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Re:	Call for technical proposals 802.16j-06/027.
Abstract	This contribution contains a technical proposal for a modified frame structure that enables communications to occur between an MR-BS, RS and SS. It requires no changes to the existing SS as defined in the IEEE Std. 802.16 and minimal changes to the existing BS. The frame structure is optimized for two-hop relaying and is extendible to support multihop relaying. The contribution also defines two new MAP IEs to support operation and a new SBC related TLV.
Purpose	For discussion and approval of inclusion of the proposed text into the P802.16j baseline document.
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Frame structure for multihop relaying support

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Introduction

In order to facilitate the introduction of non-transparent relays (i.e. RS that broadcasts its own preamble and other control messages) operating in the TDD mode of the OFDMA-PHY, modification to the current text in the standard is required to: define frame structure that supports multihop relaying; rules of operation in terms of RS transmission and reception intervals; and also the rules that the RS and MR-BS must follow in order to allow for turn-around in the RS and SS transceivers.

This contribution introduces a frame structure that is an extension to the existing TDD mode of the OFDMA-PHY. It enables BS and RS frame synchronous operation and also supports preamble, FCH and MAP transmission from an RS.

Whilst the frame structures introduced do require changes to the existing BS specification, they do not require any changes to the MS/SS as described in IEEE Std. 802.16. Also the frame structure is designed to provide an optimal solution for two-hop relaying that minimizes the number of changes required at the BS. It also enables the RS to reuse many of the standards features developed for the BS and SS, only requiring two new MAP IE's and one TLV to support the modified frame structure.

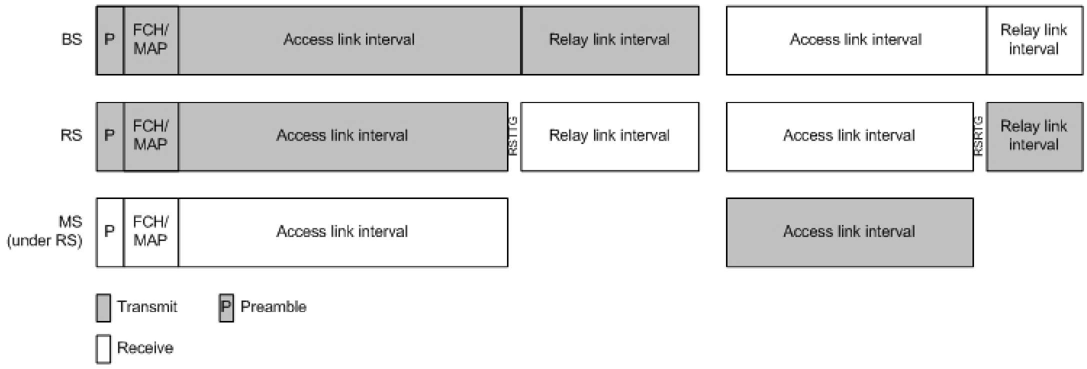
Proposed Frame Structure

The current TDD frame structure divides the frame into two subframes for downlink and uplink transmission. In this proposal, a simple extension to the frame structure is proposed to enable relaying that involves defining the existence of one or more relay link transmission and reception intervals in the MR-BS DL and UL subframes, respectively, to facilitate BS-RS communication. For beyond two-hop relaying, it is also possible to define a further relay link transmission and reception interval using two different approaches to facilitate RS-RS relaying.

Overview

The proposed frame structure for two-hop relaying is illustrated in Figure 1. The access link interval at the BS and RS require no changes to the frame structure in IEEE Std. 802.16 to define them. The new relay link (R-Link) interval does require new text to define its structure and also methods for allocating a R-Link interval.

Figure 2 illustrates the composition of the R-Link interval. The first symbol is optionally used for a relay midamble transmission (see [1] for further details) that can be used by the RS when operational as it cannot receive the preamble at the frame start. The first mandatory part of the R-Link interval is the FCH and MAP transmission, followed by optional data burst transmission. The structure of the FCH and MAP messages are unchanged from those defined in IEEE Std. 802.16 as used on the access link interval. The only change is that the MAP IEs supported on this link could be a combination of a subset of those supported on the access link and some new messages required for optimizing communications on the R-Link. The set of MAP IE messages supported on the R-Link are FFS, and at the moment this proposal provides no restriction assuming that full support of existing IEs is provided. Such discussion is out of scope of this contribution that focuses solely on frame structure definition.



