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Title	**Normal MAP Extension for H-ARQ**
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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	
Release	
Patent Policy and Procedures	

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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.

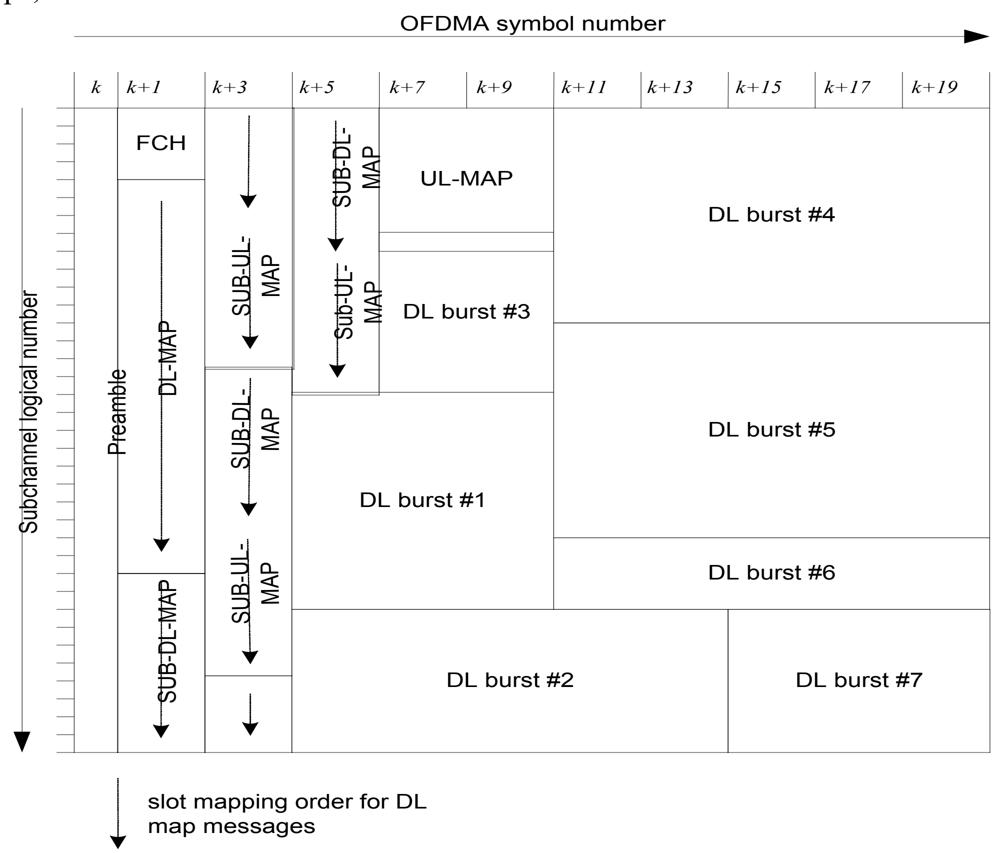
2 Overview of the proposed solution

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

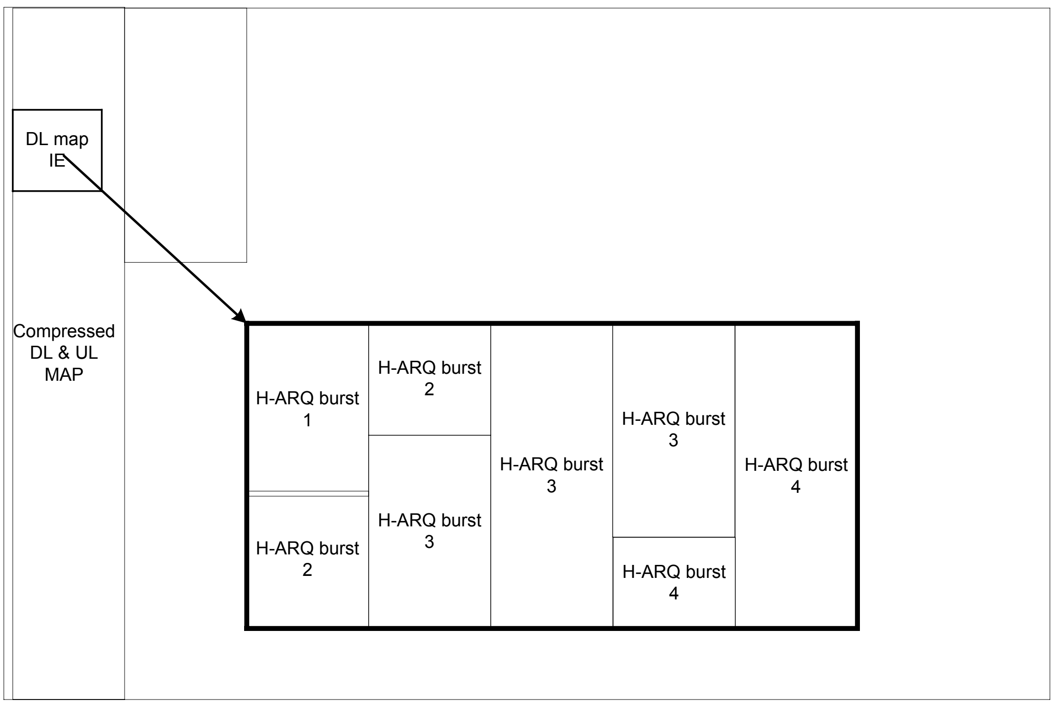
The support for multiple maps is enabled by a modification of the H-ARQ map pointer IE. Following the modification the IE can point to a map including normal DL/UL MAP_IEs. The sub-map has a similar structure to the DL/UL maps, but without the fixed overhead.



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 Text Change

3.1 H-ARQ Support in Normal MAP

3.1.1 H-ARQ DL MAP Extension

[Add a new section 8.4.5.9 as follows]

8.4.5.9 H-ARQ Support in Normal MAP

8.4.5.9.1 H-ARQ DL MAP Extension

Table 306a H-ARQ DL MAP IE Format

Syntax	Size	Note
H-ARQ DL MAP IE {		
Extended DIUC	Variable	4 bits if this IE inside a Main MAP 6 bits if this IE inside a Sub MAP
Length	Variable	4 bits if this IE inside a Main MAP 8 bits if this IE inside a Sub MAP
RCID_Type	2 bits	00 = Normal CID 01 = RCID11 10 = RCID7 11 = RCID3
While (data remains) {		
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	
N sub burst	3 bits	Number of sub-bursts in 2D region
Mode	2 bits	Indicates the mode of this IE Bit #1 : 0 = No H-ARQ, 1 = H-ARQ Bit #0: 0 = DIUC/Length, 1 = Nep/Nsch
If (Mode== 00) {		

DL DIUC Sub-Burst IE ()		Variable		.	
