps in the normal map

The support for H-ARQ is enabled by adding the following IEs to the normal map:
- H-ARQ DL/UL IE to make the burst allocations and supply H-ARQ control information
- ACKCH allocation IE to allocate uplink ACK channels
- H-ARQ ACK IE to indicate the downlink ACK/NACKs

The support for multiple maps is enabled by a modification of the H-ARQ map pointer IE. Following the modification the IE can point to a map including normal DL/UL MAP_IEs. The sub-map has a similar structure to the DL/UL maps, but without the fixed overhead.
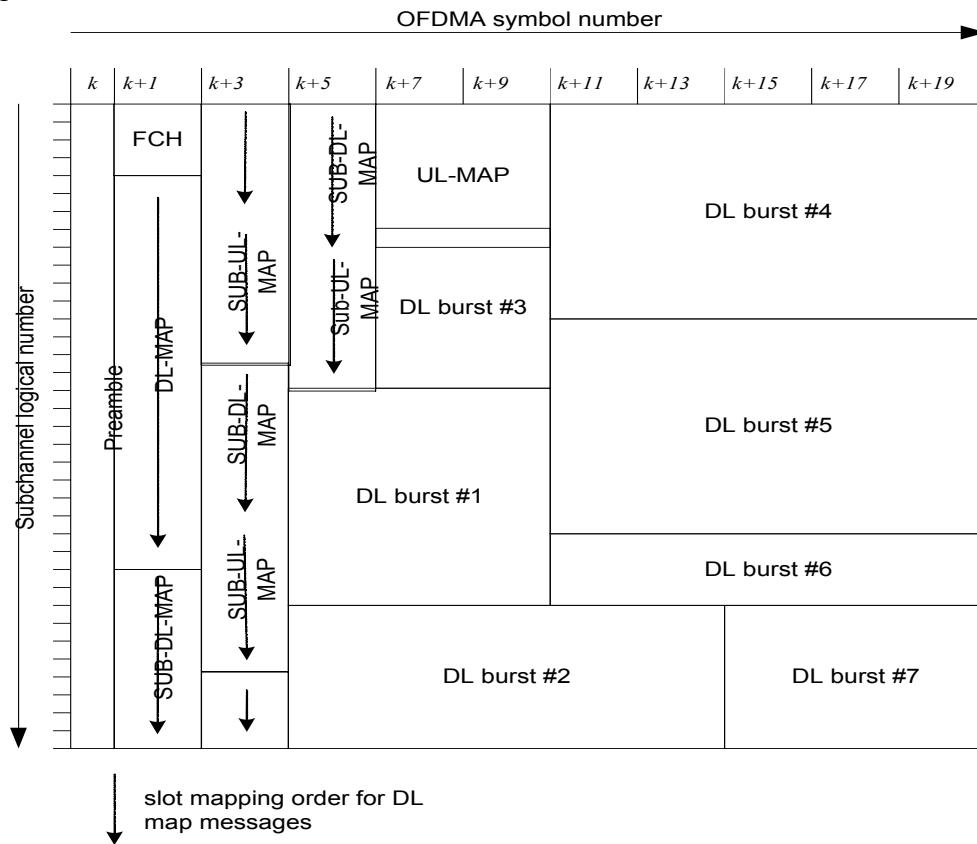
2.2 Optimizing IE overhead of H-ARQ burst allocation

Two dimensional (2D) allocations that exist in the normal map enable to reduce the interference between cells by correctly adopting the number of used subchannels and the boosting level of each, however the overhead of allocating 2D allocations is large. H-ARQ requires to allocate a PHY burst for each subscriber, rather than concatenate the PDUs of several subscribers to reduce overhead.

Therefore the proposed solution is a two level allocation: to first define a 2D region, and then partition this region in a 1D frequency-first manner into bursts. All the bursts in the 2D allocation share the same burst profile and boosting parameters (similar to PDU concatenation in non-HARQ burst).

2.3 MAC implications of H-ARQ operation

H-ARQ is commonly used in cellular networks to provide additional protection for data connections under the highly dynamic link situations that a mobile platform introduces. As such, it is deemed as an important feature in 802.16. However, initial 802.16 MAC definitions have not taken H-ARQ into consideration and a wide set of problems exists in supporting H-ARQ with the current MAC definitions.
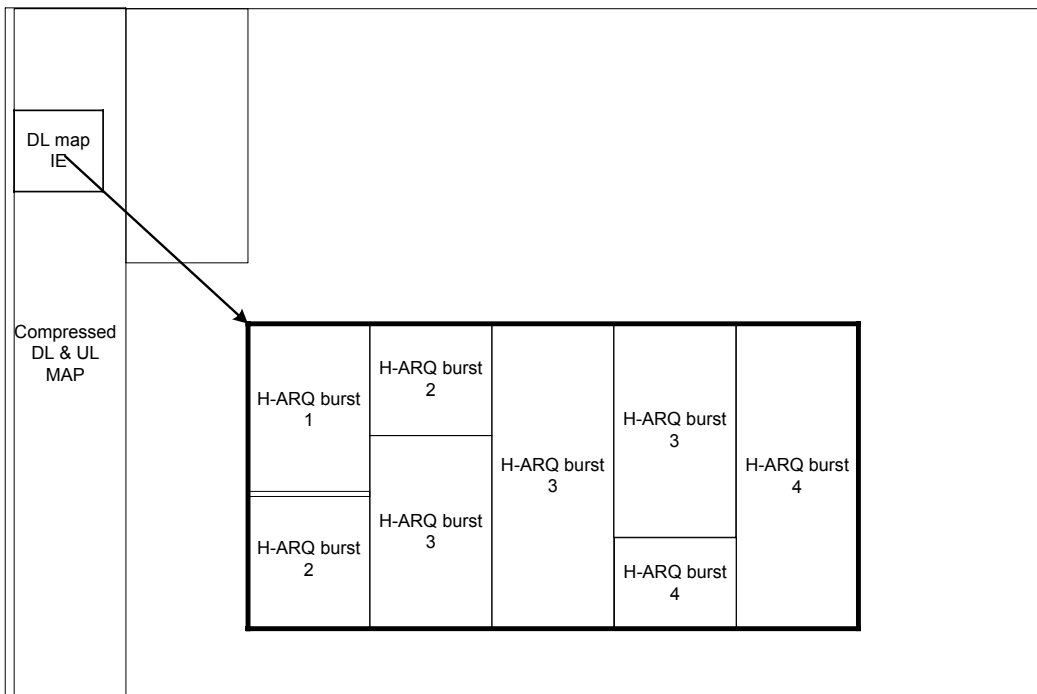When using H-ARQ, the MAC receives PDUs from the PHY without any guarantee for ordering. This is due to the fact that the PHY is itself responsible for retransmissions of PDUs and thus can disrupt their order.

