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Channel Estimation and Feedback Report for AAS OFDM mode

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1. Introduction

The objective of this document is to improve the support for DL beam forming in OFDM AAS mode. The improvements are achieved by introducing channel estimation and feedback report elements.

The proposed changes address the following needs:

a. Beamforming in initial ranging response
In an AAS system, the response to an initial ranging request should be transmitted using a directional beam. This is required since the SS may be located at the edge of the cell and the gain of the adaptive array should be utilized.
However, in order to form the beam towards the SS, the BST needs to know the vector channel response seen by the SS. The existing channel feedback report mechanism, AAS-FBCK-REQ/RSP, relies on the establishment of MAC layer handshake, while the initial ranging response should occur prior to that.
Some mechanisms are therefore required, to facilitate beamforming of an initial ranging response.

b. Open loop beamforming
The existing AAS feedback mechanism supports channel estimation which is performed either on the DL preambles or on the DL data. In both cases, channel estimation is performed on the already formed beam, and supports only closed loop beam-forming.
It is advantageous to facilitate also open loop beamforming, in which the channel response from each of the transmitting antennas can be directly estimated and reported. Open loop beamforming can significantly speed up the forming process and reduce the UL overhead associated with the feedback messages.

The above items are crucial for FDD operation since no reciprocity can be assumed. However, the design of TDD systems may be simplified if no channel reciprocity is assumed. The proposed mechanisms support a wide variety of AAS and beam forming systems and concepts. They are integrated well into the current definition of the air-protocol.

This contribution is an accompaniment to [1]. The proposed changes, however, can be adopted independently of [1].

2. Basic Principles

2.1. Signals for channel estimation

The concept is to transmit orthogonal waveforms from each of the BST antennas. The waveforms act as channel sounding waveforms and are used by the SS to estimate the vector channel response. These waveforms are transmitted during the AAS network entry preamble[1] ([2] 8.3.6.2) and also perform the function of identifying the AAS alert slots ([2] 6.4.7.6.4). Thus, no additional overhead is imposed on the DL.

In each AAS network entry preamble, up to four orthogonal signals can be transmitted, each from a different antenna. The subset of antennas, which are transmitted in each network entry preamble, may vary from frame to frame. Thus a high number of transmitted antennas may be supported.

The orthogonality is achieved by using different subset of subcarriers. In particular, the m^{th} antenna signal is transmitted on subcarriers $k_{\mathrm{mod}4} = m, k = -100{:}100$. The advantage of this approach is that the AAS-FBCK-RSP ([2] 6.4.2.3.39) message can be readily applied.

2.2. Network entry

The network entry is procedure is as follows:

1. The SS synchronizes to the DL preambles and extracts frequency and timing information.
2. The SS detects the AAS NE preambles that mark the AAS alert slots.
3. The SS selects an AAS alert slot using the regular backoff procedure. The SS may consider for the backoff procedure only the slots whose preambles were received with sufficient CINR and RSSI.
4. The SS estimates channel response from the selected preamble, extracts channel parameters and compactly encodes them in an information element called SHORT-AAS-FBCK-IE.
5. The SS appends the SHORT-AAS-FBCK-IE to the initial ranging request.
6. If the BST receives the initial range request it responds with an initial ranging response. The burst carrying the response is transmitted using the channel parameters embedded in the SHORT-AAS-FBCK-IE and the specific alert slot.

The procedure outlined above supports two BST strategies:

a. Scanning beams

The AAS BST scans the sector using one or more directional beams. The AAS NE preambles are transmitted on those beams. The SS may only respond to the alert slots which are pointed towards it. This has the following advantages:

a. The detection of the initial ranging request is simplified, since the BST needs to detect the response only on the beams that were used for the transmission of the corresponding AAS-NE preambles.
b. The alert slot, on which the initial ranging request was received, implicitly indicates what is the subset of optimal beams to that subscriber.

b. Wide beam antennas

The BST uses wide beam antennas. The orthogonal preambles are transmitted from subsets of different antennas. The BST uses the information embedded in the SHORT-AAS-FBCK-IE as well the implicit information embedded in the selected alert slot.

