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Multiple Broadcast Maps for OFDMA PHY

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1 Introduction

In the current IEEE P802.16-2004 specification, a frame contains a single DL-MAP and UL-MAP, each transmitted at a single rate. This constraint leads to large map overheads, especially in AA (Adaptive Antenna) systems where the single broadcast map must be transmitted at a very robust rate in order to bridge the gap between AAS transmissions and broadcast transmissions.

In this contribution the concept of multiple broadcast maps is introduced. The overhead due to maps is analyzed for a typical AAS scenario. The proposal is then described followed by specific text changes. Backward compatibility to IEEE P802.16-2004 is maintained.

2 Problem Statement

Consider the following scenario: a BS utilizing an *N*-element adaptive antenna array is designed to provide coverage so that single-antenna users at the edge of the cell are capable of decoding data transmissions at rate *R* when optimal beamforming is employed at the transmitter. This implies that broadcast (non-beamformed) DL-MAP/UL-MAP messages must be transmitted at a rate of *R/N* to ensure that the farthest user can decode them. The inability to transmit the MAP messages at variable rates results in a large single map message transmitted to all users at the most robust rate *R/N* mandated by the farthest user.

As an example, let us assume:

- A 4-element antenna array (N=4).
- Rate distribution (QAM-64 ¾ to QPSK ½) throughout the cell assumes path loss exponent n=4.
- Basic data transmission rate of QPSK ½ (R=1 bit/subcarrier).
- Frame duration of 5msec.
- Bandwidth of 5MHz.
- TDD split at 60% of the frame duration.
- 30% of the users require maps at the robust rate (*R/N*).
- Maps are compressed, CID is not included.

Figure 1 depicts the overhead for maps transmitted at rate *R/N* as a function of the average payload length. The figure further shows how this overhead can be reduced by supporting two broadcast maps with different rates, the 1st is the robust rate of *R/N* and the 2nd is the rate *R*. The map overhead is calculated as a fraction of the overall DL sub-frame.

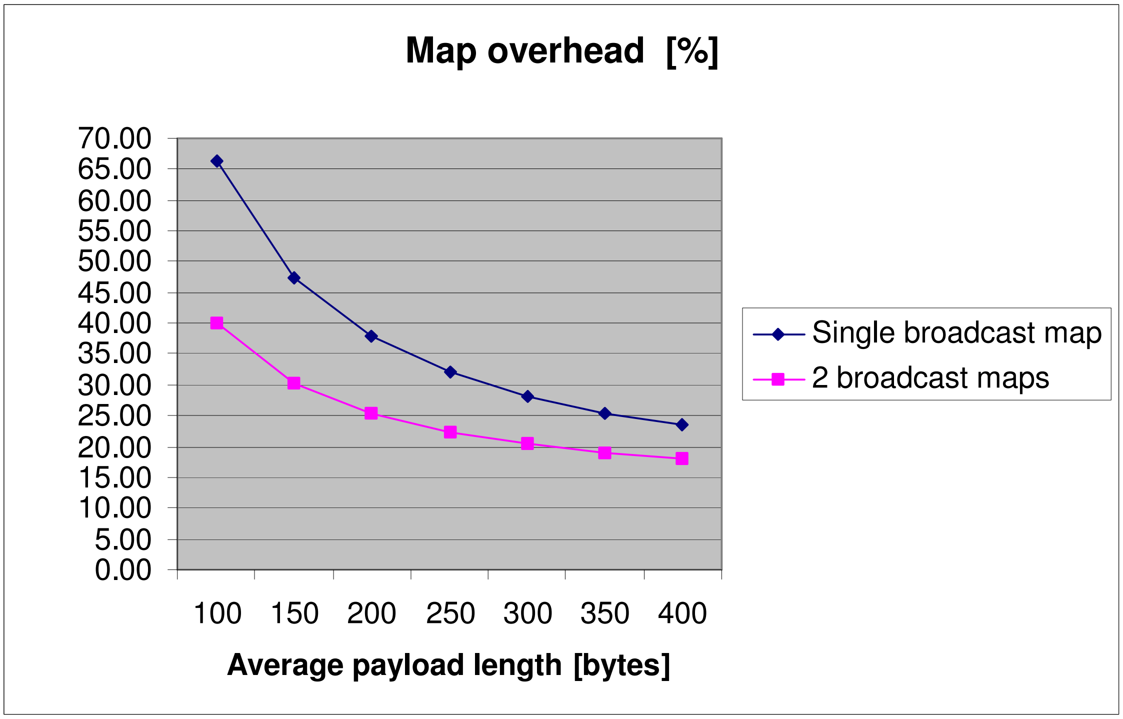

Figure 1 – Map overhead as a function of average payload length.