To deal with this, several fixes are needed:
        1) Since Encryption is normally defined in 802.16 for ordered PDUs, the Replay Attack detection will be triggered when de-encrypting PDUs out of order. The proposed solution is to define a Replay Attack window (See below).
        2) It is required to use some sort of sequencing over H-ARQ connections to be able to re-order PDUs at the receiving MAC. The proposed solution is to use standard 802.16 ARQ (MAC-ARQ) mechanisms for sequencing.

3) It is required to use some sort of time-keeping and synchronization between transmitter and receiver to be able to track the state of lost PDUs which the H-ARQ layer has not been able to recover. The proposed solution is to use standard 802.16 ARQ mechanisms (BLOCK_LIFETIME, SYNC_LOSS_TIMEOUT, DISCARD messages) for this.

The recommendation is thus to use standard 802.16 ARQ (MAC-ARQ) over H-ARQ connections. This mode has some special requirements and limitations which are listed below.

Capitalizing on this approach, this document proposes an additional improvement to the ARQ mechanism in the form of Fast-ARQ. Fast-ARQ can be used instead of H-ARQ but uses the H-ARQ defined ACK channel for drastically improving on regular MAC-ARQ performance and cost.

3 Remedy 1: Text Changes for H-ARQ and telescopic maps

3.1 H-ARQ Support in Normal MAP

3.1.1 H-ARQ DL MAP Extension

[Add a new section 8.4.5.3.20 as follows]

8.4.5.3.20 H-ARQ DL MAP IE
The following modes of H-ARQ are supported by the H-ARQ DL MAP IE:
1. Chase combining H-ARQ for all FEC types (H-ARQ Chase). In this mode the burst profile is indicated by a DIUC.
2. Incremental redundancy H-ARQ with CTC (H-ARQ IR). In this mode the burst profile is indicated by the parameters Nep, Nsch.
3. Incremental redundancy H-ARQ for convolutional code (H-ARQ CC-IR).
The IE may also be used to indicate a non-HARQ transmission.

The H-ARQ DL MAP IE defines one or more two dimensional data regions (a number of symbols by a number of subchannels). These allocations are further partitioned into bursts, termed sub-bursts, by allocating a specified number of slots to each burst. . All sub-bursts of a data region shall only support one of the H-ARQ modes. The number of slots is indicated by duration or Nsch fields. The slots are allocated in a frequency-first order, starting from the slot with the smallest symbol number and smallest subchannel, and continuing to slots with increasing subchannel number. When the edge of the allocation is reached, the symbol number is increased by a slot duration, as depicted in the following diagram. Each sub-burst is separately encoded.

Downlink zone
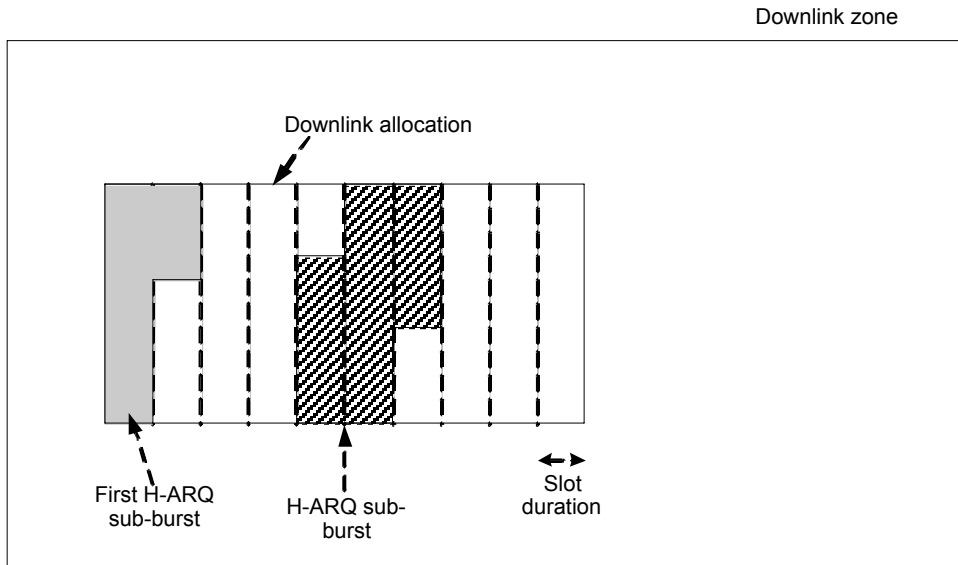
Figure XX – H-ARQ downlink allocation

Table 306a H-ARQ DL MAP IE Format

Syntax	Size	Note
H-ARQ DL MAP IE {		
Extended DIUC 2	4	Set to 0x1
Length	8	Length of the IE in bytes
RCID_Type	2 bits	00 = Normal CID 01 = RCID11 10 = RCID7 11 = RCID3
While (data remains) {		Number of allocations is deducted from the length field.
OFDMA Symbol offset	8 bits	Offset from the start symbol of DL sub-frame
Subchannel offset	6 bits	
Boosting	3 bits	000: normal (not boosted); 001: +6dB; 010: -6dB; 011: +9dB; 100: +3dB; 101: -3dB; 110: -9dB; 111: -12dB;
No. OFDMA Symbols	7 bits	
No. Subchannels	6 bits	
Mode	4 bits	Indicates the mode of this IE 0 = Chase H-ARQ 1 = Inremental redundancy H-ARQ for CTC 2 = Inremental redundancy H-ARQ for convolutional code 3 – 15 *Reserved*
If (Mode== 0) {		
DL H-ARQ Chase Sub-Burst IE ()	Variable	
} else if (Mode== 1) {		

DL H-ARQ IR CTC Sub-Burst IE ()	Variable	
} else if (Mode== 2) {		
DL H-ARQ IR CC Sub-Burst IE ()	Variable	
}		
Padding	Variable	Padding to byte; shall be set to 0
}		

Table 306c DL H-ARQ Chase Sub-Burst IE Format

DL H-ARQ Chase Sub-Burst IE {		
DIUC	4 bits	
Repetition Coding Indication	2 bits	0b00 – No repetition coding 0b01 – Repetition coding of 2 used 0b10 – Repetition coding of 4 used 0b11 – Repetition coding of 6 used
N sub burst[IS2]	5 bits	Number of sub-bursts in 2D region
For (j=0; j< N sub burst; j++){		
RCID_IE()	Variable	
Duration	10 bits	Duration in slots
ACID	4 bits	
AI_SN	1 bit	
CQICH Control Indicator	1 bits	
If(CQICH Control Indicator == 1){		
Allocation Index	6 bits	Index to the channel in a frame the CQI report should be transmitted by the SS
Period (p)	3 bits	A CQI feedback is transmitted on the CQI channels indexed by the (CQI Channel Index) by the SS in every 2^p frames.
Frame offset	3 bits	The MSS starts reporting at the frame of which the number has the same 3 LSB as the specified frame offset. If the current frame is specified, the MSS should start reporting in 8 frames.
Duration (d)	4 bits	A CQI feedback is transmitted on the CQI channels indexed by the (CQI Channel Index) by the SS for $2^{(d-1)}$ frames. If d is 0b0000, the CQICH is de-allocated. If d is 0b1111, the MSS should report until the BS command for the MSS to stop
}		
Dedicated DL Control Indicator	1 bit	
If (Dedicated DL Control Indicator ==1) {		
Dedicated DL Control IE ()	Variable	
}		
}		
}		