2.2.1. SHORT-AAS-FBCK

The SHORT-AAS-FBCK-IE is comprised of the relative phase shifts required to form the beam towards the SS. The actual method used to compute the phases is vendor specific and is outside the scope of the standard. The phases are quantized to units $360^{o}/16$ radians.

[1] The term 'AAS network entry preamble' is grossly misleading since it does not preamble the network entry signal itself. We recommend replacing it with 'AAS alert slot delimiter'. For continuity we shall use the original term.

Note the relative phase information constitutes only a subset of the parameters required for optimal beamforming. The optimal set is composed of phase and amplitude per frequency. As demonstrated in the appendix, the lack of optimality is small and may be compensated when the link is established and the complete information is transmitted using AAS_FBCK-REQ/RSP.

3. Proposed text

Text in blue is added. Text in ~~red~~ is deleted. Notes to editor are marked in <<< >>>.

3.1. Changes to initial ranging request 6.4.2.3.5

Add after line 62 pg 67:

The following parameters shall be included in the RNG-REQ message when transmitted on the Initial Ranging connection:

SS MAC Address
MAC Version

In initial ranging requests transmitted on AAS alert slots, in OFDM mode, the SHORT-AAS-FBCK-IE shall also be reported.

3.2. Changes to AAS-FBCK-REQ/RSP 6.4.2.3.39

The AAS Channel Feedback Request message shall be used by a system supporting AAS ~~and operating in frequency division duplex (FDD) mode. It may also be used by a system supporting AAS and operating in TDD mode.~~ This message serves to request channel measurement that will help in adjusting the direction of the adaptive array.

Table 82

Syntax	Size	Notes
AAS_FBCK_REQ_message-format(){		
Management message type=44	8bits	
Frame number	24bits	
Measurement data type	~~1~~2bits	0b00 = measure on downlink preamble only 0b01 = measure on downlink data (for this SS) only. 0b10 = measure on network entry preamble transmitted in the frame indicated by frame number. (OFDM PHY only) 0b11 = measure on network entry preamble transmitted in the frame indicated by frame number and respond using a short format (OFDM PHY only)
Number of frames	6bits	
Reserved	2 bits	
Feedback request counter	4~~6~~ bits	
Frequency measurement resolution	2bits	For SC/SCa 0b00 = 64 measurement points 0b01 = 32 measurement points 0b10 = 16 measurement points 0b11 = 8 measurement points For OFDM: 0b00 = 4 subcarriers 0b01 = 8 subcarriers

		0b10 = 16 subcarriers 0b11 = 32 subcarriers For OFDMA: 0b00 = 32 subcarriers 0b01 = 64 subcarriers 0b10 = 128 subcarriers 0b11 = 256 subcarriers

Table –83 AAS Feedback response

Syntax	Size	Notes
AAS_FBCK_REQ_message-format(){		
Management message type=45	8bits	
Feedback request number	~~6~~4 bits	
if (data measurement type ==0b11){		
Phase offset 1	4	The required phase offset of antenna 1, relative to antenna 0.
Phase offset 2	4	The mean phase offset of antenna 2 relative to antenna 0. 4 bit signed number, in units of $360^o/16$.
Phase offset 3	4	The mean phase offset of antenna 3 relative to antenna 0. 4 bit signed number, in units of $360^o/16$.
} else if (data measurement type ==0b10){		
for (i=0; i<**NumberOfFrequencies**; i++) {		
for (j=0; j<4; j++){		
Re (Frequency_value_ant[i,j])		
Im(Frequency_value_ant[i,j])		
}		
}		
} else		
for (i=0; i<**NumberOfFrequencies**; i++) {		
Re (Frequency_value[i])		
Im(Frequency_value[i])		
}		

Feedback Request Counter
Counter from the AAS-FBCK-REQ messages to which this is the response.

Phase offset 1…3
The phase offsets that are required to be performed by the BST, in order to from the beam towards the SS. The phase offsets are estimated using the network entry preamble indicated by the frame number of the corresponding AAS-FBCK-REQ, and are given relative to the first antenna.

