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Abstract	To allow for concurrent transmission of bursts, this contribution proposes three new extended IE formats (OFDM DL-MAP IE, SCa DL-MAP IE and SCa UL-MAP IE). The approach of using extended IEs for concurrent transmission of bursts will neither affect the control structure during normal operation nor will it introduce additional overhead.
Purpose	For inclusion in the 802.16-REVd_D3 document
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Extended IE format for concurrent transmission of bursts

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References

[SmartAntennas] T. Rappaport, J. Liberti, "Smart Antennas for Wireless Communications: IS-95 and Third Generation CDMA Applications", Prentice Hall, 1999

[802.16a-2003] IEEE802.16a-2003

[802.16-REVd/D3-2004] IEEE802.16-REVd/D3-2004

[WWRF03_SDMA] Hoymann, Ibing, Forkel, *"MAC Layer Concepts to Support Space Division Multiple Access in Wireless Metropolitan Area Networks (IEEE 802.16a)"*, 10th WWRF Meeting, October 2003, USA
www.comnets.rwth-aachen.de/publications/Abstracts/hoyibiifl_wwrf03.html

Executive summary

To allow for concurrent transmission of bursts, this contribution proposes three new extended IE formats (OFDM DL-MAP IE, SCa DL-MAP IE and SCa UL-MAP IE). The approach of using extended IEs for concurrent transmission of bursts will neither affect the control structure during normal operation nor will it introduce additional overhead.

Introduction

If an antenna array is applied at the 802.16 base station, beamforming algorithms allow the transmission of power in certain directions to increase the receiver signal-to-noise ratio. It is also possible to steer nulls into certain directions to decrease co-channel interference. A beam is steered by applying a weight, i.e. a complex number to each antenna element. Thus, a beam is represented by a weight vector $\mathbf{w_i}$ which contains one weight per antenna element (see figure 1). If multiple beams are applied, one weight vector per beam has to be calculated ($\mathbf{w_0}$, $\mathbf{w_1}$, $\mathbf{w_{K-1}}$).

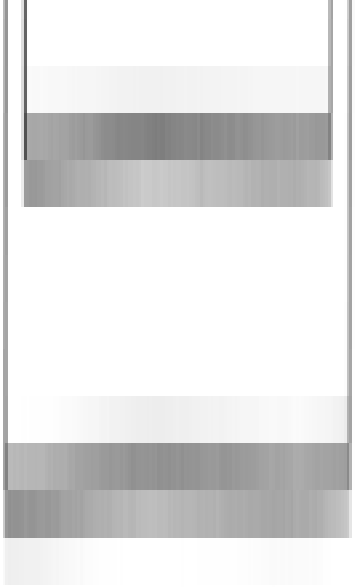

figure 1: Beamformer for multiple signals [SmartAntennas]

By applying multiple beams, a signal can be directed to a certain SS, e.g. user 1, and a null can be placed in the direction of another SS, e.g. user 2, assuming the SSs can be separated well enough by the applied algorithm. At the same time, on the same frequency a different signal can be sent by the BS which is directed to user 2 and has a null steered to user 1. The amplitude factors of an optimized beamforming algorithm in a two-user scenario are shown in figure 2. Similarly several SSs can be served simultaneously without significant interactions. This principle can be applied in downlink as well as in uplink.

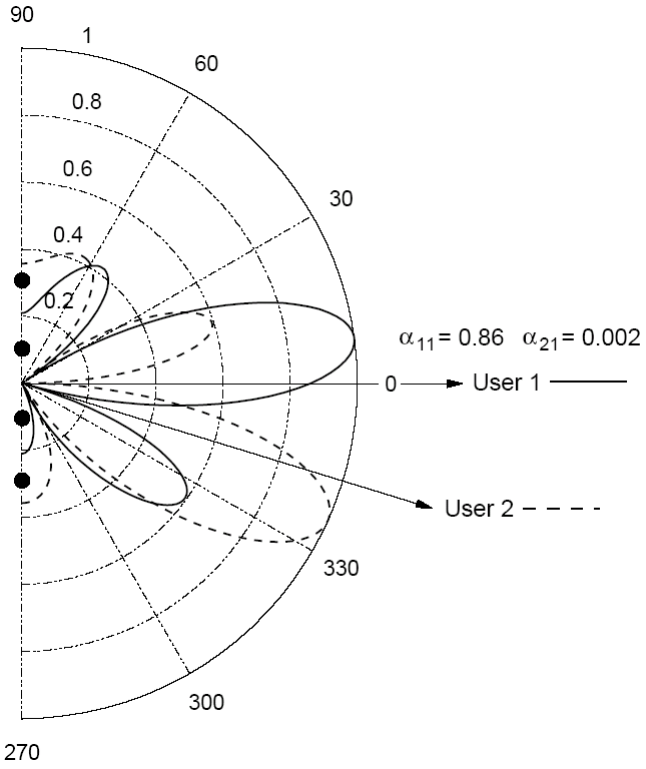

figure 2: Amplitude factors in a two user scenario and two optimized beam patterns

The resulting structure of the IEEE 802.16 MAC frame with concurrent DL/UL bursts has to be specified by the DL-MAP and UL-MAP respectively. Besides the time dimension a new spatial dimension occurs, this is outlined in figure 3.

