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Proposed Changes to OFDM AAS mode

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1. Background

The AAS mode as defined for the OFDM PHY has several major deficiencies. These are related to

- The format of the DL traffic and the control mechanisms.
- The network entry procedure.

This section identifies the identified problems. The following sections provide the proposed solutions.

1.1. Frame format and control mechanism

From the current specifications,([1]) it is not clear how the DL burst parameters (modulation and length) are conveyed to the listening SSs. In the non-AAS section there is a mechanism of a Frame Control Header (FCH) which contains the Down Link Frame Prefix (DLFP). The DLFP conveys the modulation and length of burst #1. It is not clear from the text if the FCH+DLFP mechanism is used in the AAS section. If yes, this mechanism is inefficient since it will mandate that an FCH burst shall be used with every DL-burst.

More importantly, the use of DL beam-forming requires that every burst shall be preceded by a preamble symbol. This is required to allow channel estimation at the SS. The preamble symbol cannot be shared among all the bursts, (as in the non-AAS DL), since each burst is directed towards a different SS, and the channel response will differ from burst to burst.

To quantify these effects, let us assume that a short payload, (64 bytes) is transmitted at QAM16 with coding rate ½. Let us assume that an FCH burst is used. The burst is transmitted at the most robust rate, QPSK rate ½ and carries 24 bytes of data. The FCH burst contains the DLFP (3 bytes), part of the payload, and a tail byte. Thus 24-3-1=20 bytes are carried in the FCH. The rest of the payload, 64-20=44, is carried in an additional OFDM symbol. The burst is preceded by a preamble symbol. The preamble overhead is 50%. The overall air efficiency (number of data bits divided by used subcarriers and by the net spectral efficiency) is 64*8bits / (3*192subc)/ 2bits/subc=44%.

By repeating this analysis for uniformly distributed payload lengths in the range [48,512] the average air efficiency is 69%. For QAM64 rate¾, the average air efficiency is 49%.

1.2. Network entry

The network entry procedure is not properly defined.

Firstly, the initial ranging signal is not clearly defined. In the common description of 'Optional MAC support for of 2-11GHz AASs, [1], pp. 208, 6.4.7.6.4, the text reads: "Unlike usual initial ranging, the SS shall use all available contention slots, in order to allow the BS adaptive array enough time and processing gain to shape the beam for it.". However, in the corresponding OFDM PHY section, no mentioning is made on what is the actual initial ranging signal for AAS mode and how to utilize all contention slots.

Secondly, there are some problems associated with the mechanism used for marking the 'Alert slots'. According to [1], 8.3.6.2, pp 432, the text reads:

" A BS supporting the AAS option may allocate in the uplink sub frame a 8 OFDM symbol initial ranging slot for AAS SSs that have to initially alert the BS of their presence … During the first OFDM symbol of this AAS initial ranging slot, the BS shall transmit the AAS network entry preamble."

The network entry preamble is important, because it allows SSs to determine if they operate in an AAS cell. A SS needs to first detect the network entry preamble, and transmit the network entry request in the following 8 symbols. This requires a Rx-Tx turn around, which may be as high as 100uS in the FDD case (see [1] 11.4.2.2.10).

Another associated problem is the duration of the alert slots. Currently it is specified in units of OFDM symbols, whereas it should be specified in absolute time units. At high BWs the resulting duration will be too short. For instance, at a BW of 28MHz, the duration of one OFDM symbol is ~10uS. The supported round-trip delay is (8-3)*10us=50uS, (assuming that 3 symbols are used for the initial ranging burst, and zero turn around time). This is equivalent to a cell radius of 7.5Km.

A third problem associated with the network entry procedure is that the BST has no channel measurement it can use to form the beam towards the SS entering the network. This is crucial for FDD operation for channel reciprocity is not guaranteed. The AAS-FDBK-REQ/RSP does provide such measurements but it requires that some handshake will be established. However, the response to an initial ranging should be performed prior to the establishment of such handshake.

2. AAS DL structure

2.1. Proposed approach

The approach proposed here is to arrange the AAS DL in an OFDMA manner. The DL channel is divided into 16 subchannels. A single subchannel is dedicated for the control messages.

