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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 may lead to large map overheads in many realistic scenarios. One example is 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.

Another example is a BS that supports efficient MSS power consumption. In this case, the BS may separate unicast MAC payloads to distinct PHY bursts and transmit a separate map element per payload. In such scenarios, DL maps are expected to be very large and significant overhead reduction can be achieved by matching the map rate to the payload rate.

An additional benefit of multiple broadcast maps is that map elements may be transmitted using different FEC types (CC, CTC, etc.) within a single frame.

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.

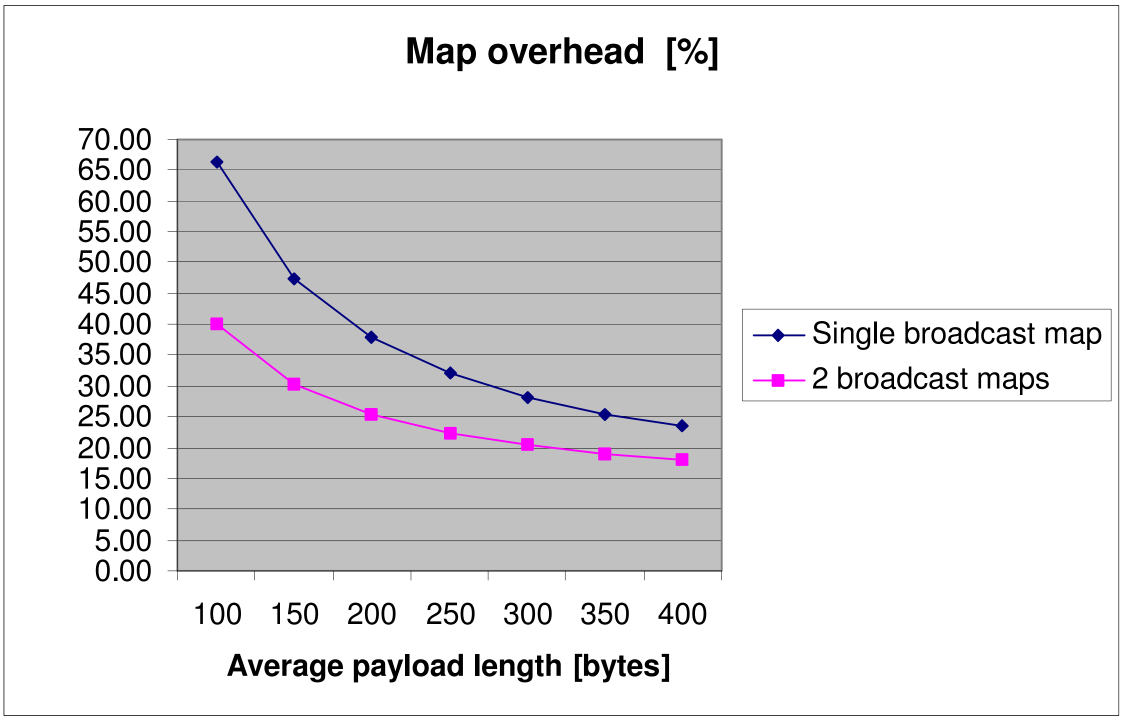


**Figure 1 – Map overhead as a function of average payload length.**

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 same uni-dimensional frequency-first mapping order defined in [1] for the regular DL-MAP PHY burst. The first IE in the mandatory DL-MAP (if exists) provides a description of the subsequent DL map messages).

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.