It should be noted that the benefits from going from a single broadcast map to two broadcast maps continue as still more broadcast maps are added, until the tradeoff crossover when the diminishing returns of providing close matches for the broadcast map transmission rates of all users is overcome by the overhead of adding additional maps.

3 Proposed solution

3.1 Multiple DL-MAPs

According to [1], the DL-MAP message appears immediately following the FCH in a uni-dimensional frequency-first slot mapping order. The message begins with a generic MAC header[1] followed by an IE describing the burst containing an UL-MAP message (if one exists) and other IEs as required.

We propose to add support for multiple broadcast DL map messages, each transmitted as a separate PHY burst. The slots of these PHY bursts are ordered consecutively using the

[1] Compressed maps will be described in a separate section.

same uni-dimensional frequency-first mapping order defined in [1] for the regular DL-MAP PHY burst. The IE immediately following the IE that describes the UL-MAP burst (if one exists) in each DL map may describe the slot offset and profile of the next DL map, thus forming a linked list of DL maps.

The first mandatory DL-MAP message in the frame is the same MAC management message defined in [1] (section 6.3.2.3.2). Since the constant part of this message need not be repeated in the subsequent DL map messages, these messages shall use a new trimmed version of the DL-MAP message ('RDC-DL-MAP').

The ordering of IEs within each DL map message is the same as defined for the mandatory DL-MAP message. The 'include CID' switch and preamble modifier are reset to their respective default values before processing each map message.

3.1.1 Support for multiple zones

Zone switch IEs shall only be specified in the first mandatory DL-MAP message. This eliminates contradictions and unneeded overhead. Note that the zone switch IE should also specify the starting OFDMA symbol number (otherwise an SS having only partial visibility of the allocated IEs does not know the zone boundaries). This modification to the zone switch IE is backward compatible.

3.2 Multiple UL-MAPs

As specified in [1], the UL-MAP message is an independent PHY burst pointed to by the first IE in the DL-MAP. With multiple DL map messages, each DL map may use its first IE to point to a PHY burst carrying a UL-MAP message, so that multiple UL-MAPs are allowed.

In order to ensure independence between the UL-MAP messages, each UL-MAP shall carry the information required for correct parsing of the IEs it carries (including zone-switch IEs, among others). The zone- switch IE should also carry the slot offset (relative to the beginning of the zone) to which the first IE following the zone switch is mapped. This avoids ambiguous interpretation of multiple zone switch IEs and ensures that the UL-MAP messages can be parsed independently.

A schematic example with four DL maps is illustrated in Figure 2.