To quantify the merits of this approach let us consider the example of section 1.1. Assume again that the 64 bytes payload is transmitted at QAM16 rate ½ using 1/16 of the channel. The AAS format proposed below uses 8 bytes of control information. The payload and control information would require 24 symbols w/o midambles, and 27 symbols with midambles. The overall number of subcarriers is (27)*192/16. The total air efficiency is 79%. By repeating this analysis for uniformly distributed payload lengths in the range [48,512] the average air efficiency is 84%. For QAM64 rate ¾, the average air efficiency is 83%. This is compared with 69% and 49%, for QAM16 -½ and QAM64- 3/4, respectively, for the OFDM case.

2.2. Basic principles

To support the DL OFDMA a control subchannel (CCH) is designated . The CCH contains map information elements, AAS_MAP_IEs, which point to specific DL or UL allocations. These map inform ation elements can be embedded in the DL bursts. See Figure 1. All map information elements are relevant to the next frame. A BST shall assume that the SS is not capable of receiving more than one burst in a single frame.

The map structure defined above forms a chain of maps. The control channel is typically used to initiate such a chain. Additionally, the BST may echo some of the embedded DL map information elements on the control subchannel. This may be used for recovery in case one of the embedded DL map IEs was lost.

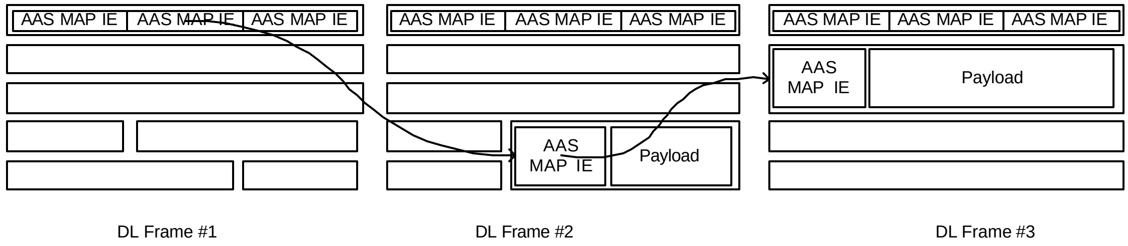

Figure 1 MAP structure in AAS mode

2.3. Information Elements

Field	Length, bits	Comments
direction	1	0=This element defines a DL allocation 1=This element defines an UL allocation
Last MAP IE in the chain	1	If '1', points to payload that does not contain more MAP IEs. Otherwise points to payload that starts with similar IE pointing to the next payload etc.
UL MAP present	1	If '1', next in the burst is UL IE, otherwise regular MAC messages; relevant only if the IE is embedded in the DL burst,
reserved	1	
IUC	4	IUC. Interpreted as UIUC if direction==1. Otherwise interpreted as DIUC
If (IUC!=1 && direction = =1)		
CID	16	
else {		Response to AAS network entry signal
Frame index number	4	Identifies the frame in which the network entry request, which this message responds to, was transmitted. Indicates the number of DL frames elapsed since the network entry request was transmitted, to the current frame. If the request was transmitted in the previous frame, Frame index number=0.
Network entry code	4	
reserved	8	
}		
Length	10	Length of the UL burst in symbols
Offset	11	Offset in symbols from the beginning of the next frame
Subchannel index	4+4	start subchannel + width
Preamble cyclic delay code	1	Cyclic delay used in the preamble and midambles of this burst. (See 8.3.53.7) 0=Zero delay 1= Delay with M=128.
Midamble repetition code code	2	Information about the preamble rotation and midamble repetition. 0b00: Preamble only 0b01: Midamble after every 8 data symbols 0b10: Midamble after every 16 data symbols 0b11: Midamble after every 32 data symbols
HCS	8	
Total	64	

2.4. PHY parameters of the DL AAS section

The DL is partitioned into 16 subchannels, with the same parameters as in the OFDM section. The following differences apply

1. The subchannelization allocation granularity is 1.
2. The interleaver structure is changed to accommodate an allocation granularity of 1.
3. The subchannel index code is changed. See table XXX.
4. Preambles may be rotated according to the preamble code.

2.5. The control channel

The CCH is composed of a single subchannel, carrying several PHY bursts. Each burst carries a single AAS_MAP_IE, defined below, and is transmitted using the most robust modulation.