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

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

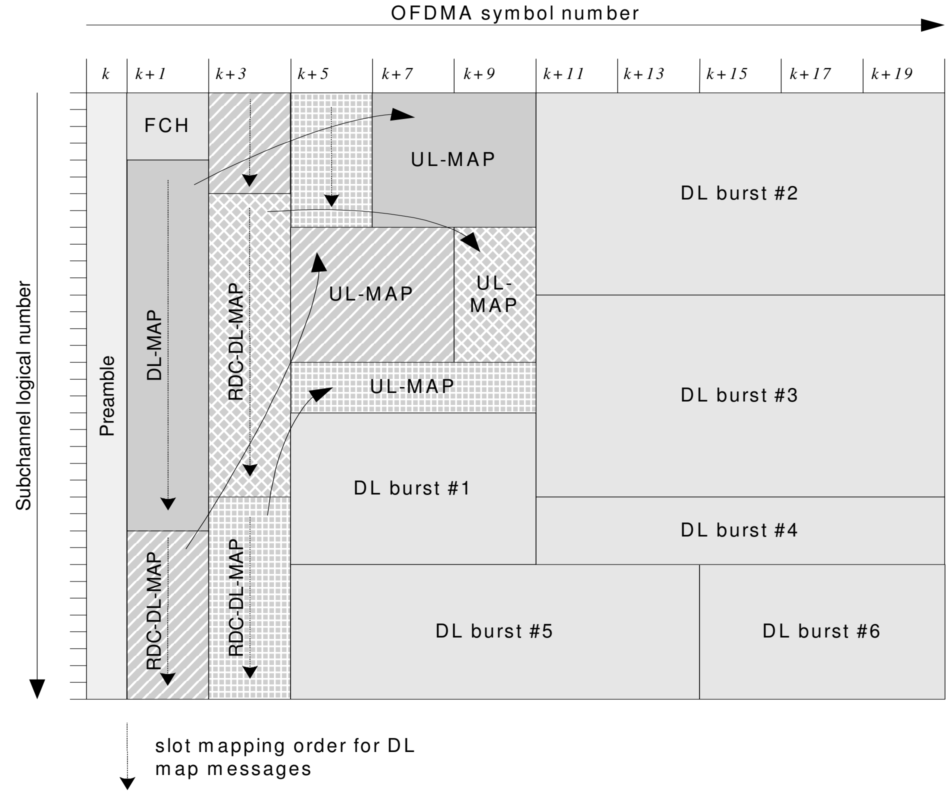


**Figure 2 – Multiple broadcast map structure**

## 3.3 Multiple compressed maps

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 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. This message is only relevant to OFDMA PHY.

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 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 RDC-DL-MAP messages.

One of the DL-MAP_IEs within the RDC-DL-MAP message may describe a burst containing an RDC-UL-MAP message. Such an IE (if exists) shall always appear first in the RDC-DL-MAP message.

*[Add new section 6.3.2.3.60]*

## 6.3.2.3.60 Reduced uplink map (RDC-UL-MAP) message

The RDC-UL-MAP message is a modified form of UL-MAP that may only be described by an RDC-DL-MAP message in a manner that is PHY specific. The RDC-UL-MAP message shall be as shown in Table 107d. This message is only relevant to OFDMA PHY.

Table 107d—RDC-UL-MAP message format

| Syntax | Size | Notes |
|---|---|---|
| RDC-UL-MAP Message Format() { | | |
| Management Message Type = 65 | 8 bits | |
| Uplink Channel ID | 8 bits | |

| | | |
|---|---|---|
| UCD Count | 8 bits | |
| Allocation Start Time | 32 bits | |
| Map index | 2 bits | |
| *reserved* | 2 bits | |
| Begin PHY specific section { | | See applicable PHY section |
| for (*i* = 1; *i* <= *n*; *i*++) { | | For each UL-MAP element 1 to n. |
| UL-MAP_IE() | *Variable* | See corresponding PHY specification |
| } | | |
| } | | |
| if !(byte boundary) { | | |
| Padding Nibble | 4 bits | Padding to reach byte boundary. |
| } | | |
| } | | |
| | | |

The BS shall generate the UL-MAP with the following parameters:

**Uplink Channel ID**
The identifier of the uplink channel to which this message refers.
**UCD Count**
Matches the value of the Configuration Change Count of the UCD which describes the uplink burst profiles which apply to this map.
**Allocation Start Time**
Effective start time of the uplink allocation defined by the RDC-UL-MAP (units are PHY-specific, see 10.3).
**Map index**
RDC-UL-MAP messages shall be numbered consecutively starting from 1, in the same order in which the referencing RDC-DL-MAP messages appear in the frame.
**Map IEs**
The contents of a UL-MAP IE is PHY-specification dependent.