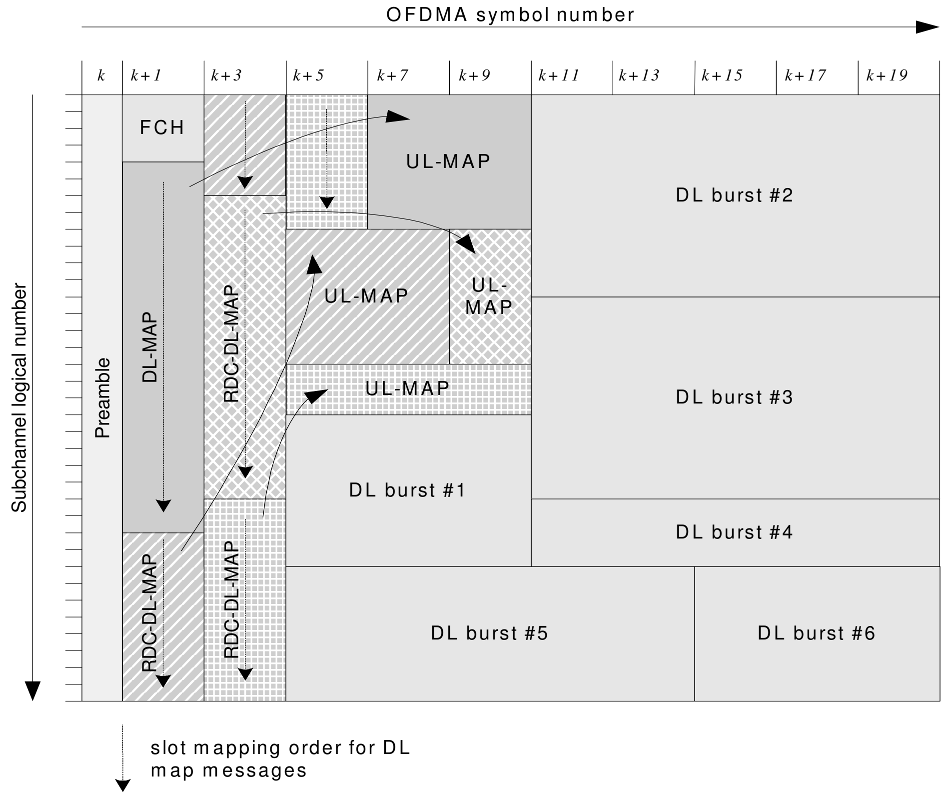

Figure 2 – Multiple broadcast map structure

3.3 <u>Multiple compressed maps</u>

Multiple broadcast maps may be compressed, provided that they are all either compressed or non-compressed. The first compressed map message in the frame is the one defined in section 8.4.5.6. Subsequent compressed UL/DL map messages in the frame shall be trimmed so that the constant portion is not repeated. The missing fields are maintained from the last non-trimmed compressed map.

4 Detailed text changes

[Add new section 6.3.2.3.59]

6.3.2.3.59 Reduced downlink map (RDC-DL-MAP) message

The RDC-DL-MAP message is a reduced form of DL-MAP. It may appear in a frame after a DL-MAP message in a manner that is PHY specific. DL-MAP fields that are omitted from RDC-DL-MAP are retained from the most recent DL-MAP message. A BS shall generate RDC-DL-MAP messages in the format shown in Table 107c.

The encoding of the RDC-DL-MAP message is PHY-specification dependent. Refer to the appropriate PHY specification.

Table 107c—RDC-DL-MAP message format

Syntax	Size	Notes
RDC-DL-MAP Message Format() {		
Management Message Type = 64	8 bits	
Begin PHY specific section {		See applicable PHY section
for (*i* = 1; *i* <= *n*; *i*++) {		For each DL-MAP element 1 to n.
DL-MAP_IE()	*Variable*	See corresponding PHY specification
}		
}		
if !(byte boundary) {		
Padding Nibble	4 bits	Padding to reach byte boundary.
}		
}		

The order of DL-MAP_IEs in the RDC-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 bursts are mapped to the PHY layer bursts in the downlink is defined as the order of DL-MAP_IEs in the RDC-DL-MAP message.

One of the DL-MAP_IEs within the RDC-DL-MAP message may describe a burst containing an UL-MAP message. Such an IE (if it exists) shall always appear before any other IEs that describe data bursts.

[Add new section 8.4.4.8]

8.4.4.8 Optional Multiple Broadcast Maps

The BS may allocate dedicated PHY bursts, each containing a single RDC-DL-MAP message, for transmitting additional DL-MAP_IEs with different burst profiles to SSs that support multiple broadcast maps. Such bursts, if exist, shall be allocated consecutively using the same uni-dimensional frequency-first slot mapping order used for the DL-MAP burst. The first burst containing an RDC-DL-MAP message shall be allocated starting at the slot immediately following the DL-MAP. Each RDC-DL-MAP message may also describe an UL-MAP message. Each of these UL-MAP messages shall be processed independently. UL-MAP messages shall be numbered consecutively starting from 1, in the same order in which the referencing DL-MAP/RDC-DL-MAP messages appear in the frame.

Bursts containing RDC-DL-MAP messages shall be only described by a DL-MAP-UNI_IE. The DL-MAP and RDC-DL-MAP messages may contain a single DL-MAP-UNI_IE that describes the next PHY burst containing the RDC-DL-MAP message. This IE (if exists) shall appear first in the DL-MAP or RDC-DL-MAP message. Each DL-MAP or RDC-DL-MAP may contain at most one DL-MAP-UNI_IE.

An SS supporting multiple broadcast maps shall attempt to decode all PHY bursts containing RDC-DL-MAP messages.