Table 306d DL H-ARQ IR CTC Sub-Burst IE Format

DL H-ARQ IR Sub-Burst IE {		
N sub burst	5 bits	
For (j=0; j< N sub burst; j++){		
RCID_IE()	Variable	
Nep	4 bits	
Nsch	4 bits	
SPID	2 bits	
ACID	4 bits	
AI_SN	1 bit	
ACK disable	1 bit	When this bit is "1" no ACK channel is allocated and the SS shall not reply with an ACK.
CQICH Control Indicator	1 bits	
If(CQICH Control Indicator == 1){		
Allocation Index	6 bits	Index to the channel in a frame the CQI report should be transmitted by the SS
Period (p)	3 bits	A CQI feedback is transmitted on the CQI channels indexed by the (CQI Channel Index) by the SS in every 2^p frames.
Frame offset	3 bits	The MSS starts reporting at the frame of which the number has the same 3 LSB as the specified frame offset. If the current frame is specified, the MSS should start reporting in 8 frames.
Duration (d)	4 bits	A CQI feedback is transmitted on the CQI channels indexed by the (CQI Channel Index) by the SS for $2^{(d-1)}$ frames. If d is 0b0000, the CQICH is de-allocated. If d is 0b1111, the MSS should report until the BS command for the MSS to stop
}		
Dedicated DL Control Indicator	1 bit	
If (Dedicated DL Control Indicator ==1) {		
Dedicated DL Control IE ()	Variable	
}		
}		
}		

Table 306e DL H-ARQ IR CC Sub-Burst IE Format

DL H-ARQ IR CC Sub-Burst IE {		
DIUC	4 bits	
Repetition Coding Indication	2 bits	0b00 – No repetition coding 0b01 – Repetition coding of 2 used 0b10 – Repetition coding of 4 used 0b11 – Repetition coding of 6 used
N sub burst	5 bits	
For (j=0; j< N sub burst; j++){		
RCID_IE()	Variable	
Duration	10 bits	Duration in slots
ACID	4 bits	

AI_SN	1 bit	
SPID	2 bits	
CQICH Control Indicator	1 bits	
If(CQICH Control Indicator == 1){		
Allocation Index	6 bits	Index to the channel in a frame the CQI report should be transmitted by the SS
Period (p)	3 bits	A CQI feedback is transmitted on the CQI channels indexed by the (CQI Channel Index) by the SS in every 2^p frames.
Frame offset	3 bits	The MSS starts reporting at the frame of which the number has the same 3 LSB as the specified frame offset. If the current frame is specified, the MSS should start reporting in 8 frames.
Duration (d)	4 bits	A CQI feedback is transmitted on the CQI channels indexed by the (CQI Channel Index) by the SS for $2^{(d-1)}$ frames. If d is 0b0000, the CQICH is de-allocated. If d is 0b1111, the MSS should report until the BS command for the MSS to stop
}		
Dedicated DL Control Indicator	1 bit	
If (Dedicated DL Control Indicator ==1) {		
Dedicated DL Control IE ()	Variable	
}		
}		
}		

[End of "Add a new section 8.4.5.3.20 as follows"]

Dedicated DL Control IE contains additional control information for each sub-burst in the tables above.. Because each sub-burst may have its own control information format dependent on the MSS capability, the length of the Dedicated DL Control IE is variable.

[Add a new section 8.4.5.3.20.1 as follows]

8.4.5.3.20.1 Dedicated DL Control IE

Table 306e Dedicated DL Control IE Format

Syntax	Size	Note
Dedicated DL Control IE() {		
Length	4 bits	Length of following control information in Nibble.
Control Header	4 bits	Bit #0: SDMA Control Info Bit #1-3: Reserved
If(SDMA Control Info Bit == 1){		
Num SDMA layers	2 bit	Number of SDMA layers minus 1
}		
Padding bits	variable	
}		

Num SDMA layers
This field shall appear for the first sub burst in each layer of an SDMA allocation, and indicates activation of SDMA. Each SDMA layer has a different pilot pattern (layer *n* uses pilot pattern *n*). The appearance of another burst with Num SDMA layers indicates a new SDMA layer. The number of SDMA layer is incremented and the symbol and subchannel offsets are reset to the beginning of the allocation. The Num SDMA layers appearing in first burst of each layer must be equal.

8.4.5.3.20.2 Reduced CID IE
[Copy the contents of section 6.3.2.3.43.3 (Reduced CID), renumber the tables and figures accordingly]

[End of "Add a new section 8.4.5.3.20.1 as follows"]

3.1.2 H-ARQ UL MAP Extension

[Add a new section 8.4.5.4.23 as follows]

8.4.5.4.23 H-ARQ UL MAP IE
The following modes of H-ARQ are supported by the H-ARQ UL MAP IE:
1. Chase combining H-ARQ for all FEC types (H-ARQ Chase). In this mode the burst profile is indicated by a DIUC.
2. Incremental redundancy H-ARQ for CTC (H-ARQ IR). In this mode the burst profile is indicated by the parameters Nep, Nsch.
3. Incremental redundancy H-ARQ for convolutional code (H-ARQ CC-IR).

The IE may also be used to indicate also a non-HARQ transmission.

The H-ARQ UL MAP IE defines one or more bursts. Each burst is separately encoded.

When Allocation Start Indication is '1', the H-ARQ UL MAP IE indicates the starting symbol and subchannel of the allocation. The starting symbol and subchannel shall indicate a valid slot location in the uplink subframe. The slots are allocated in a time-first order (as specified in 8.4.5.4). The starting symbol and subchannel are relevant only in the context of the H-ARQ UL MAP IE in which they appear. Allocations made without an Allocation Start Indication (such as H-ARQ UL MAP IE with Allocation Start Indication '0', or regular UL-MAP_IE), shall based on the global slot index, each of these allocations shall follow the last allocation which didn't contain Allocation Start indication.