IEs define uplink bandwidth allocations. Each RDC-UL-MAP message shall contain at least one IE that marks the end of the last allocated burst. Ordering of IEs carried by the RDC-UL-MAP is PHY-specific.
The CID represents the assignment of the IE to either a unicast, multicast, or broadcast address. When specifically addressed to allocate a bandwidth grant, the CID shall be the Basic CID of the SS. A UIUC shall be used to define the type of uplink access and the uplink burst profile associated with that access. An Uplink_Burst_Profile shall be included in the UCD for each UIUC to be used in the RDC-UL-MAP.

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 RDC-UL-MAP message

***[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 RDC-UL-MAP message. The UL-MAP and RDC-UL-MAP messages shall each be processed independently.

The bursts containing the RDC-DL-MAP messages shall only be described by an RDC-DL-MAP-LIST_IE. This IE (if exists) shall be the first IE in the mandatory DL-MAP message. An SS supporting multiple broadcast maps shall attempt to decode all PHY bursts containing RDC-DL-MAP messages.

When both UL-MAP and RDC-UL-MAP messages exist in the frame, the zone transitions and rectangular (UIUC=12,13) allocations shall be consistent between the UL maps. All the allocations for a single SS (including data, fast feedback, H-ARQ acks, etc.) shall be in the same UL map message in the frame.

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.

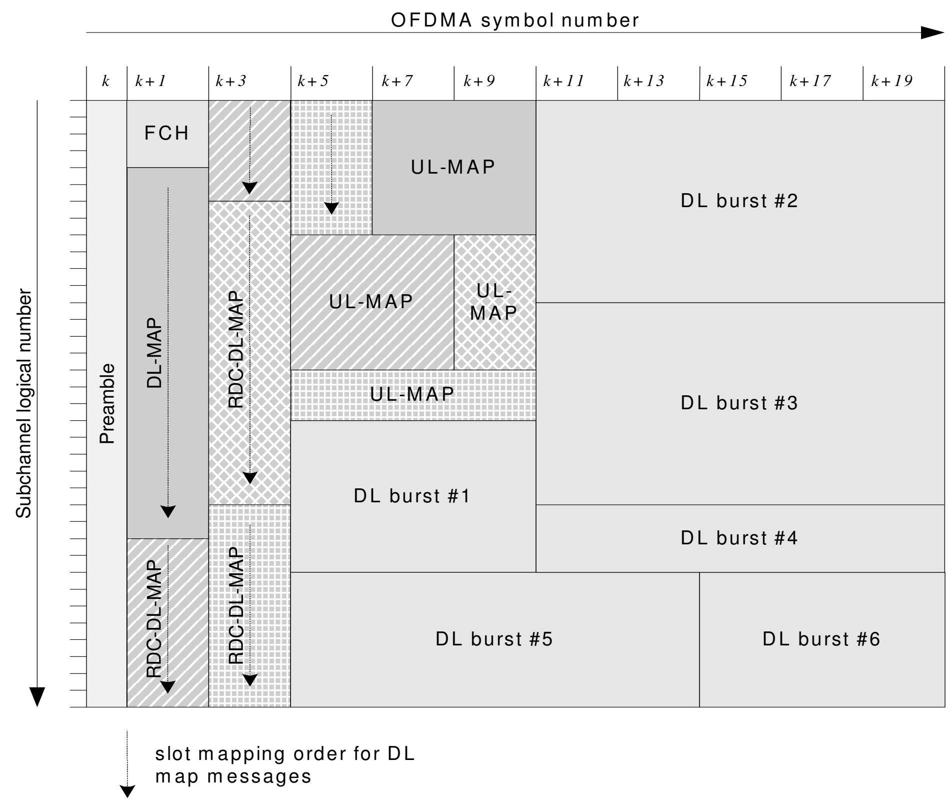


**Figure 229a – Illustration of DL sub-frame structure with multiple broadcast maps**

***[Add new section 8.4.5.3.19]***

## 8.4.5.3.19 RDC-DL-MAP-LIST_IE format

In the mandatory DL-MAP, the BS may transmit DIUC=15 with RDC-DL-MAP-LIST_IE() to describe the RDC-DL-MAP messages that follow the DL-MAP (in frequency-first slot mapping order). This IE is defined in table 284j.