Key: P Preamble
FCH Frame control header (including DLFP)
MAP Broadcast control including DL & UL data allocation map

Figure 1. Example frame structure for two hop relaying.

The only changes required to IEs defined in IEEE Std. 802.16 are an extra IE for use in the DL-MAP and UL-MAP to indicate where the relay link interval starts at a particular transmitter. These IEs can also be used in the DL-MAP and UL-MAP in the relay interval to indicate the location of the relay link interval in the next frame thus allowing the higher layers to control the relative amount of resource allocated to the access and relay links. The proposed IEs are shown in detail in the text proposal, in short they allow the transmitter to define the end of the R-Link interval and also enable indication of the DIUC used to convey the FCH and MAP messages.

If the RS does not successfully receive the MAP information in the relay link interval in any one frame, it can refer back to the MAP in the access link to find the location again, resulting in minimal impact on performance in future frames.

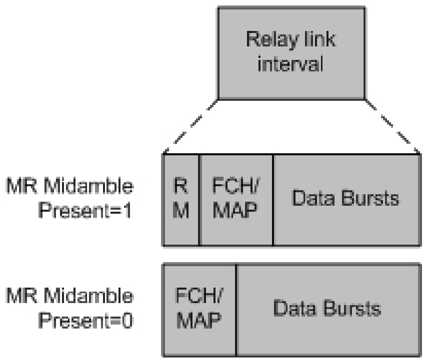


Figure 2. Relay link interval detail.

The two alternative methods for supporting beyond two hop relaying are shown in Figures 3 and 4.

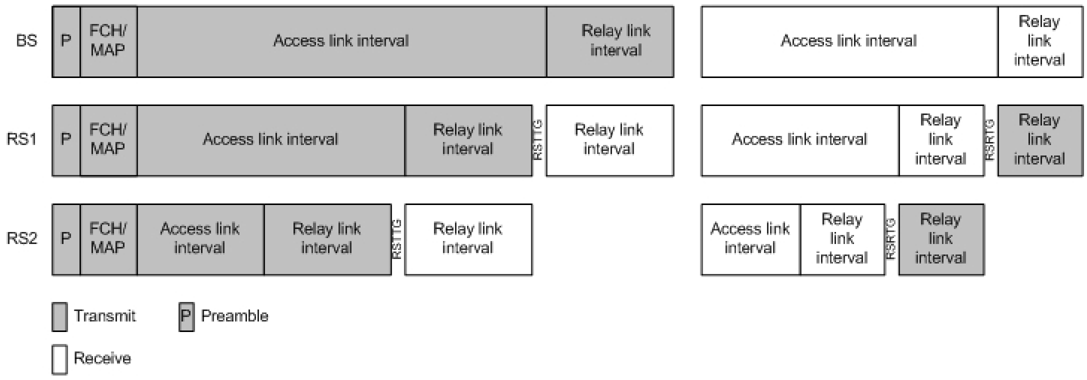


Figure 3. First example frame structure for beyond two hop relaying.

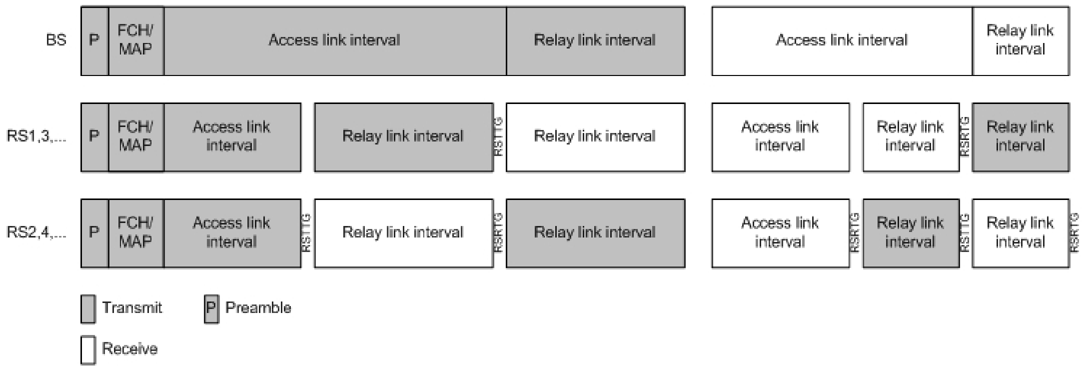


Figure 4. Second example frame structure for beyond two hop relaying.