} else if (Mode== 10) {					
DL H-ARQ CC Sub-Burst IE ()		Variable			
} else if (Mode== 11) {					
DL H-ARQ IR Sub-Burst IE ()		Variable			
}					
}					

Table 306b DL DIUC Sub-Burst IE Format

DL DIUC 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	
For (j=0; j< N sub burst; j++){					
RCID_IE()		Variable			
Dedicated Control Indicator		1 bit			
If (Dedicated Control Indicator ==1) {					
Dedicated Control IE ()		Variable			
}					
}					
}					

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

DL H-ARQ 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	
For (j=0; j< N sub burst; j++){					
RCID_IE()		Variable			
Duration (in slots)		10 bits			
ACID		4 bits			
AI_SN		1 bit			
Dedicated Control Indicator		1 bit			
If (Dedicated Control Indicator ==1) {					
Dedicated Control IE ()		Variable			
}					
}					
}					

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

DL H-ARQ IR Sub-Burst IE {					

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	
Dedicated Control Indicator	1 bit	
If (Dedicated Control Indicator ==1) {		
Dedicated DL Control IE ()	Variable	
}		
}		
}		

[End of "Add a new section 8.4.5.9 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 8.4.5.9.1.1 as follows]

8.4.5.9.1.1 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 : CQICH Control Info Bit #1-3: Reserved
If(CQICH Control Info Bit == 1){		
Allocation Index	6 bits	
Period	2 bits	
Frame offset	3 bits	
Duration	4 bits	
}		
}		

Control Indicator
4 bits are used to indicate the following control information. If the first bit is set to 1, this means that CQICH Control information follows Control Indicator. Other bits are reserved for future extension.