**Table 284j—RDC-DL-MAP-LIST extended IE format**

| **Syntax** | **Size** | **Notes** |
|---|---|---|
| RDC-DL-MAP-LIST_IE() { | | |
| Extended DIUC | 4 bits | DL-MAP-UNI = 0xE |
| Length | 4 bits | Length = 2*n |
| For (i=0; i< n; i++) | | |
| DIUC | 4 bits | |
| Number of slots | 8 bits | |
| Repetition coding indication | 2 bits | 0b00 - No repetition coding<br>0b01 - Repetition coding of 2 used<br>0b10 - Repetition coding of 4 used<br>0b11 - Repetition coding of 6 used |
| Initial INC_CID | 1 bit | Initial value of INC_CID that shall be assumed when processing this RDC-DL-MAP. |
| *Reserved* | 1 bit | Shall be set to zero |
| } | | |

| | | |
|---|---|---|
| } | | |

**DIUC**
DIUC used for the i-*th* burst described by this IE.

**Number of slots**
Defines the length of the i-*th* burst in slots (including repetition code).

**Repetition coding indication**
Indicates the repetition code used inside the i-*th* 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 shall begin in the mode where CIDs are not included. RDC-DL-MAP messages shall begin in the mode specified in the RDC-DL-MAP-LIST_IE. The first appearance of the CID-Switch_IE() shall toggle the 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<br>0b01 = Optional PUSC permutation<br>0b10 = adjacent-subcarrier permutation<br>0b11 = *Reserved* |
| OFDMA symbol offset | 8 bits | |
| Preamble indication | 2 bits | 0b00 = No preamble<br>0b01 = Preamble used<br>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<br>0b01 = FUSC permutation<br>0b10 = Optional FUSC permutation<br>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* |
| Map Index | 2 bits | Index of RDC-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:<br>00: no change;<br>01: +2dB;<br>10: -1dB;<br>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 |
| } | | |
| } | | |

## *[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, and RDC-UL-MAP formats described in 6.3.2.3.2, 6.3.2.3.59, and 6.3.2.3.4, and 6.3.2.3.60, these messages the 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. A compressed RDC-UL-MAP shall only appear after a compressed RDC-DL-MAP. The presence of a compressed UL-MAP (RDC-UL-MAP) is indicated by a bit in the corresponding compressed DL-MAP (RDC-DL-MAP) data structure.

***[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 304a. 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 304a—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 | |
| Compressed map type | 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 0b11 in this field indicates the map message conforms to the compressed format described here. A value of binary 0b00 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.
**Compressed map type**
This value shall be set to 0b10 here to differentiate from other types of compressed maps.
**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.

***[Add new section 8.4.5.6.4]***

### 8.4.5.6.4 Compressed RDC-UL-MAP

The compressed RDC-UL-MAP format is presented in Table 304b. The message may only appear after a compressed RDC-DL-MAP message to which it shall be appended. The message presents the same information as the compressed UL-MAP with the addition of the 'Map index' field.

**Table 304b —** Compressed RDC-UL-MAP message format

| Syntax | Size | Notes |
|---|---|---|
| Compressed_RDC-UL-MAP () { | | |
| UCD Count | 8 bits | |
| Allocation Start Time | 32 bits | |
| Map index | 2 bits | |
| *reserved* | 2 bits | |
| while (map data remains){ | | |
| UL-MAP_IE() | *variable* | |
| } | | |
| If !(byte boundary) { | | |
| Padding Nibble | 4 bits | Padding to reach byte boundary. |
| } | | |
| } | | |

***[Modify section 11.8.3.7.6]***

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

# 5 References

[1] IEEE P802.16-2004.