Both extensions involve further subdivision of the access link interval at the RS to enable RS to RS communication. In the first technique, the access link is further subdivided for each additional hop. The second technique involves just one subdivision of the access link interval with multi-hopping being supported by alternating the usage of the two R-link intervals within the DL & UL subframes between transmission and reception.

As a result, in this proposed method the BS and the SS still obey the same frame structure as defined in IEEE 802.16-2004. Within the DL subframe, the RS may operate in both transmit and receive modes at different intervals to receive communications directed in a forward direction from a BS or RS and transmit signals to other RS or SS in a forward direction. Likewise, in the UL subframe, the RS may operate in both transmit and receive modes at different intervals to receive communications directed in a reverse direction from a SS or RS and transmit signals to other RS or BS in a reverse direction. However, the RS will never be required to perform simultaneous transmission and reception. Every time the RS transitions between transmit and receive a transition gap must be allowed for.

Finally, the process of RS network entry when utilizing this frame structure is described in [2].

Advantages of the proposal

The proposed frame structure ensures that the frame start times at the BS and RSs are synchronized. By operating in a time synchronized mode (i.e. transmitting 0b01 or 0b10 in the PHY Profile ID in the MOB_NBR-ADV message) it ensures that in the single frequency network case the boosted preamble transmissions do not cause interference with data transmissions, and in the case of time/frequency synchronization enables support of macro-diversity based communications such as Multi-BS-MBS and optimized handover. Through the allocation of different segments to the RSs during network entry [2] it is possible to minimize the interference between broadcast messages when using a segmented PUSC zone at the start of the frames. Thus for the SS point-of-view the composite network formed by BS and RSs looks just like a standard IEEE Std. 802.16 network.

This frame structure enables relaying with only a single frame latency on the DL and minimizes the number of transmit/receive transitions at the RS, requiring no extra transitions for two-hop relaying due to the ordering in time of the access link and relay link intervals. Whilst it could be possible to devise frame structures that theoretically enable in-frame relaying on the DL, it is considered that the processing time requirements would impose significant burden on the RS transceiver. This is becuase within the period of less than the DL subframe the RS would have to process the control and data transmission on the access link and construct the control and data transmission for the relay downlink. Based on the typical TDD realizations this would provide processing time of the much less than 1ms for the RS to perform such operations.

However, the proposed frame structure would enable the RS to perform fast relaying on the UL (i.e. within the same subframe) and this may be feasible to implement for the control related messages such as those on the ACK and Fastfeedback channels where special modulation techniques are used to facilitate fast processing at the receiver.

For three or more hop relaying two variants exist, as described. The first is beneficial in that it does not require further transceiver transitions, however it requires subdivision of the DL and UL subframes, such that the available resource for the access link decreases with increasing hop number. Therefore, this solution is not suitable for large number of hops. The second is beneficial in that only requires one extra relay link interval in the DL and UL subframe, however it does require further transceiver transitions, and hence transition gaps.

Finally, a further benefit is that the RS is the same as the BS from the point of transmission on the access link. Further, the RS is very similar to the SS on the relay link, from the point-of-view of the BS. Therefore, all of the existing messages and information elements defined for the access link can be reused on the relay link.

Conclusion

This proposal provides a simple extension to the existing frame structure defined in IEEE Std. 802.16 that enables support for non-transparent relaying. It provides an optimal solution for the two-hop case and is extendible to support multihop relaying. In order to support this frame structure only two new MAP IEs are required along with one TLV. This enables reuse of much of the features already defined for the BS and SS for the purposes of defining the operation of the RS.

Proposed text changes

[Insert the following text at the end of the subclause 6.3.7.2:]

If the BS supports multihop relay then the DL and UL subframes shall be subdivided into a number of transmission intervals to define the time in the subframe that the MR-BS and RS can expect to be either operating in transmit or receive mode. The ordering of the different intervals is defined in the OFDMA PHY specific section and the duration of each of these intervals within the subframe is controlled in the higher layers within the system.

[Change subclause 6.3.7.3 as indicated:]

6.3.7.3 DL-MAP

The DL-MAP message defines the usage of the dowlink intervals on the access and relay links for a burst mode PHY.

[Change subclause 6.3.7.4 as indicated:]

6.3.7.4 UL-MAP

The UL-MAP message defines the uplink usage on the access and relay links in terms of the offset of the burst relative to the Allocation Start Time (units PHY-specific).