Allocation Index
Indicates position from the start of the CQICH region.

Period
Informs the SS of the period of CQI reports.

Frame Offset
Informs the SS when to start transmitting reports. The SS starts reporting at the frame number which has the

same 3 LSBs as the specified Frame Offset. If the current frame is specified, the SS shall start reporting in 8 frames.

Duration

Indicates when the SS should stop reporting unless the CQICH allocation is refreshed beforehand. If Duration is set to 0b0000, the BS shall de-allocate the CQICH. If Duration is set to 0b1111, the CQICH is allocated indefinitely and the SS should report until it receives another MAP_IE with Duration set to 0b0000.

[End of "Add a new section 8.4.5.9.1.1 as follows"]

3.1.2 H-ARQ UL MAP Extension

[Add a new section 8.4.5.9.3 as follows]

8.4.5.9.3 H-ARQ UL MAP Extension

Table 306l H-ARQ UL MAP IE

Syntax	Size	Note
H-ARQ UL MAP IE() {		
Extended UIUC	Variable	4 bits if this IE inside a Main MAP 6 bits if this IE inside a Sub MAP
Length	Variable	4 bits if this IE inside a Main MAP 8 bits if this IE inside a Sub MAP
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	6 bits	This value indicates start Subchannel offset of subsequent sub-bursts in this H-ARQ UL MAP IE
}		
Mode	2 bit	Indicates the mode of each burst Bit #1 : 0 = No H-ARQ, 1 = H-ARQ Bit #0: 0 = DIUC/Length, 1 = Nep/Nsch
N Burst	4 bits	This field indicates the number of bursts in this UL MAP IE
For (i =0 ;i < N Sub-burst; i++){		
RCID IE()	Variable	
Dedicated Control Indicator	1 bit	
If (Dedicated Control Indicator ==1) {		
Dedicated Control IE ()	variable	
}		
if (Mode == 00) {		

UL UIUC Sub-Burst IE ()					
} else if (Mode== 10) {					
UL HARQ CC Sub-Burst IE ()					
} else if (Mode== 11) {					
UL HARQ IR Sub-Burst IE ()					
}					
}					
}					
}					

Table 306m UL UIUC Sub-Burst IE Format

UL UIUC Sub-Burst IE{					
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			
}					

Table 306n UL HARQ CC Sub-Burst IE Format

HARQ CC UL Sub-Burst IE {					
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 Sub-Burst IE Format

HARQ IR UL Sub-Burst IE {					
Nep		4 bits			
Nsch		4 bits			
SPID		2 bits			
ACID		4 bits			
AI_SN		1 bit			
}					

[End of "Add a new section 8.4.5.9.3 as follows"]

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

[Add a new section 8.4.5.9.3.1 as follows]

8.4.5.9.3.1 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 Header	4 bits	Bit #0-#3: Reserved
}		

Length

This field indicates the following control information including Control Header.

Control Header

4 bits are used to indicates following control information. All bits are reserved for future extension.

[End of "Add a new section 8.4.5.9.3.1 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 8.4.5.9.5 as follows]

8.4.5.9.5 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 tiles1,3,5; the second half-slot is composed of tiles 2,4,6. 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).

In case of Fast ARQ the "half suchannel offset" is to be specified via an absolute value in the Extended Sub header of the PDU.

Table 306w. ACKCH_region MAP IE format.

Syntax	Size (bits)	Note
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 8.4.5.9.6 as follows]

8.4.5.9.6 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. When the IE is absent, MSS shall assume that the UL H-ARQ is not received by the BS.

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 CC H-ARQ and definition of CRC

[Add new section 8.4.5.9.7 as follows]
8.4.5.9.7 **Optional CC H-ARQ (Chase combining H-ARQ) Support**
The optional CC 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.

8.4.5.9.7.1 **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.

8.4.5.9.7.2 **CRC**
Bursts transmitted using CC 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.

8.4.5.9.7.3 **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.

8.4.5.9.7.4 **Encoding**
When using CC-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.