Table 306l H-ARQ UL MAP IE[IS3]

Syntax	Size	Note
H-ARQ UL MAP IE() {		
Extended UIUC	4	Set to 0x1
Length	8	Indicates the length of the IE in bytes
RCID_Type	2 bits	00 = Normal CID 01 = RCID11 10 = RCID7 11 = RCID3

while (data remains) {		
Allocation Start Indication	1 bit	0: No allocation start information 1: Allocation start information follows
If (Allocation Start Indication == 1) {		
OFDMA Symbol offset	8 bits	This value indicates start Symbol offset of subsequent sub-bursts in this H-ARQ UL MAP IE
Subchannel offset	7 bits	This value indicates start Subchannel offset of subsequent sub-bursts in this H-ARQ UL MAP IE
}		
Mode	3 bits	Indicates the mode of this IE 000 = Chase H-ARQ 001 = Inremental redundancy H-ARQ for CTC 010 = Inremental redundancy H-ARQ for convolutional code 011 – 111 *Reserved*
N sub Burst	4 bits	This field indicates the number of bursts in this UL MAP IE
For (i =0 ;i < N Sub-burst; i++){		
Dedicated UL Control Indicator	1 bit	
If (Dedicated UL Control Indicator ==1) {		
Dedicated UL Control IE ()	variable	
}		
If (Mode == 000) {		
UL HARQ Chase Sub-Burst IE ()		
} else if (Mode== 001) {		
UL HARQ IR CTC Sub-Burst IE ()		
} else if (Mode== 010) {		
UL HARQ IR CC Sub-Burst IE ()		
}		
}		
}		
Padding	Variable	Padding to byte; shall be set to 0
}		

Table 306n UL HARQ Chase Sub-Burst IE Format

HARQ Chase UL Sub-Burst IE {		
RCID IE()	Variable	
Dedicated UL Control Indicator	1 bit	
If (Dedicated UL Control Indicator ==1) {		
Dedicated UL Control IE ()	variable	

}				
UIUC	4 bits			
Repetition Coding Indication	2 bits		0b00 – No repetition coding 0b01 – Repetition coding of 2 used 0b10 – Repetition coding of 4 used 0b11 – Repetition coding of 6 used	
Duration	10 bits			
ACID	4 bits			
AI_SN	1 bit			
}				

Table 306o UL HARQ IR CTC Sub-Burst IE Format

HARQ IR UL Sub-Burst IE {				
RCID IE()	Variable			
Dedicated UL Control Indicator	1 bit			
If (Dedicated UL Control Indicator ==1) {				
Dedicated UL Control IE ()	variable			
}				
Nep	4 bits			
Nsch	4 bits			
SPID	2 bits			
ACID	4 bits			
AI_SN	1 bit			
}				

Table 306o UL HARQ IR CC Sub-Burst IE Format

HARQ Chase UL Sub-Burst IE {				
RCID IE()	Variable			
Dedicated UL Control Indicator	1 bit			
If (Dedicated UL Control Indicator ==1) {				
Dedicated UL Control IE ()	variable			
}				
UIUC	4 bits			
Repetition Coding Indication	2 bits		0b00 – No repetition coding 0b01 – Repetition coding of 2 used 0b10 – Repetition coding of 4 used 0b11 – Repetition coding of 6 used	
Duration	10 bits			
SPID	2 bits			
ACID	4 bits			
AI_SN	1 bit			
}				

[End of "Add a new section 8.4.5.4.23 as follows"]

Dedicated UL Control IE contains additional control information for each sub bursts.

[Add a new section 8.4.5.4.23.1 as follows]

8.4.5.4.23.1 Dedicated UL Control IE

Table 306p Dedicated UL Control IE Format

Syntax	Size	Note
Dedicated UL Control IE() {		
Length	4 bits	Length of following control information in Nibble.
Control Information	Variable	
}		

Length
This field indicates the following control information.
Control Information
Variable size control information.

[End of "Add a new section 8.4.5.4.23.1 as follows"]

3.1.3 UL H-ARQ ACK channel definition

3.1.3.1 H-ARQ ACK Region Allocation IE

[Add a new section 8.4.5.4.24 as follows]

8.4.5.4.24 HARQ ACK Region Allocation IE

This IE is used by BS to define a UL region to include one or more ACK channel(s) for H-ARQ supporting MSS. The IE format is shown in Table 306w. The slots in the ACKCH region are divided into two half-slots. The first half-slot is composed of tiles 0,2,4; the second half-slot is composed of tiles 1,3,5. In the ACKCH Region, ACK channel 2n is the first half of slot n; ACK channel (2n+1) is the second half of slot n. The slot number n is increased first along the time axis until the end of the ACKCH region, and then along the subchannel axis.

The H-ARQ enabled MSS that receives H-ARQ DL burst at frame "i" should transmit the ACK signal through the ACK channel in the ACKCH region at frame (i+j). The frame offset 'j' is defined by the "H-ARQ ACK Delay for DL Burst" field in the UCD message.

The half-subchannel offset in the ACKCH Region is determined by the order of H-ARQ enabled DL burst in the DL MAP. For example, when a MSS receives a H-ARQ enabled burst at frame i, and the burst is the n-th H-ARQ enabled burst amoung the H-ARQ related IEs, the MSS should transmit H-ARQ ACK at n-th half-subchannel in ACKCH Region that is allocated by the BS at frame (i+j).

Each SS should specify support of either "UL ACK" channel, or "Enhanced UL ACK" (see 11.8.3.7.9). A subscriber supporting Enhanced UL ACK shall always transmit Enhanced UL ACK as defined in 8.4.5.4.17.

When the "ACK disable" bit is set (in DL H-ARQ IR CTC Sub-Burst IE Format), no ACK channel is allocated for the sub-burst.

Table 306w. HARQ ACKCH_region MAP IE format.

Syntax	Size (bits)	Note
HARQ ACKCH_Region_IE() {		
Extended UIUC	4	
Length	4	0x3
OFDMA Symbol offset	8	
Subchannel offset	7	
No. OFDMA symbols	5	
No. subchannels	4	
}		

OFDMA Symbol offset
Subchannel offset
No. OFDMA Symbols
No. Subchannels
        Specify the start symbol offset, the start subchannel offset, the number of allocated symbols and the number of subchannels for the H-ARQ acknowledgement region respectively.

3.1.4 DL H-ARQ ACK IE Format

[Add a new section 8.4.5.3.21 as follows]

8.4.5.3.21 DL H-ARQ ACK IE

This IE is used by BS to send H-ARQ acknowledgment to UL H-ARQ enabled traffic. The bit position in the bitmap is determined by the order of the H-ARQ enabled UL bursts in the UL-MAP. The frame offset "j" between the UL burst and the H-ARQ ACK-BITMAP is specified by "H-ARQ_ACK_Delay_for UL Burst" field in the DCD message. For example, when a MSS transmits a H-ARQ enabled burst at frame i and the burst is the n-th H-ARQ enabled burst in the MAP, the MSS should receive H-ARQ ACK at n-th bit of the BITMAP which is sent by the BS at frame (i+j).
The existence of this IE shall be optional.

If the H-ARQ ACK BITMAP is omitted, the H-ARQ MSS should retain the transmitted H-ARQ burst and retransmit it when the BS request retransmission with AI_SN. This IE may only be exist in the DL-MAP message.