[Insert a new subclause 8.4.4.2.1:]

8.4.4.2.1 TDD frame structure extension for MR

When implementing a TDD system that supports multihop relaying, the frame structure is built from RS transmissions as well as MR-BS and SS transmissions. In the DL transmission period the BS and RS may transmit and in the UL transmission period the SS and RS may transmit.

The OFDMA frame may include one or more R-Link transmission and reception intervals and the RS may perform both transmission and reception in one subframe. In general the access link interval shall precede the R-Link interval(s). For two-hop relaying the DL subframe consists of a DL access link interval followed by one R-DL interval. The UL subframe consists of an access link interval followed by one R-UL interval. The details of the R-Link interval are provided later in this section. Figure xxx illustrates the frame structure for the two-hop case.

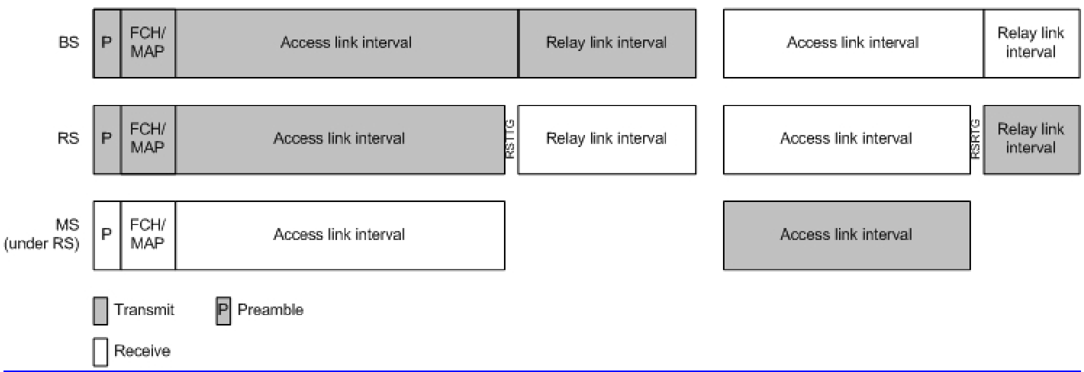


Figure xxx – Example two-hop MR frame structure.

For the case of more than two hop relaying one extra R-Link interval may be utilized in the DL and UL subframes at an RS, prior to the R-Link intervals illustrated in Figure xxx. Two different options are available for facilitating more than two hop relaying. The first is illustrated in Figure xxx and involves using part of the access link to provide an R-Link when an RS connects to the BS or RS that is not already communicating with another RS.

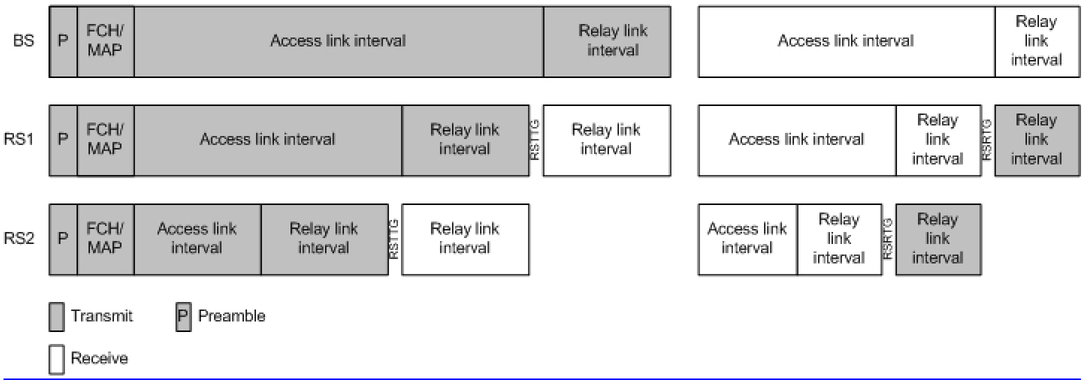


Figure xxx – Frame structure for beyond two-hop relaying (Option 1).

The second frame structure option for more than two-hop relaying is illustrated in Figure xxx. It involves two R-Link intervals in both the DL and UL subframes that alternate between transmission and reception with increasing number of hops from the BS.