3.1.5.1 Distinction between IR and CC 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 CC-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)

[Add the following words in the title and contents of of 8.4.9.6. This section defines some encodings for CC-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]

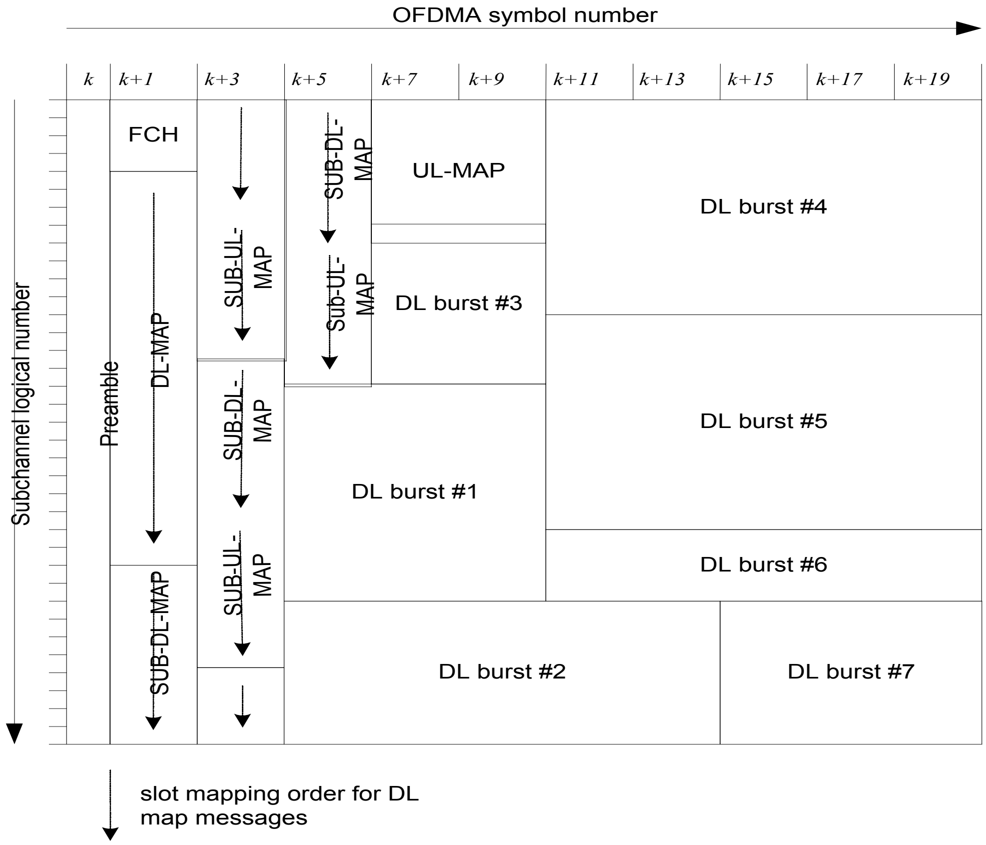


Figure 23a Sub-MAP Burst

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-MAP message format

Syntax	Size	Notes
SUB-DL-UL-MAP () {		
Compressed map indicator	2 bits	Set to binary 11 for compressed format
Map message length	10 bits	
DL IE Count	8 bits	
For (i=1; i <= DL IE Count; i++)		
DL-MAP_IE()	Variable	
}		
Slot offset	11 bits	
while (map data remains){		

UL-MAP_IE()	Variable	
}		
If !(byte boundary) {		
Padding Nibble	Variable	Padding to reach byte boundary.
}		
}		

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 DL 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 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. 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.

DL Zone switch IEs (Extended DIUC 0x01) must not be included in the SUB-DL-UL-MAP.
UL Zone switch IEs (Extended UIUC 0x04) may be included also in the SUB-DL-UL-MAP. The IE slot offset field sell be used to specify the start offset inside the zone.

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

Sub MAP must be used only with compressed MAP structure.