Table 306x. H-ARQ_ACK IE format.

Syntax	Size (bits)	Note
Generic H-ARQ_ACK_IE() {		
Extended DIUC	4	
Length	4	
Bitmap	Variable	
}		

BITMAP
Includes H-ARQ ACK information for H-ARQ enabled UL bursts. The size of BITMAP should be equal or larger than the number of H-ARQ enabled UL-bursts. Each byte carriers 8 ACK indications ordered from LSB (smallest index ACK channel) to MSB.

3.1.5 Overview of Chase H-ARQ and definition of CRC

[Add new section 8.4.15 as follows]
8.4.15 Optional H-ARQ support
The following optional modes exist for H-ARQ
   • Incremental redundancy for CTC – specified in 6.3.17 and in 8.4.9.2.3.5.
   • Incremental redundancy for CC (convolutional code) – specified in 8.4.15.2 and 8.4.9.2.1.2
   • Chase combining for all coding schemes specified in 8.4.15.1
These modes can be supposed by the normal map and the H-ARQ map.

8.4.15.1 Optional Chase H-ARQ Support
The optional Chase H-ARQ scheme enables BS and SS to enhance performance of ARQ based connection by means of chase combining scheme. This scheme is supported for all coding schemes. Each burst is appended with a CRC which is checked by the receiver. An uplink and a downlink ACK channels are defined (see 8.4.5.4.13 and 8.4.5.4.17). The receiver replies with an ACK in the corresponding ACK channel if the decoding succeeded and with a NACK if the decoding failed.

If the burst was not ACK-ed, the transmitter may transmit a burst with exactly the same data contents again. The receiver may combine the newly received burst with the formerly received burst(s) to enhance decoding performance.

8.4.15.1.1 **H-ARQ Retransmission process**
The process of retransmissions is controlled by the BS using the ACID (ARQ Channel ID) and AI_SN fields in the DL and UL maps. Each ARQ channel (indicated by specific ACID of 0-15) is managed separately.

When the AI_SN field in the H-ARQ channel remains the same between two H-ARQ burst allocations it indicates retransmission. In this case in the transmitter is required to retransmit the same data that was

transmitted using the same ACID and AI_SN. The burst profile of the retransmission must be the same as in the first transmission, however the level of boosting and repetition may be changed.

When the AI_SN field in the H-ARQ channel is changed, it indicates transmission of new data. In this case the data stored in the transmitter and receiver for this ACID and the previously used AI_SN may be discarded.

8.4.15.1.2 CRC

Bursts transmitted using Chase H-ARQ shall include CRC of 16 bits. The CRC is appended to MAC data after padding (before partitioning to FEC blocks and encoding as defined in 8.4.9). Padding is done so that the total length after CRC concatenation matches the size of the burst indicated by the map.

The CRC shall be CRC16-CCITT, as defined in ITU-T Recommendation X.25, and it is calculated over all the bits in the burst.

This CRC shall be used for error detection and for ACK/NACK transmission.

8.4.15.1.3 Concurrent transmission of UL H-ARQ bursts

The BS may allocate more than one UL H-ARQ burst for a SS (see 8.4.4.5). The maximal number of UL bursts supported by an H-ARQ enabled SS is indicated by the capability field in 11.8.3.7.12 and includes both H-ARQ and non-HARQ bursts.

8.4.15.1.4 Encoding

When using Chase-HARQ with H-ARQ DL/UL IE in the normal maps the encoding scheme is indicated by DIUC/UIUC code and the encoding process shall be the same as in non-HARQ transmission with the same DIUC/UIUC.

8.4.15.2 Optional IR H-ARQ for CC (convolutional code)

This mode of operation is similar to Chase H-ARQ (see 8.4.15.1). The specifications in 8.4.15.1 apply to this mode, except for the following differences:

1. An SPID field is supplied by the H-ARQ DL/UL MAP IE.
2. The value of SPID may be arbitrarily changed by the BS between retransmissions.
3. The encoding process is based on the non-HARQ coding scheme, except for the changes indicated in 8.4.9.2.1.2.

3.1.5.1 Distinction between IR and Chase H-ARQ

[Change the title and contents of 8.4.9.2.3.5 as following]
8.4.9.2.3.5 Optional IR H-ARQ (Incremental redundancy H-ARQ) Support

3.1.5.2 Changes to distinguish existing ChaseChase-HARQ scheme from the new one

[Add the following words in the title of 8.4.9.2.1.2 (defining IR scheme for convolutional code)]
8.4.9.2.1.2 Incremental Redundancy H-ARQ support (optional)

[Make the following replacements in first column of table 316a]

| ~~1st retransmission~~ SPID=0 |
| ~~2nd retransmission~~ SPID=1 |

| 3rd ~~retransmission~~ SPID=2 |
| 4th ~~retransmission~~ SPID=3 |

[Add the following words in the title and contents of of 8.4.9.6. This section defines some encodings for Chase combining -hARQ that are needed only for working with H-ARQ map]

8.4.9.6 Chase Combining HARQ using H-ARQ map (optional)

Chase Combining HARQ may be enabled for any of the existing FEC modes. When Chase combining H-ARQ is indicated by the H-ARQ map, 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 333.