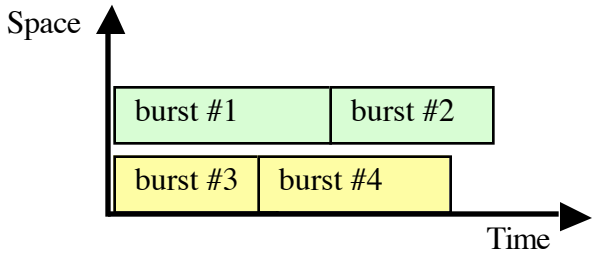

figure 3: Concurrent bursts

OFDM

The 802.16a OFDM PHY is based on a successive sequence of bursts. It is sufficient to specify the start time in the DL-MAP information element (IE), due to the fact that the start time of the following burst is implicitly the end of the current downlink burst. For the UL-MAP IE, only the duration of the burst (and the CID) is given. The start time and the end of each uplink burst can be easily calculated by adding up all preceding burst durations [802.16a-2003].

To support the introduction of concurrently transmitted bursts, knowledge of the start time of a burst does not provide all required information. Both, the UL- and the DL-MAP IEs need to determine the start and the end of each burst to be able to signal the enhanced structure of the MAC frame to the SSs. The frame structure must not rely on the sequential nature of the bursts. In downlink, a preamble shall be included in front of each parallel burst, because the change of the antenna array's beam pattern might change the received signal. Channel estimation and synchronization might be updated during reception of the preamble. A detailed description of the specification of concurrent bursts by a WirelessMAN MAC frame can be found in [WWRF03_SDMA].

Within the OFDM PHY of the new draft of 802.16 [802.16-REVd/D3-2004] some of the requirements for the support of concurrent bursts have already been introduced. The UL-MAP IE contains the start time, the CID and the duration (refer to table 210 on page 432f). The DL-MAP IE contains the CID and the start time (refer to table 203 on page 429). But within the DL-MAP IE the duration is still missing and that disables the transmission of simultaneous bursts in DL direction. Thus, this contribution proposes a new extended OFDM DL-MAP IE to include the burst duration.

OFDMA

The OFDMA MAP IEs contain all necessary information to specify concurrent bursts. No changes are proposed for this PHY mode.

SCa

The current SCa PHY is based on a successive sequence of bursts. It is sufficient to specify the Offset, i.e. start time, in the DL- and UL-MAP information element (IE), due to the fact that the Offset of the following burst is implicitly the end of the current burst. Having a new degree of freedom, the successive structure may be substituted by a parallel one. Both, the UL- and the DL-MAP IEs need to determine the start and the end of each burst to be

able to signal concurrent bursts to the SSs. For the downlink, a preamble shall be included in front of each concurrent burst and the CID of the assigned SS has to be specified. Thus, a SCa DL- and UL-MAP extended IE is proposed.

The approach of using extended IEs for concurrent bursts will neither affect the control structure during normal operation nor will it introduce additional overhead.

Proposed Contribution

Insert at the end of the first paragraph of 6.4.7.6.1 (line 30 on page 160):

Combining the benefits of increasing the SNR of certain subscribers and steering nulls to others, enables bursts to be concurrently transmitted to spatially separated SSs. For the uplink direction the same principle can be applied in a reciprocal fashion. A concurrent transmission of bursts does not necessarily increase the system's range but may enhance system capacity.

Insert into line 43of 6.4.7.6.1 (line 43 on page 160):

AAS enabled SSs **may** use dedicated private DL-MAP/UL-MAP messages and are therefore prevented from colliding with non-AAS traffic.

Insert at the end of 6.4.7.6.2 (line 55 on page 160):

The control of AAS **enabled SSs may** ~~**part of the frame shall**~~ be done by unicasting private management messages to individual SSs. These messages shall be the same as the broadcast management messages, except that the basic CID assigned to the SS is used instead of the Broadcast CID.

If AAS enabled SSs can decode the broadcast DL-MAP and DCD messages, the BS may specify concurrent bursts by means of the extended concurrent transmission IE format as described in 8.2.1.5.5.2.6, 8.2.1.5.5.3.4 and 8.3.5.2.6.