[Section 8.4.5.4.7]

[Modify table 292 as follows]

Syntax	Size	Notes
ZONE_IE() {		
Extended UIUC	4 bits	ZONE = 0x04
Length	4 bits	variable ~~Length = 0x02~~
OFDMA symbol offset	7 bits	
If(This Zone IE appears in Sub-MAP) {		
Include Slot offset	1 bit	
If (Include Slot offset == 1) {		
Slot offset	11 bits	The slot offset (according to data slot mapping order), relative to the start of the zone, from which to begin allocating data slots to subsequent allocations. Slot offset

		is implicitly set to zero if 'Include slot offset' = 0.
Reserved	5 bits	
}		
Else {		
Reserved	7 bits	
}		
} else {		
Permutation	2 bits	0b00 = PUSC permutation 0b01 = FUSC permutation 0b10 = Optional FUSC permutation 0b11 = Adjcent subcarrier permutation
PUSC UL_IDcell	7 bits	
}		
}		

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
}		
}		

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.

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 bit #3-7: 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

Type	Length	Value	Scope
160	1	Bits 0-4: Downlink H-ARQ buffering capability. The maximal number of data bits the SS is able to store for H-ARQ. The sum over all H-ARQ channels, of the number of bits that were transmitted in the H-ARQ channel by the BS in the last transmission, must not exceed this number. The downlink buffering capability is indicated by a number K=0..15 which indicates buffering capability of N = floor(512·2^(K/2)) Bits. Bits 5-7 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	*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 CC* *Bit #6: H-ARQ IR* *Bit #7: H-ARQ with SPID=0 only*	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

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

Type	Length	Value	Scope
152	1	*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 CC* *Bit #6: H-ARQ IR* *Bit #7: H-ARQ with SPID=0 only*	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)

3.4 MAC implications of H-ARQ operation

3.4.1 Changes overview

3.4.1.1 MAC-ARQ Mode for H-ARQ

Using the standard MAC-ARQ mechanism over H-ARQ presents some problems. The MAC-ARQ itself generates feedbacks, which are costly in bandwidth. Additionally, it is not necessarily the case that an operator will want to enable MAC-ARQ, for example in UGS connections. It should be noted that UGS connections are not compatible with MAC-ARQ since there is no way to allocate bandwidth for MAC-ARQ retransmissions or feedbacks. The proposal of this document is to define a new 802.16 ARQ mode for support of H-ARQ. Under this mode, all regular MAC-ARQ parameters are defined, e.g. BLOCK_LIFETIME, WINDOW_SIZE, SYNC_LOSS_TIMEOUT, etc. However, the receiver MAC under this mode shall not generate MAC-ARQ feedbacks. Rather, it is the responsibility of the underlying H-ARQ mechanism to send and receive H-ARQ ACK signaling. The proposal of this document is that the transmitter PHY will generate ARQ Feedback messages for its own transmitter MAC layer and thus allow integration of these two mechanisms. In other words, the transmitter H-ARQ receives H-ARQ ACK signals from the receiver H-ARQ. The transmitter H-ARQ shall convert these H-ARQ ACK signals into MAC-ARQ feedbacks and pass them to the transmitter MAC-ARQ, on the same machine. Thus, both H-ARQ and MAC-ARQ can coexist, without the need to send ACK signals at both levels; the H-ARQ ACK signaling suffices.

To sum, H-ARQ provides retransmissions and ACK signaling. MAC-ARQ provides sequencing, reordering, time-keeping for PDUs and synchronization between the receiver and transmitter ARQs.

3.4.1.2 Fast ARQ

The mechanisms described herein lead to a natural improvement to the ARQ mechanisms, in the form of Fast-ARQ. It is possible to use the proposed combination of MAC-ARQ functionality with H-ARQ functionality, even when the PHY does not support H-ARQ. This can be achieved as follows:

1) MAC-ARQ is used as described above for sequencing, re-ordering, time-keeping and synchronization.
2) Fast-ARQ is used for retransmissions and ACK signaling.

Fast-ARQ uses the same UL-ACK-channel proposed by H-ARQ. However, Fast-ARQ does not involve Chase Combining, but only regular PDU retransmissions. The information indicating the UL-ACK slot is pre-pended to each PDU when using Fast-ARQ. The UL-ACK slot is inserted into the PDU using the ESF field.

The benefits of Fast-ARQ over MAC-ARQ are clear: it is far less costly in bandwidth, it allows for extremely fast ARQ feedbacking using the H-ARQ defined UL-ACK channel, and it requires no bandwidth allocation for its feedbacks.

3.4.1.3 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.