The number of RDC-DL-MAPs in a frame shall not exceed 3. The structure of the DL sub-frame with multiple broadcast maps is illustrated in figure 229a.

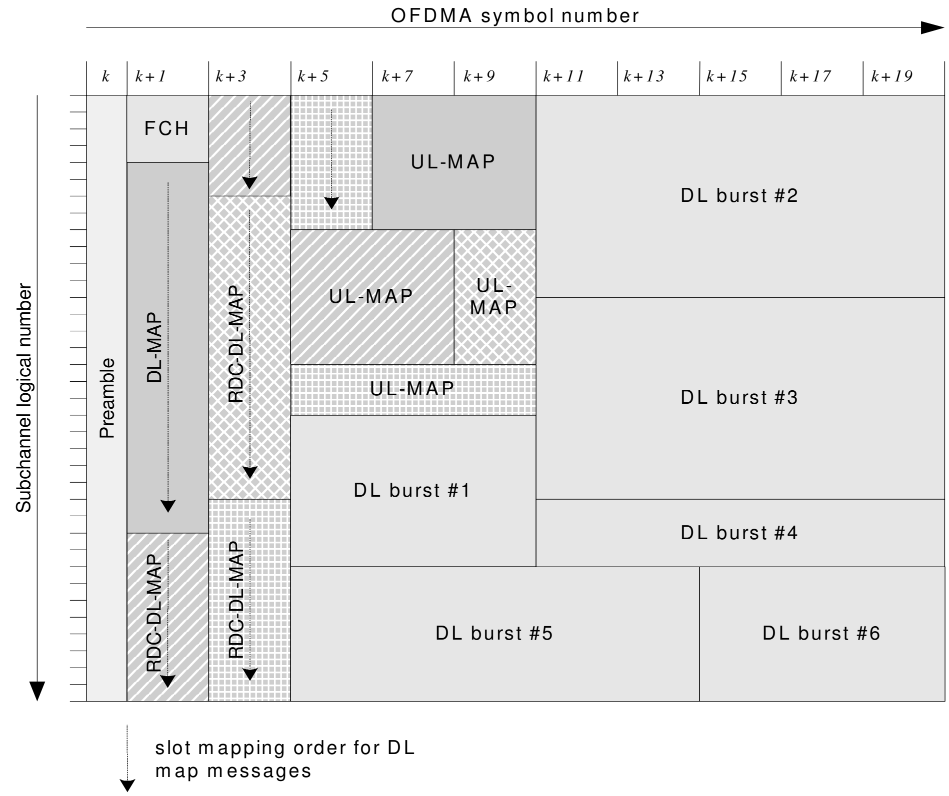

Figure 229a – Illustration of DL sub-frame structure with multiple broadcast maps

[Add new section 8.4.5.3.19]

8.4.5.3.19 DL-MAP-UNI IE format

In the DL-MAP and RDC-DL-MAP messages, the BS may transmit DIUC=15 with DL-MAP-UNI_IE() to describe the next PHY burst (in frequency-first slot mapping order) containing a RDC-DL-MAP message. This IE is defined in table 284j.

Table 284j—DL-MAP-UNI extended IE format

Syntax	Size	Notes
DL-MAP-UNI_IE() {		
Extended DIUC	4 bits	DL-MAP-UNI = 0xE
Length	4 bits	Length = 0x03
DIUC	4 bits	
Number of slots	8 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
}		

DIUC
DIUC used for the burst described by this IE.

Number of slots
Defines the length of the burst in slots (including repetition code).

Repetition coding indication
Indicates the repetition code used inside the allocated burst.

[Section 8.4.5.3.3]

[Modify the Length field in table 276 to the following:]

Length	4 bits	Length = ~~0x03~~ 0x04

[Add the following line to table 276 after "Last bin index"]

OFDMA symbol offset	8 bits	

[Add the following text before the end of section 8.4.5.3.3]

AAS_DL_IE may only be specified in the DL-MAP message. The zone permutation and boundaries shall apply to all allocations described in subsequent RDC-DL-MAP messages that exist in the same frame.

[Section 8.4.5.3.4]

[Modify the Length field in table 277a to the following:]

Length	4 bits	Length = ~~0x02~~ 0x03

[Add the following line to table 277a after "2/3 antennas select"]

OFDMA symbol offset	8 bits	

[Add the following text before the end of section 8.4.5.3.4]

Zone permutation changes shall only be specified in the DL-MAP message. The zone boundaries and permutation shall apply to all allocations described in subsequent RDC-DL-MAP messages that exist in the same frame. STC changes may be specified in RDC-DL-MAP messages, in which case any instructed permutation changes shall be ignored.