There are two options:

a. The CCH is transmitted on a wide beam covering the entire sector. In this case the CCH may be boosted relative to the data subchannels to compensate for the reduction in antenna gain.
b. Each burst carrying CCH_MAP_IE is directed towards a specific SU.

The subchannel in which the CCH is transmitted is varied from sector to sector. During network entry, The SS searches for the subchannel carrying the CCH. The search is facilitated by the fact that the CCH bursts use well known parameters: modulation and length.

The capacity of the control channel can be increased by assigning an auxiliary CCH. The auxiliary CCH is allocated at the subchannel adjacent to the CCH subchannel. The SS can check this subchannel to see if an auxiliary CCH has been transmitted. This is the only case when the SS is required to decode two simultaneous subchannels.

3. Network entry procedure

3.1. Basic principles

3.1.1. Marking of the alert slot

- The alert slot is located at the ***end*** of the frame. This is true for both FDD and TDD systems.
- The network entry preamble is used to mark the offset of the alert slots in the ***next*** frame. It is assumed that the SS can determine the frame duration from the DL preambles. Both preamble and alert slot are marked as GAP in DL and UL MAPs.
- The alert slot is not restricted to a predefined duration.
- In TDD, transmitting the network entry preamble requires additional Rx-Tx and Tx-Rx transitions at the BST. No fast transitions are required at the SS.

3.1.2. Channel Feedback report in initial ranging

- The SS prepares a short channel feedback message containing the necessary information for the BST to form the beam towards the SS.
- The feedback message is appended to the initial ranging request.
- The network entry preamble is transmitted from all antennas using orthogonal preambles. This is used by the SS to prepare the short channel feedback message.

3.1.3. The initial ranging burst

- The initial ranging burst is transmitted in subchannelized mode. The subchannelization gain is used to partially compensate for the fact that the BST has no beam directed towards the specific SS. The request is transmitted on subchannel 0b00001.
- The network entry uses the same mechanism as in subchannelized network entry, where a 4 bit code is used to identify the request. This is needed because the network entry message carries a channel feedback message, and has to be kept as short as possible.
- The initial ranging is composes as follows:
  a. A 4x64 preamble on the entire symbol
  b. A 2x128 preamble on the entire symbol
  c. A subchannelized preamble on subchannel 0b00001.
  d. The network entry message.

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3.2. Network entry procedure

In AAS mode the network entry procedure is as follows:

1. AAS Alert slots are marked by the network entry preamble. The network entry preamble indicates the interval beginning one frame duration after the network entry preamble, and ending at the end of the frame is used as an AAS alert slot.
2. The SU selects at random an AAS random network entry alert slot [backoff needed?] and a 4 bit network entry code. The SS follows regular backoff procedure (see [1] 6.4.8), with ranging backoff start =1 and ranging backoff end=64. An alert slot is considered a single transmission opportunity.
3. In the selected AAS alert slot, the SU transmits the AAS network entry request signal. The signal is composed as follows:
    a. A 4x64 preamble transmitted on the entire BW
    b. A 2x128 preamble transmitted on the entire BW.
    c. A subchannelized preamble.
    d. The AAS_NETWORK_ENTRY_REQ, defined below, which contains the random network entry code and the estimated phase offsets. The AAS_NETWORK_ENTRY_REQ is transmitted on subchannel 0 using the most robust rate.
    e. The burst carries a SHORT_CHANNEL_FBCK message, which provides information for forming the beam towards the SS.
    f. The BST detects the signal, extracts ranging information and decodes the message.
    g. The BST response to the network entry request by allocating an UL TO identified by the relative frame index in which the network entry was transmitted and the network entry code. The allocation is performed by the CCH_MAP_IE. When transmitting the CCH_MAP_IE the BST may use the information embedded in SHORT_CHANNEL_FBCK.

AAS_NETWORK_ENTRY_REQ

Field	**Length, bits**	**Comments**
Network entry code	4	A randomly selected code.
SHORT_CHANNEL_FBCK	TBD	DL beam-forming information
padding bits	0/4	Padding to an integer number of bytes.
HCS	8	Header check sum.
Total	TBD	

4. References

[1] IEEE P802.16-REVd/ D2-2003