3.4.1.4 Extended Subheader Field (ESF)

The current MAC PDU format is very limited in introducing additional information fields which need to be conveyed along with the PDU. A recent contribution has enhanced the PDU with the MSF bit indicating an additional field containing the Mode Selection Feedback subheader. This document proposes to extend this bit to allow mini-TLVs to be used within a MAC PDU. This allows the standard to introduce new information fields easily and in a scalable way, whereas today the MSF bit and other values change the GMH header directly in a restricting and inflexible way.

The mini-TLVs are composed of a 4-bit Type field, 4-bit Length field in octets and the value itself. Thus, fields of up to 16 octets can be used. The overhead for any field is 1 octet. For example, the Mode Selection Feedback subheader will become 2 octets instead of 1 octet as it is defined today.

The MSF bit in the GMH will be overridden to become the Extended Subheader Fields (ESF) bit. If it is 1, immediately following the GMH will be the ESF octet indicating the total length of the mini-TLVs following. The ESF octet will be followed by mini-TLVs, each mini-TLV is at least 1 octet in length and up to 16 octets in length.

3.4.2 Specific text changes to the Standard

[Change in section 6.3.2.1.1]

Figure 19a

Change MSF (1) to ESF (1)

Table 5a

Name	Length (Bits)	Description
<remove MSF>		
ESF	1	Extended Subheader Field. If ESF = 0, the ESF is absent. If ESF=1, the ESF is present and will follow the GMH immediately. (See section 6.3.2.2.7). An MSS shall set this bit to 1 only if it has successfully negotiated the support of ESF with the BS through the capabilities exchange dialog (SBC-REQ/RSP).

[Change in section 6.3.2.2]
[Modify the following sentences]

~~Five~~Six types of subheaders may be present in a MAC PDU with generic MAC header. The per-PDU subheaders (i.e., Mode Selection Feedback, Mesh, Fragmentation, ~~FASTFEEDBACK~~ Fast-feedback Allocation and Grant Management) may be inserted in MAC PDUs immediately following the Generic MAC header. If both the Fragmentation subheader and Grant Management subheader are indicated, the Grant Management subheader shall come first. If the Mesh subheader is indicated, it shall precede all other subheaders. In the downlink, the ~~FAST-FEEDBACK~~ Fast-feedback Allocation subheader shall always appear as the last per-PDU subheader~~, while in the uplink the Mode Selection Feedback subheader shall always appear as the last per-PDU subheader. The Mode Selection Feedback subheader, if indicated in UL Generic MAC header, shall always appear as the last per-PDU subheader in a UL MAC PDU.~~

Add the following to end of section

The ESF bit in the GMH indicates that the Extended Subheader Field is present. Using this field, a number of additional subheaders can be used within a PDU. The ESF field shall always appear immediately after the GMH, and before all other subheaders. The ESF field and all subheaders related to it are not encrypted. (See section 6.3.2.2.7)

[Add the following section 6.3.2.2.7]

6.3.2.2.7 Extended Subheader Field

The Extended Subheader Field subheader is specified in Table 13. The Extended Subheader Field, when used, shall always appear immediately after the GMH and before all other subheaders, as described in 6.3.2.2. The ESF field and all mini-TLVs related to it sell not be encrypted.

Table 13

Name	Length (Bits)	Description
Total length (in octets) of mini-TLVs	8	Indicates the total length of all the mini-TLVs following the ESF subheader. The length is specified in octets.

[Change in section 6.3.4.6.3]
[add to end of section]

If H-ARQ is enabled for a connection, it is possible for the receiver not to generate ARQ Feedback messages. Instead, the transmitter PHY shall use HARQ signaling to emulate ARQ Feedback indications. See section 6.3.17.6

[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

[Insert new section 6.3.17.6]

6.3.17.6 H-ARQ and MAC-ARQ Interaction

H-ARQ enabled connections shall have regular ARQ (MAC-ARQ) enabled for them as well. However, since acknowledgement signaling is taken care of at the H-ARQ level, the receiver MAC shall not generate ARQ Feedback Messages for acknowledgment. Instead, the transmitter PHY shall emulate ARQ Feedback Messages, according to the H-ARQ acknowledgements received, and shall forward these ARQ Feedbacks to the transmitter MAC. ARQ Discard and ARQ Reset messages shall be transmitted normally.