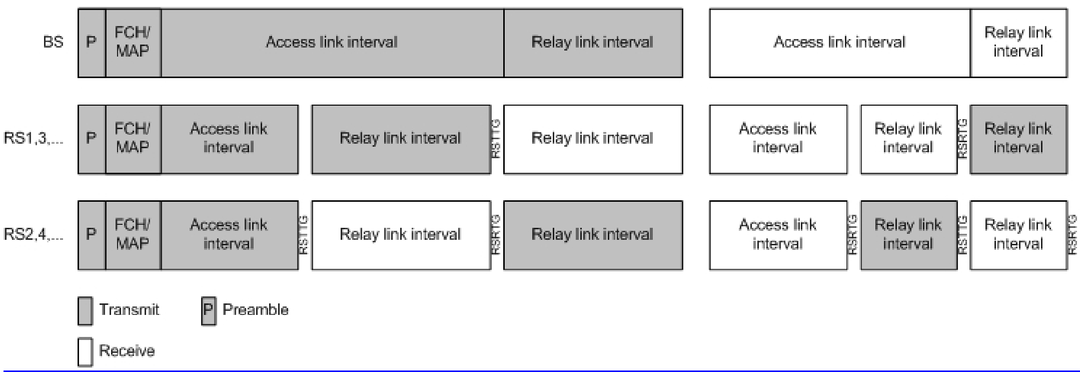


Figure xxx – Frame structure for beyond two-hop relaying (Option 2).

The frame start time at the BS and RSs shall be synchronized within the timing tolerance of 1/8 of the CP.

Allowances shall be made by an RSTTG and RSRTG in between transmit and receive periods to allow the RS to turn around. The capabilities RSTTG and RSRTG will be provided by the RS during RS network entry (see 11.8.3.7.20).

When the RS transmission and reception operation is not controlled by the RS, information shall not be transmitted to an RS later than (RSRTG+RTD) before an RS transmit allocation, and information shall not be transmitted to it earlier than (RSTTG-RTD) after the end of the an RS transmit allocation, where RTD denotes the round-trip-delay between the transmitter and the RS.

The RS shall make allowances for the subscriber station by an SSRTG and SSTTG. The capabilities SSRTG and SSTTG will be acquired by the RS during SS network entry.

The RS shall not transmit to an SS later than (SSRTG+RTD) before its scheduled uplink allocation, and shall not transmit downlink information to it earlier than (SSTTG-RTD) after the end of its scheduled uplink allocation, where RTD denotes the RS to SS round trip delay.

The RS shall transmit a preamble signal, FCH and MAP at the start of the DL subframe on the access link. In order to facilitate the reception of control related information from the MR-BS, the MR-BS shall make use of the R-Link transmission interval that is arranged to occur after the RS has completed transmission of the access link to optionally transmit a MR midamble followed by a mandatory FCH. The FCH contains the DL Frame Prefix described in Section 8.4.4.3, and specifies the length of the DL-MAP message that immediately follows the DL Frame Prefix and the coding used for the DL-MAP message. The FCH and MAP messages in the R-Link interval shall transmitted in a PUSC zone using the DIUC indicated in the DL-MAP IE that defined the R-Link interval. The structure of the R-DL interval is illustrated in Figure xxx.

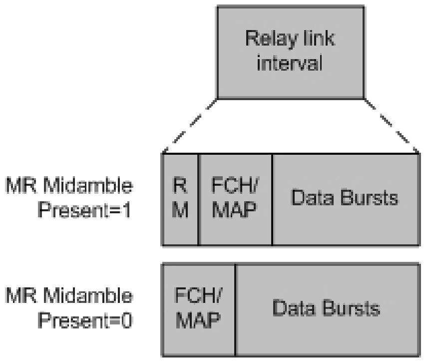


Figure xxx – Structure of the R-DL interval.

The existence of a MR midamble and the start position of the R-DL transmission interval shall be signaled in the MR_DL_Allocation IE. This message shall also indicate the DIUC to be used for the FCH and MAP messages and indicates the duration of the R-DL interval. Once an R-DL transmission interval is defined, the start position and duration can be changed at any time by altering the values in the MR_DL_Allocation_IE. A similar MR_UL_Allocation_IE shall be used in the UL-MAP to define the R-UL reception interval. The MR_DL_Allocation_IE and MR_UL_Allocation_IE may also be used in the DL-MAP and UL-MAP messages respectively on the R-DL to indicated the location of the R-Link intervals in the DL and UL subframes in the next frame.

An RS shall be capable of receiving control information on the R-Link that may impose restrictions on the resource usage on the access link to prevent the RS performing resource allocation at certain intervals in time.