[Section 8.4.5.3.7]

[Modify the text on page 528, lines 25-30]

In the DL-MAP, a BS may transmit DIUC=15 with the CID-Switch_IE() to toggle the inclusion of the CID parameter in DL-MAP allocations. The DL-MAP and each RDC-DL-MAP message shall begin in the mode where CIDs are not included. The first appearance of the CID-Switch_IE() shall toggle the DL-MAP / RDC-DL-MAP mode to include CIDs. Any subsequent appearance of the CID-Switch_IE() shall toggle the DL-MAP / RDC-DL-MAP CID inclusion mode.

[Section 8.4.5.3.11]

[Modify the text on page 532, lines 28-32]

where *ck* are the preamble tone values, and *t* is the time, elapsed since the beginning of the OFDMA symbol, with $0 < t < T_s$. The PHYMOD_DL_IE can appear anywhere in ~~the~~ DL-MAP/RDC-DL-MAP messages ~~map~~, and it shall remain in effect until another PHYMOD_DL_IE is encountered~~, or until the end of the DL map~~. The modifier shall be reset at the beginning of each DL-MAP/RDC-DL-MAP message.

[Section 8.4.5.4.6]

[Modify table 291 as follows]

Syntax	Size	Notes
AAS_UL_IE() {		
Extended UIUC	4 bits	AAS = 0x02
Length	4 bits	*variable* ~~Length = 0x03~~
Permutation	2 bits	0b00 = PUSC permutation 0b01 = Optional PUSC permutation 0b10 = adjacent-subcarrier permutation 0b11 = *Reserved*
OFDMA symbol offset	8 bits	
Preamble indication	2 bits	0b00 = No preamble 0b01 = Preamble used 0b10-0b11 = *Reserved*
First bin index	6 bits	When Permutation=0b10, this indicates the index of the first band allocated to this AMC segment.
Last bin index	6 bits	When Permutation=0b10, this indicates the index of the last band allocated to this AMC segment.
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 set to zero if 'Include slot offset' = 0.
Reserved	5 bits	
}		
Else {		
Reserved	7 bits	
}		
}		

[Add the following text after table 291]

The BS shall set the 'Include Slot offset' field to zero in all AAS_IEs that appear in the UL-MAP that is described by an IE in the mandatory DL-MAP.

[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	

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

[Add the following text after table 292]

The BS shall set the 'Include Slot offset' field to zero in all AAS_IEs that appear in the UL-MAP that is described by an IE in the mandatory DL-MAP.

[Section 8.4.5.4.21]

[Modify table 298h as follows]

Syntax	**Size**	**Notes**
UL_Fast_tracking_IE() {		
Extended UIUC	4 bits	Fast-Indication = 0x03
~~Number of~~ Length	4 bits	*Variable*
Num UL-MAPs	2 bits	Number of broadcast UL-MAPs in previous frame, for which fast-tracking bytes are assigned in this IE.
reserved	2 bits	Shall be set to zero
for (*j* = 1; *j* <= Num UL-MAPs; *j*++) {		
Num Allocs	4 bits	Number of allocations in broadcast UL-MAP #j in previous frame for which fast-tracking bytes are assigned in this IE (see 8.4.4.8 for numbering of multiple broadcast UL-MAPs).
for (*i* = 1; *i* <= Num Allocs *n*; *i*++) {		For each Fast Indication bytes 1 to Num Allocs ~~n (n=Length)~~
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
}		
}		
If (! Byte boundary) {		
reserved	4 bits	padding
}		
}		

[add the following text before the end of section 8.4.5.4.21]

This IE shall only be transmitted in the first UL-MAP of the frame, if multiple broadcast UL-MAPs exist (section 8.4.4.8).