The ARQ state machines shall be aware that a certain connection is H-ARQ enabled and shall not generate ARQ Feedback Messages in this case.

[Insert new section 6.3.17.7]

6.3.17.7 Fast-ARQ

Fast-ARQ is a form of ARQ whereby retransmissions and acknowledgements are handled much like in H-ARQ, using an ACK channel. However, in Fast-ARQ the PHY takes no part in reconstructing the data like in IR or Chase Combining. Rather, retransmissions are done on whole PDUs much like in regular ARQ.

This allows for fast acknowledgements and retransmissions, without necessitating to slow mechanisms like Bandwidth Requests.

Fast-ARQ enabled connections shall use a UL-ACK channeled defined for H-ARQ. Every PDU transmitted in the DL shall indicate the ACK slot that shall be used for acknowledging it; this information shall be pre-pended to the PDU using the ESF subheader. As defined in 6.3.17.6, Fast-ARQ enabled connections shall have ARQ enabled for them as well. However, the regular ARQ mechanism shall not generate ARQ Feedback messages. The transmitter Fast-ARQ shall emulate ARQ Feedbacks for its own transmitter MAC based on the ACK indications received in the ACK channels.

[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

[Change in section 11.8.2]

11.8.2 Capabilities for Construction and Transmission of MAC PDUs

Type	Length	Value	Scope
4	1	Bit #2: Specifies support for ESF capability (see 6.3.2.2.7) Bit #3-#7: *Reserved,* shall be set to zero	SBC-REQ, SBC-RSP

[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 11.13.18.10]

11.13.18.10 ARQ Feedback Generation

Specifies whether the receiver MAC shall generate ARQ Feedback messages. For H-ARQ or Fast-ARQ enabled connections, even though ARQ is used, ARQ Feedback messages may be disabled (see 6.3.17.6).

Type	Length	Value	Scope
44	1	0 = Generate ARQ Feedbacks (default) 1 = Do not generate ARQ Feedbacks (H-ARQ/ Fast-ARQ)	DSA-REQ, DSA-RSP, REG-REQ, REG-RSP

[Insert new section 11.13.32]

11.13.32 H-ARQ/Fast-ARQ Service Flows

Specifies whether the connection uses H-ARQ or Fast-ARQ.

Type	Length	Value	Scope
44	1	0 = Non H-ARQ 1 = H-ARQ Connection 2 = Fast-ARQ Connection	DSA-REQ, DSA-RSP, REG-REQ, REG-RSP

[Insert new section 11.20]

11.20 Mini-TLV Encodings

The format of mini-TLVs is specified in Table 11.20.1. Mini-TLVs are used with the Extended Subheader Field (see section 6.3.2.2.7). The list of defined mini-TLVs is given in Table 11.20.2.

Table 11.20.1

Name	Length (Bits)	Description
Type	4	Mini-TLV Type (0-15)
Length	4	Mini-TLV Length in octets (0-15 octets) not including the Type and Length fields
Value	<Indicated by the Length field in octets>	The Mini-TLV Value

Table 11.20.2

Type	Name	Length (Octets)	Description
0b0000	*Reserved*		*Reserved*
0b0001	Mode Selection Feedback	1	See 11.20.1
0b0010	UL-ACK Slot Indication	1	See 11.20.2
0b0011-0b1111	*Reserved*		*Reserved*

[Insert new section 11.20.1]

11.20.1 Mode Selection Feedback mini-TLV

<move section 6.3.2.2.7 here>

[Insert new section 11.20.2]

11.20.2 H-ARQ ACK half sub-channel offset

The H-ARQ ACK half sub-channel offset indication is used in Fast-ARQ enabled connections. For each PDU in the DL, the BS shall indicate in the extended subheader (ESF) the parameters for the ACK slot to be used in the UL H-ARQ ACK Channel. The format of this mini-TLV is specified in Table x.x.x.

Table x.x.x

Name	Length (Octets)	Description
H-ARQ ACK half sub-channel offset	1	Absolute value of the half subchannel offset in the HARQ

ACK channel in which an acknowledgment should be transmitted for this PDU.