3.2 Sub-MAP Message

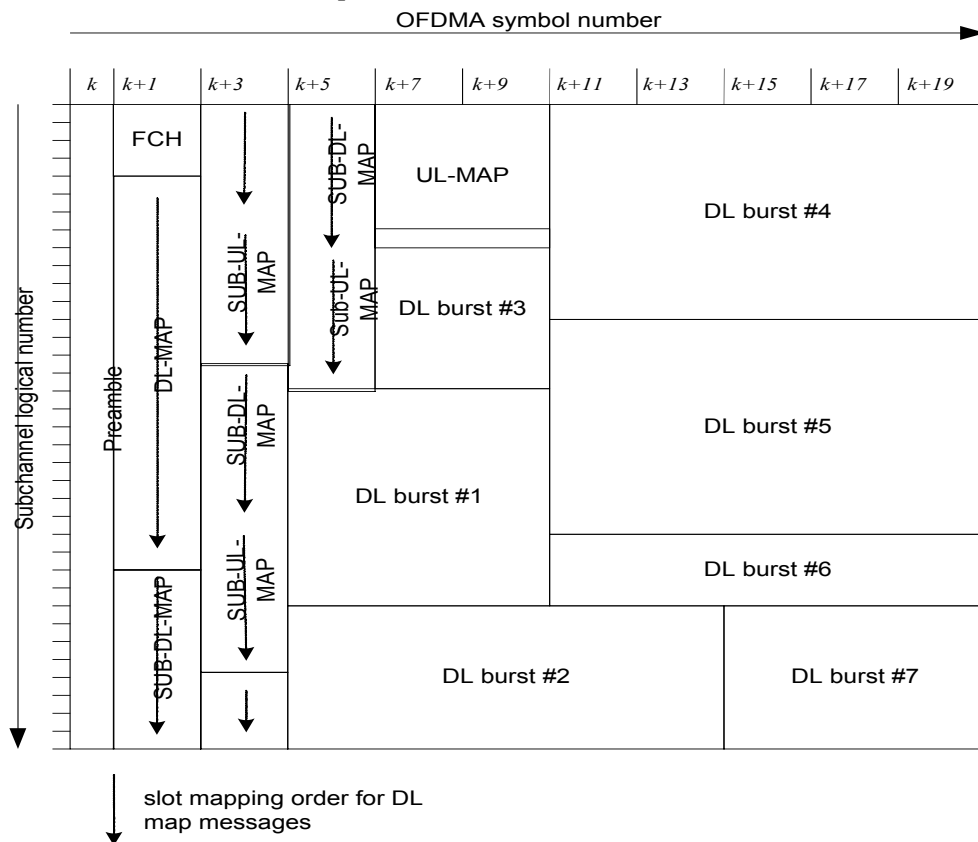## 3.2.1 Sub-MAP Message

[Add new section 6.3.2.3.59]

Figure 23a Sub-MAP Burst

6.3.2.3.59 Sub downlink/uplink map (SUB-DL-UL-MAP) message
This message shall only apply to OFDMA PHY.

The SUB-DL-UL-MAP message shall appear in a compressed form, in which the generic MAC header is

omitted. This is indicated by setting the two most significant bits of the first data byte in the message's PHY burst to 1 (an invalid combination for a generic MAC header).

The SUB-DL-UL-MAP format is presented in Table 107f.

Table 107f—SUB-DL-UL-MAP message format

Syntax	Size	Notes
SUB-DL-UL-MAP () {		
Compressed map indicator	3 bits	Set to binary 111
Map message length	10 bits	
Reserved	2 bits	Shall be set to 0
H-ARQ ACK offset indicator	1 bit	
If (H-ARQ ACK offset indicator == 1){		
DL H-ARQ ACK offset	8 bits	
UL H-ARQ ACK offset	8 bits	
}		
DL IE Count	8 bits	
For (i=1; i <= DL IE Count; i++)		
DL-MAP_IE()	Variable	
}		
UL starting slot offset	11 bits	
Reserved	2 bits	Shall be set to 0
while (map data remains){		
UL-MAP_IE()	Variable	
}		
If !(byte boundary) {		
Padding Nibble	Variable	Padding to reach byte boundary.
}		
}		

Map message length
The length of the submap message in bytes including the compressed map indicator and the CRC.

H-ARQ ACK offset indicator
This field toggles the inclusion of H-ARQ offsets. If this field is '0', then the ACK offsets shall be follow the last allocation made by previous maps. An SS which failed to decode any of the previous maps shall disregard all H-ARQ allocations made by this map, if H-ARQ ACK offset indicator is '0'.

UL H-ARQ ACK offset
Indicates the ACK channel in the ACKCH Region that corresponds to the first H-ARQ enabled uplink burst specified in this map message.

DL H-ARQ ACK offset
Indicates the ACK bit index in the DL H-ARQ ACK IE that corresponds to the first H-ARQ enabled downlink burst specified in this map message.

DL IE Count
The number of DL-MAP_IE-s.

UL starting slot offset
Indicates the initial slot offset of the UL bursts defined in this map, in the zone starting from the first uplink symbol (except for H-ARQ UL MAP IE with Allocation Start Indication of '1').

A CCITT CRC 16 value is appended to the end of the burst. The CRC is computed across all bytes of the SUB-DL-UL-MAP message,.

The order of DL-MAP_IEs in the SUB-DL-MAP message shall conform to the order defined for the DL-MAP message in section 6.3.2.3.2.

The logical order in which MAC PDUs are mapped to the PHY layer bursts in the downlink is defined as the order of increasing start time of all PHY bursts in the frame regardless of the MAP message in which they are described. If two or more PHY bursts have the same start time, the logical order is determined according to the order of appearance in the concatenation of DL-MAP and all SUB-DL-UL-MAP messages.

The logical order in which MAC PDUs are mapped to the PHY layer bursts in the uplink is defined as the order of UL-MAP_IEs in the SUB-DL-UL-MAP message.

The SUB-DL-UL-MAP message can be located in the first zone of the frame or in any of the zones within the frame. In each zone, the SUB-DL-UL-MAP messages shall be allocated consecutively using the same uni-dimensional frequency-first slot mapping order used for the DL-MAP and H-ARQ MAP bursts. For the first zone in the frame, the first burst containing a SUB-DL-UL-MAP message shall be allocated immediately following the bursts containing H-ARQ MAP messages, or following the DL-MAP if no H-ARQ MAPs exist in the frame. For all subsequent zones, the first burst containing a SUB-DL-UL-MAP message shall be allocated starting at the first subchannel of the first OFDMA symbol in the zone. DL-MAP_IEs that appear in an SUB-DL-UL-MAP message shall only describe allocations whose starting OFDMA symbol is equal to or later than the first OFDMA symbol of the zone in which the SUB-DL-UL-MAP message is located. The bursts containing the SUB-DL-UL-MAP messages shall only be described by a SUB-MAP Pointer IE. This IE (if exists) shall immediately follow a STC_Zone_IE to describe SUB-DL-UL-MAP messages that are located in that zone.

The INC_CID flag shall be reset to 0 in the beginning of each SUB-DL-UL-MAP message.

The physical modifier (PHY-MOD) shall be reset at the beginning of each SUB-DL-UL-MAP message and before the first UL-MAP_IE.

All DL and UL zone switch IEs (Extended DIUC 0x01, Extended UIUC 0x04) shall be defined in the main DL and UL MAPs. SUB-DL-UL-MAP shall comply with the main DL and UL MAP zone switch. The SUB-DL-UL-MAP shall not include the downlink zone switch IE. Instead, the zone shall be identified by the symbol number (indicated in DL-MAP_IE and other IE-s defining allocations).

The DL-MAP_IEs in the SUB-DL-UL-MAP shall be ordered in the increasing order of the transmission start time of the relevant PHY burst/allocation. The uplink allocations in the SUB-DL-UL-MAP shall be ordered in increasing order of zones

The maximum number of SUB-DL-UL-MAP messages per frame is 3.

SUB-DL-UL-MAP message shall be used only with compressed DL and appended UL MAP structure.

[Add a new section 8.4.5.4.25]

8.4.5.2.25 UL Allocation start IE

Syntax	Size	Notes
UL Allocation start IE () {		
Extended UIUC	4 bits	TBD
Length	4 bits	
OFDMA Symbol offset	8 bits	This value indicates start Symbol offset of subsequent sub-bursts in this UL Allocation start IE
Subchannel offset	7 bits	This value indicates start Subchannel offset of subsequent sub-bursts in this UL Allocation start IE
reserved	1 bit	Shall be set to 0
}		

This IE shall not be used in UL-MAP; it may be used in SUB-DL-UL-MAP.
 [Add the following to the end of section 8.4.5.4.7]

This IE should not be used within SUB-DL-UL-MAP.