[Section 8.4.5.6]

[Modify the text on page 550, lines 53-61]

In addition to the standard DL-MAP, RDC-DL-MAP, and UL-MAP formats described in 6.3.2.3.2, 6.3.2.3.59, and 6.3.2.3.4, the DL-MAP, RDC-DL-MAP, and UL-MAP may conform to the format presented in the following subclauses. The presence of the compressed DL-MAP format is indicated by the contents of the most significant two bits of the first data byte following the DL Frame Prefix. These bytes overlay the HT and EC bits of a generic MAC header. When these bits are both set to 1 (an invalid combination for a standard header), the compressed DL-MAP format is present. The presence of the compressed DL-MAP mandates that all PHY bursts containing RDC-DL-MAP messages have compressed form as well. Similar to the DL-MAP message, the presence of a compressed RDC-DL-MAP is indicated by setting the most significant two bits of the first data byte of the message's PHY burst to 1. A compressed UL-MAP shall only appear after a compressed DL-MAP or RDC-DL-MAP as part of the same PHY burst. The presence of a compressed UL-MAP is indicated by a bit in the appropriate compressed DL-MAP / RDC-DL-MAP data structures.

[Modify entry 'CRC appended' in table 303]

~~CRC appended~~ Reduced DL-MAP	1 bit	Shall be set to 0

[Section 8.4.5.6.2]

[Modify the text on page 552, lines 26-29]

The compressed UL-MAP format is presented in Table 304 for the first compressed UL-MAP message in the frame, and in Table 304a for any subsequent compressed UL-MAPs. The message may only appear after a compressed DL-MAP or compressed RDC-DL-MAP message to which it shall be appended. The message format in table 304 presents the same information as the standard format with the exception that the Generic MAC header and the Uplink Channel ID are omitted. The UL-MAP message format in table 304a omits the constant part that appears in table 304. This constant part is retained from the first compressed UL-MAP message of the frame.

[Modify title of table 304 to]

Table 304—Format of the first compressed UL-MAP message in the frame

[Add the following table before the end of section 8.4.5.6.2]

Table 304a — Format of subsequent compressed UL-MAP messages

Syntax	Size	Notes
Compressed_UL-MAP() {		
While (map data remains) {		
UL-MAP_IE()	*variable*	
}		
If !(byte_boundary) {	10 bits	
Padding Nibble	4 bits	Padding to reach byte boundary.
}		
}		

[Add new section 8.4.5.6.3]

8.4.5.6.3 Compressed RDC-DL-MAP

The compressed RDC-DL-MAP format is presented in Table 304b. The message is similar to the standard format of RDC-DL-MAP compressed DL-MAP except that the 'management message type' field is omitted.

Table 304b—Compressed RDC-DL-MAP message format

Syntax	Size	Notes
Compressed_RDC-DL-MAP () {		
Compressed map indicator	2 bits	Set to binary 11 for compressed format
reserved	1 bit	Shall be set to zero
UL-MAP appended	1 bit	
Map type indicator	2 bits	Shall be set to 0b10
Map message length	10 bits	
DL IE Count	8 bits	
for (i=1; i <= DL IE Count; i++)		
DL-MAP_IE()	*variable*	
}		
If !(byte boundary) {		
Padding Nibble	4 bits	Padding to reach byte boundary.
}		
}		

Compressed map indicator
A value of binary 11 in this field indicates the map message conforms to the compressed format described here. A value of binary 00 in this field indicates the map message conforms to the standard format described in 6.3.2.3.59. Any other value is an error.
UL-MAP appended
A value of 1 indicates a compressed UL-MAP (see 8.4.5.2.6.2) is appended to the current compressed RDC-DL-MAP data structure.
Map message length
This value specifies the length of the compressed map message(s) beginning with the byte containing the Compressed map indicator and ending with the last byte of the compressed DL-MAP message if the UL-MAP appended bit is not set or the last byte of the UL-MAP compressed message if the UL-MAP appended bit is set. The length includes the computed 32-bit CRC value.
DL IE count
This field holds the number of IE entries in the following list of DL-MAP IEs.

A CRC-32 value is appended to the end of the compressed map(s) data. The CRC is computed across all bytes of the compressed map(s) starting with the byte containing the Compressed map indicator through the last byte of the map(s) as specified by the Map message length field. The CRC calculation is the same as that used for standard MAC messages.

[Modify section 11.8.3.7.6]

Type	Length	Value	Scope
155	1	bit #0: H-ARQ Map capability bit #1: Multiple broadcast maps capability bit #~~1~~ 2-7: reserved	SBC-REQ (see 6.3.2.3.23) SBC-RSP (see 6.3.2.3.24)

5 References

[1] IEEE P802.16-2004.