Insert at the end of 6.4.2.3 (line 16 on page 62):

To control ~~**During the**~~ adaptive antenna system (AAS) **enabled SSs** ~~**portion of the frame**~~, DL-MAP, UL-MAP, DCD, UCD, and CLK-CMP messages **may** ~~**shall**~~ be sent using the basic CID.

Insert new section 8.2.1.5.5.2.6, fix up the table numbers as required (line 1 on page 391):

8.2.1.5.5.2.6 Concurrent transmission IE format

In the DL-MAP, a BS may transmit DIUC=15 with a DL_Concurrent_IE() to specify one of a set of parallel downlink bursts for transmission. The extended format explicitly specifies the duration and the CID of the corresponding downlink burst. A preamble may precede the downlink burst specified by this IE. When present the preamble shall have the same characteristics as the burst set preamble of the current DL subframe.

Table 178 – SCa Concurrent transmission IE format

Syntax	Size	Notes
DL_Concurrent_IE() {		
Subcode	4 bits	CONC = 0x04
Length	4 bits	Length = 7
Preamble present	1 bit	0 – No preamble preceding burst 1 – Preamble precedes burst
Reserved	3 bits	
DIUC	4 bits	
Offset	16 bits	
CID	16 bits	
Duration	16 bits	Duration of burst in PS
}		

DIUC:

A 4-bit DIUC shall be used to define the burst type associated with that burst. Burst Descriptor shall be included into DCD message for each DIUC used in the DL-MAP. The DIUC shall be one of the Data Grant (1-12) values defined in Table 172.

Offset:

Offset (in units of PSs) to the start of the data burst from the start of the frame.

CID:

Identifies the target of the concurrent burst. The value may be a unicast, multicast, or broadcast address. When specifically addressed, the CID shall be the Basic CID of the SS.

Duration:

Specifies the length of the associated burst in PS.

Insert new section 8.2.1.5.5.3.4, fix up the table numbers as required (line 17 on page 394):

8.2.1.5.5.3.4 Concurrent transmission IE format

In the UL-MAP, a BS may transmit UIUC=15 with the UL_Concurrent_IE() to specify one of a set of parallel uplink allocations for transmission. This format allows to explicitly determine the duration of the corresponding uplink burst.

Table 183 – SCa Concurrent transmission IE format

Syntax	Size	Notes
UL_Concurrent_IE() {		
Subcode	4 bits	CONC = 0x03
Length	4 bits	Length = 4 if Burst set type is not Subchannel 5 if Burst set type is Subchannel
UIUC	4 bits	
Offset	12 bits	
Duration	12 bits	Duration of burst in minislots
Reserved	4 bits	
If (Burst set type is Subchannel) {		
Starting subchannel	4 bits	
Subchannel count	4 bits	
}		
}		

UIUC:

UIUC shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included into an UCD message for each UIUC used in the UL-MAP. The UIUC shall be one of the values defined in Table 179 except Gap, End of map or Extended UIUC.

Offset:

Indicates the start time, in units of minislots, of the burst relative to the Allocation Start Time given in the UL-MAP message.

Duration:

Specifies the length of the associated burst in minislots.

Starting subchannel:

For bursts associated with the subchannel burst frame type, this parameter specifies starting subchannel assigned to the transmission. Specifies the length of the associated burst in minislots.

Subchannel count:

For bursts associated with the subchannel burst set type, this parameter specifies the number of adjacent subchannels assigned to the transmission.

Insert new section 8.3.5.2.6, fix up the table numbers as required (page 432):

8.3.5.2.6 DL-MAP concurrent transmission IE format

In the DL-MAP, a BS may transmit DIUC=15 with a DL_Concurrent_IE() to specify one of a set of parallel downlink bursts for transmission. The extended format explicitly specifies the duration of the corresponding downlink burst. A preamble may precede the downlink burst specified by this IE.

Table 209 – OFDM DL_MAP Concurrent transmission IE format

Syntax	Size	Notes
DL_Concurrent_IE() {		
Extended DIUC	4 bits	CONC = 0x03
Length	4 bits	Length = 2
DIUC	4 bits	
Duration	12 bits	Duration of burst in OFDM symbols
}		

DIUC

A 4-bit DIUC shall be used to define the burst type associated with that time interval. Burst Descriptor shall be included into DCD message for each DIUC used in the DL-MAP. The DIUC shall be one of the Burst Profile values (1-12) defined in Table 204.

Duration

Indicates the duration of the burst, in units of OFDM symbols. The duration is inclusive of the preamble contained in the allocation, if present.

Change entry of table 203 (on page 429):

Preamble present	1 bit	0 = not present, 1 = present if **(**DIUC == 15 **AND NOT Extended DIUC = 3)**, shall be 0

Change section number 8.3.5.2.6 to 8.3.5.2.7 (on page 432)

Change entry of table 209 (on page 432):

Extended DIUC	4 bits	~~**0x03**~~ **0x04** … 0x0F