[add the following to end of section 8.4.5.3.4 Transmit diversity (TD)/Zone switch IE format]
This IE should not be used within SUB-DL-UL-MAP

3.2.2 Sub-MAP Pointer IE

Use existing H-ARQ MAP Pointer to indicate the Sub-MAP burst. The MAP Version field in the H-ARQ MAP Pointer IE is set to 01 for Sub-MAP burst.
The Pointer IE shall be appear before any other burst allocating DL-MAP IE in DL-MAP Message.

Table 283 H-ARQ MAP or Sub-MAP Pointer IE Format

Syntax	size	Note
H-ARQ and Sub- MAP Pointer IE {		
Extended DIUC	4 bits	H-ARQ MAP Pointer = 0x07
Length = 2x N	4 bits	N is the number of H-ARQ MAP or Sub MAP bursts
While (data remains) {		
~~AMC~~ DIUC	4 bits	
No. Slots	8 bits	
Repetition Coding Indication	2 bits	
MAP Version	2 bits	0b00 – H-ARQ MAP v1 0b01 – Sub-MAP
CID mask included	1 bits	0 –CID mask not included 1 – CID mask included
If (CID mask included) {		
Idle users	1 bit	Bursts for Idle users included in the Sub MAP
Sleep users	1 bit	Bursts for Sleep users included in the Sub MAP

CID Mask Length	2 bits	00: 11 bits 01: 19 bits 10: 35 bits 11: 51 bits
CID mask	n bits	n = The number of bits of CID mask is determined by CID Mask Length. When the MAP message pointed by this pointer IE includes any MAP IE for an awake mode MSS, the ((Basic CID of the MSS) MOD n)-the LSB of CID mask shall be set to 1. Otherwise, it may be set to 0..
}		
}		
}		

[Modify section 10.4, p. 274, line 37-60, text in Table 343 as shown below:]

Table 343 CIDs

CID	Value	Description
Initial Ranging	0x0000	Used by SS and BS during initial ranging process.
Basic CID	0x0001 – m	The same value is assigned to both the DL and UL connection.
Primary management	m+1 – 2m	The same value is assigned to both the DL and UL connection.
Transport CIDs, Secondary Mgt CIDs	2m+1 – 0xFE9F	For the secondary management connection, the same value is assigned to both the DL and UL connection.
Multicast CIDs	0xFEA0 – 0xFEFE	For the downlink multicast service, the same value is assigned to all MSSs on the same channel that participate in this connection.
AAS initial ranging CID	0xFEFF	A BS supporting AAS shall use this CID when allocating a Initial Ranging period for AAS devices.
Multicast polling CIDs	0xFF00 – 0xFFFDA	A BS may be included in one or more multicast polling groups for the purposes of obtaining bandwidth via polling. These connections have no associated service flow.
Normal mode multicast CID	0xFFFB	Used for transmission of DL broadcast information to normal mode MSS.
Sleep mode multicast CID	0xFFFC	Used for transmission of DL broadcast information to Sleep mode MSS
Idle mode multicast CID	0xFFFD	Used for transmission of DL broadcast information to Idle mode MSS.
Padding CID	0xFFFE	Used for transmission of padding information by SS and BS.
Broadcast CID	0xFFFF	Used for broadcast information that is transmitted on a downlink to all SS.

3.2.3 UL MAP Fast tracking IE

[Section 8.4.5.4.21, Modify table 298h as follows]

Syntax	Size	Notes
UL_MAP_Fast_tracking_IE() {		
Extended UIUC	4 bits	Fast-Indication = 0x03
Number of Length	4 bits	*Variable*
Map Index	2 bits	Index of SUB-DL-UL-MAP to which this IE refers, or zero if this IE refers to the mandatory UL-MAP.

Reserved	6 bits	Shall be set to zero.
for (*i* = 1; *i* <= *n*; *I*++) {		For each Fast Indication bytes 1 to n (n=Length-1)
Power correction	2 bits	Power correction indication: 00: no change; 01: +2dB; 10: -1dB; 11: -2dB
Frequency correction	4 bits	The correction is 0.1% of the carrier spacing multiplied by the 4-bit number interpreted as a signed integer (i.e. 1000: -8; … 0000: 0; … 0111: 7)
Time correction	2 bits	The correction is floor(2 / F$_s$) multiplied by: 00: 0; 01: 1; 10: -1; 11: Not used
}		
}		

[Add the follow Section 8.4.5.3.20]

8.4.5.3.20 Skip IE

This IE is sent by BS in the mandatory DL-MAP as a broadcast IE. This IE is used to indicate to mobility enabled MSS (negotiated through capability exchange in REG_REQ/RSP, defined in 11.7.13.1) whether to process subsequent IEs following the Skip_IE. There are two modes of operation. At the beginning of each DL-MAP, the processing of IEs is always enabled. When a Skip_IE is encountered, and if Mode is set to 1, the mobility enabled MSS may skip the processing of all subsequent IEs in the DL-MAP. However, when a Skip_IE with Mode set to 0 is encountered, the mobility enabled MSS may disable the processing of subsequent IEs until the next Skip_IE is encountered in the DL-MAP. When the next Skip_IE with Mode set to 0 is encountered, the MSS shall enable the processing of subsequent IEs. This process continues until the end of the DL-MAP.

Table 286 Skip_IE Format

Syntax	Size	Notes
Skip_IE() {		
Extended DIUC	4 bits	?
Length	4 bits	
Mode	1 bit	If set to 1, the MSS can skip the processing of all subsequent IEs in the DL-MAP If set to 0, the MSS toggle the enabling and disabling of processing of IEs following the Skip_IE, until the next Skip_IE is encountered.
Reserved	7 bits	
}		

3.3 Capability Negotiation

3.3.1 MAP Capability

11.8.3.7.8 OFDMA MAP Capability
This field indicates the different MAP options supported by a WirelessMAN-OFDMA PHY. This field is not used for other PHY specifications. A bit value of 0 indicates "not supported" while 1 indicates "supported."
Support for Extended HARQ IE in Normal MAP mandates a support for Sub MAP for first zone.