8.4.4.3 DL frame prefix

[Change the text following Table 268 as indicated:]

Repetition_Coding_Indication
Indicates the repetition code used for the DL-MAP. Repetition code may be 0 (no additional repetition), 1 (one additional repetition), 2 (three additional repetitions) or 3 (five additional repetitions). For DL_Frame_Prefix on the FCH in the R-Link this field shall not be used as repetition coding is not supported on the DL-MAP in the R-DL.
Coding_Indication
Indicates the FEC encoding code used for the DL-MAP. The DL-MAP shall be transmitted with QPSK modulation at FEC rate 1/2. Note that t The BS mustshall ensure that DL-MAP (and other MAC messages required for SS operation) are sent with the mandatory coding scheme often

enough to ensure uninterrupted operation of SS supporting only the mandatory coding scheme. For DL_Frame_Prefix on the FCH in the R-Link this field shall not be used, the FEC encoding code is indicated in the DIUC that defined the R-DL.

[Change the items in Table 277a in Section 8.4.5.3.2.1 as indicated:]

09 MR_DL_Allocation_IE
~~09~~ 0A *Reserved*

[Insert new subclause 8.4.5.3.28:]

8.4.5.3.28 MR_DL_Allocation_IE

In the DL-MAP on the access link, an MR-BS or RS may transmit DIUC = 15 with the MR_DL_Allocation_IE() to indicate the location of the R-DL interval in the DL subframe as well as whether an MR midamble is present at the start of this interval. The usage of the of the interval is described by the FCH and DL-MAP located following the MR midamble in the R-DL transmission interval. In the DL-MAP on the R-Link, an MR-BS or RS may transmit DIUC = 15 with the MR_DL_Allocation_IE() to indicate the location of the R-DL transmission interval in the next frame.

Table 286aa – MR DL Allocation

Syntax	Size	Notes
MR_DL_Allocation_IE(){		
Extended DIUC	4 bits	MR_DL_Allocation_IE = 0x09
Length	4 bits	
MR midamble present	1 bit	0b0 = No midamble 0b1 = Midamble is first symbol in the allocation.
R-DL duration present	1 bit	0b0 = No duration field present, R-DL extends to the end of the subframe 0b1 = Duration field is present, R-DL defined by this IE has a defined duration
FCH and MAP DIUC	4 bits	DIUC used to transmit the FCH and MAP messages on the R-Link.
R-DL OFDMA symbol offset	8 bits	Location of the R-DL interval relative to the frame start.
if (R-DL duration present = 1) {		
R-DL duration	8 bits	Duration of the R-DL interval in symbols.
}		
}		

[Change the items in Table 290a in Section 8.4.5.4.4.1 as indicated:]

0B MR_UL_Allocation_IE
0~~B~~C … 0F *Reserved*

[Insert new subclause 8.4.5.4.29:]

8.4.5.4.29 MR_UL_Allocation_IE

In the UL-MAP on the access link, an MR-BS or RS may transmit UIUC = 15 with the MR_UL_Allocation_IE() to indicate the location of the R-UL interval in the UL subframe. The usage of this interval is described by the UL-MAP that follows the DL-MAP in the R-DL interval. In the UL-MAP on the R-Link, an MR-BS or RS may transmit UIUC = 15 with the MR_UL_Allocation_IE() to indicate the location of the R-UL receive interval in the next frame.

Table 286ab – MR UL Allocation

Syntax	Size	Notes
MR_UL _Allocation_IE(){		
Extended UIUC	4 bits	MR_UL_Allocation_IE = 0x0B
Length	4 bits	
R-UL duration present	1 bit	0b0 = No duration field present; R-UL extends to the end of the subframe. 0b1 = Duration field is present; R-UL defined by this IE has a defined duration.
OFDMA symbol offset	8 bits	-
if (R-UL duration present = 1) {		
R-UL duration	8 bits	Duration of the R-UL interval in symbols.
}		

[Insert new subclause 11.8.3.7.21:]

11.8.3.7.21 RS transition gaps

Type	Length	Value	Scope
TBA	1	Bits #0–3: RSTTG (OFDMA symbols) Bits #4–8: RSRTG (OFDMA symbols)	SBC-REQ SBC-RSP

References

[1] Hart, M. et al., “Relay midamble”, IEEE C802.16j-06/144, IEEE 802.16 meeting #46, Dallas, November 2006.

[2] Hart, M. et al., “Network entry procedure for non-transparent relay station”, IEEE C802.16j-06/143, IEEE 802.16 meeting #46, Dallas, November 2006.