Type	Length	Value	Scope	
155	1	bit #0: H-ARQ MAP Capability ~~bit #1-7: reserved~~ bit #1: Extended HARQ IE in Normal MAP capability bit #2: Sub MAP capability for first zone Bit #3: Sub map capability for other zones bit #4-7: reserved	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)	

3.3.2 H-ARQ Burst and Buffer Capability

[Add the following text to section 11.8.3.7.12]
11.8.3.7.12 Maximum number of burst per frame capability in H-ARQ
The maximal number of uplink data burst allocations for the SS in a single UL subframe (note this number is limited to 1 in case H-ARQ is disabled)

Type	Length	Value	Scope	
159	1	Maximum number of burst per HARQ enabled SS in one UL sub frame. 0 = unlimited (default)	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)	

[Add the following text to section 11.7.8]
11.8.3.7.13   HARQ buffer capability
Downlink/Uplink H-ARQ buffering capability indicates the maximal number of data bits the SS is able to store for downlink/uplink H-ARQ. The buffering capability is separately indicated for Nep/Nsch based incremental redundancy used for CTC, and for DIUC/duration based H-ARQ methods (Chase combining and CC-IR), and separately for uplink and downlink transmissions. The buffering capability is indicated by two parameters:
  1. Number of bits per channel – this is the total number of data bits that the SS may buffer per H-ARQ channel.
  2. Aggregation flag – when this flag is clear, the number of bits is counted separately for each channel. When the flag is set, buffering capability may be shared between channels, as explained below.

The number of bits per channel is indicated as follows:

1. For incremental redundancy CTC (Nep based): Number of bits is indicated by N_{EP} code, according to table 330.
2. For Chase combining and CC-IR (DIUC based): Number of bits is indicated by a value K=0..63 according to the following equation: *Number of bits* = floor($512 \cdot 2^{K/4}$) Bits.

When aggregation flag is clear, the number of bits that were allocated in each H-ARQ channel in the last transmission must not exceed "Number of bits per channel".

When aggregation flag is set, the sum over all H-ARQ channels, of the number of bits that were allocated in the H-ARQ channel in the last transmission, must not exceed the "Number of bits per channel" multiplied by the maximum number channels supported by the SS. Note that sum total of the data bits supported is the same in both cases is the same. The number of channels supported by the SS is indicated in 11.8.3.7.3.

The IR-CTC H-ARQ buffer capability shall also be applied to bursts for which ACK channel is not allocated (ACK disable is set).

11.8.3.7.13.1   HARQ Incremental redundancy buffer capability

Type	Length	Value	Scope
160	2	Bits 0-3: N_{EP} value indicating downlink H-ARQ buffering capability for incremental redundancy CTC. Bits 4: Aggregation Flag for DL Bits 5-7: Reserved Bits 8-11: N_{EP} value indicating uplink H-ARQ buffering capability for incremental redundancy CTC. Bit 12: Aggregation Flag for UL Bits13- 15: Reserved	SBC-REQ SBC-RSP

11.8.3.7.13.2   HARQ Chase combining and CC-IR buffer capability

Type	Length	Value	Scope
161	2	Bits 0-5: Downlink H-ARQ buffering capability for chase combining (K). Bits 6: Aggregation Flag for DL Bit 7: *reserved*. Bits 8-13: Uplink H-ARQ buffering capability for chase combining (K). Bits 14: Aggregation Flag for UL Bit 15: *reserved*	SBC-REQ SBC-RSP

11.8.3.7.2 OFDMA MSS demodulator
[Apply the following change to the table:]

Type	Length	Value	Scope
151	~~1~~ Variable	*Bit #0: 64-QAM* *Bit #1: BTC* *Bit #2: CTC* *Bit #3: STC* *Bit #4: AAS Diversity Map Scan* *Bit #5: ~~AAS Direct Signaling~~ H-ARQ Chase* *Bit #6: H-ARQ CTC IR* *Bit #7: H-ARQ with SPID=0 only* *Bit #8: H-ARQ CC IR* *Bit #9-15 - reserved*	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

When the length of this TLV is 1 byte it indicates bits 8-15 are zero.

11.8.3.7.3 OFDMA MSS modulator
[Apply the following change to the table:]

Type	Length	Value	Scope
152	~~1~~ Variable	*Bit #0: 64-QAM* *Bit #1: BTC* *Bit #2: CTC* *Bit #3: STC* *Bit #4: AAS Diversity Map Scan* *Bit #5: ~~AAS Direct Signaling~~ H-ARQ Chase* *Bit #6: H-ARQ CTC IR* *Bit #7: H-ARQ with SPID=0 only* *Bit #8: H-ARQ CC IR* *Bit #9-15 - reserved*	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)
153	1	The Number of H-ARQ ACK channel	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

When the length of TLV 152 is 1 byte it indicates bits 8-15 are zero.

3.4 MAC implications of H-ARQ operation

3.4.1 Changes overview

3.4.1.1 Replay Attack Windowing

A standard mechanism in 802.16 security is replay attack protection. This is achieved by discarding any packet with a Packet Number (PN) which is lower than the highest received PN for a certain Security Association (SA). This mechanism assumes reception of PDUs at the MAC in order from the PHY. This assumption is not valid if H-ARQ is used for this CID, since H-ARQ transmits PDUs from a single CID over a number of H-ARQ channels without committing to the order at the receiver. Therefore, if a PDU is received incorrectly, H-ARQ will retransmit on this particular H-ARQ channel while receiving normally on all the other H-ARQ channels. This single PDU will be received out of order for example.

In order to prevent replay attacks even when PDU order is not guaranteed, the mechanism should be extended as follows. The receiver shall maintain a PN window for each SA. Any PDU received with a PN which is less than the beginning of the window shall be discarded as a replay attempt. Additionally, the receiver shall track which PNs have been received within the PN window. If a PDU is received with a PN that

has already been received, it shall be discarded as a replay attempt. Reception of PNs which are greater than the highest received PN for an SA shall advance the PN window forward to cover this newly received PN.

3.4.2 Specific text changes to the Standard

[Change in section 6.3.17]
[add to end of section]

H-ARQ is enabled on a CID basis. An H-ARQ enabled CID must have ARQ enabled as well for this CID. See section 6.3.17.6

[Change in section 7.5.1.2.4]
[add to end of section]

The receiver shall maintain a PN window whose size is specified by the PN_WINDOW_SIZE parameter per SA as defined in 11.9.36. Any received PDU with a PN lower than the beginning of the PN window shall be discarded as a replay attempt. The receiver shall track PNs within the PN window. Any PN that is received more than once shall be discarded as a replay attempt. Upon reception of a PN which is greater than the end of the PN window, the PN window shall be advanced to cover this PN

[Insert new section 11.18.6]

11.8.6 PN Window Size

Specifies the size capability of the receiver PN window per SAID. The receiver shall track PNs within this window to prevent replay attacks (see 7.5.1.2.4).

Type	Length	Value	Scope
44	2	PN Window Size in PNs	SBC-REQ, SBC-RSP

[Insert new section 11.13.32]

11.13.32 H-ARQ Service Flows

Specifies whether the connection uses H-ARQ or not.

Type	Length	Value	Scope
44	1	0 = Non H-ARQ (default) 1 = H-ARQ Connection	DSA-REQ, DSA-RSP, REG-REQ, REG-RSP