Re(**Frequency_value_ant[i,j]**) and Im(**Frequency_value_ant[i,j]**)
The real (Re) and imaginary (Im) part of the measured amplitude on the frequency measurement point i (low to high frequency) from antenna j in signed integer fixed point format ([±][2 bits].[5 bits].

Re(**Frequency_value[i]**) and Im(**Frequency_value[i]**)
The real (Re) and imaginary (Im) part of the measured amplitude on the frequency measurement point (low to high frequency) in signed integer fixed point format ([±][~~4~~2 bits].[~~11~~5 bits].

3.3. Changes to preamble section 8.3.3.6

<<< replace the text on page 416 lines 53-65 with the following>>>

The AAS network entry preamble shall be transmitted from up to four antennas. This preamble shall be used to mark the AAS alert slots and to perform channel estimation. If the BST support more than four antennas the subset that is transmitted on a single AAS network entry preamble may be varied from frame to frame. The preamble from antenna *m*, m=0…3, shall be transmitted on subcarriers m mod 4 and shall use the sequence $P_{AAS}^{(m)}$ given by:

For m=0

$$P_{AAS}^{(0)}(k) = \begin{cases} 0 & k \bmod 4 \neq 0 \\ P_{ALL}(k) & k \bmod 4 = 0 \end{cases}$$

For m=1..3

$$P_{AAS}^{(m)}(k) = \begin{cases} 0 & k \bmod 4 \neq m \\ P_{ALL}(k+2) & k \bmod 4 = m \end{cases}$$

3.4. Section 8.3.6.2 _initial ranging

<<<Move the text in lines 7-16 in pp. 433 to a new subsection and make the following changes.>>>

8.3.6.2.1 Initial Ranging in AAS systems

A BS supporting the AAS option may allocate in the uplink subframe an AAS alert slot ~~8 OFDM symbol initial ranging slot~~ for AAS SSs that have to initially alert the BS of their presence. This period shall be marked in the UL-MAP as Initial-Ranging (UIUC=1), but shall be marked by an AAS initial ranging CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for Initial Ranging. ~~During the first OFDM symbol of this AAS initial ranging slot, the BS shall transmit the AAS network entry preamble. In TDD mode the BS can use the last OFDM symbol of the downlink subframe to transmit the AAS network entry preamble and mark this symbol as Gap (DIUC=13) in the DLMAP. The AAS intial ranging slot shall then be at the beginning of the uplink subframe.~~

This period is identified by the AAS network entry preamble. This period begins one frame duration after the network entry preamble and ends at the end of the frame. The SS follows regular backoff procedure (see [1] 6.4.8), with ranging backoff start =1 and ranging backoff end=64. A single period is considered a single transmission opportunity.

A SS may ignore AAS alert slots whoseassociated network entry preamble was received with inadequate RSSI or CINR conditions. The ignored alert slots are excluded from count by the backoff procedure.

The network entry preamble is also used for channel estimation purposes. An AAS SS shall perform channel estimation on the network entry preamble and prepare the SHORT_AAS_FBCK-IE The SHORT_AAS_FBCK-IE shall be appended to an initial ranging request transmitted in the AAS alert slot

The SHORT_AAS_FBCK contains the phase offsets that are required to be performed by the BST, in order to from the beam towards the SS. The phase offsets are estimated using the network entry preamble and are given relative to the first antenna. The SHORT-AAS-FBCK-IE is given in table XXX:

Table XXX Short AAS feedback information element SHORT-AAS-FBCK-IE

Field	Length, bits	Comments
Phase offset 1	4	The required phase offset of antenna 1, relative to antenna 0.
Phase offset 2	4	The mean phase offset of antenna 2 relative to antenna 0. 4 bit signed number, in units of $360^o/16$.

Phase offset 3	4	The mean phase offset of antenna 3 relative to antenna 0. 4 bit signed number, in units of $360^o/16$.
Pad	4	padding bits
Total	16	

3.5. Section 11.1.3 *RNG-REQ* message encoding

Add to table 278 pg 597 the parameter

SHORT-AAS-FBCK-IE, type=7, length 2bytes, value: "Phase offsets required for beamforming"., see section 8.3.6.2.1

4. References

[1] c80216-04-01 *Proposed changes to OFDM AAS mode*

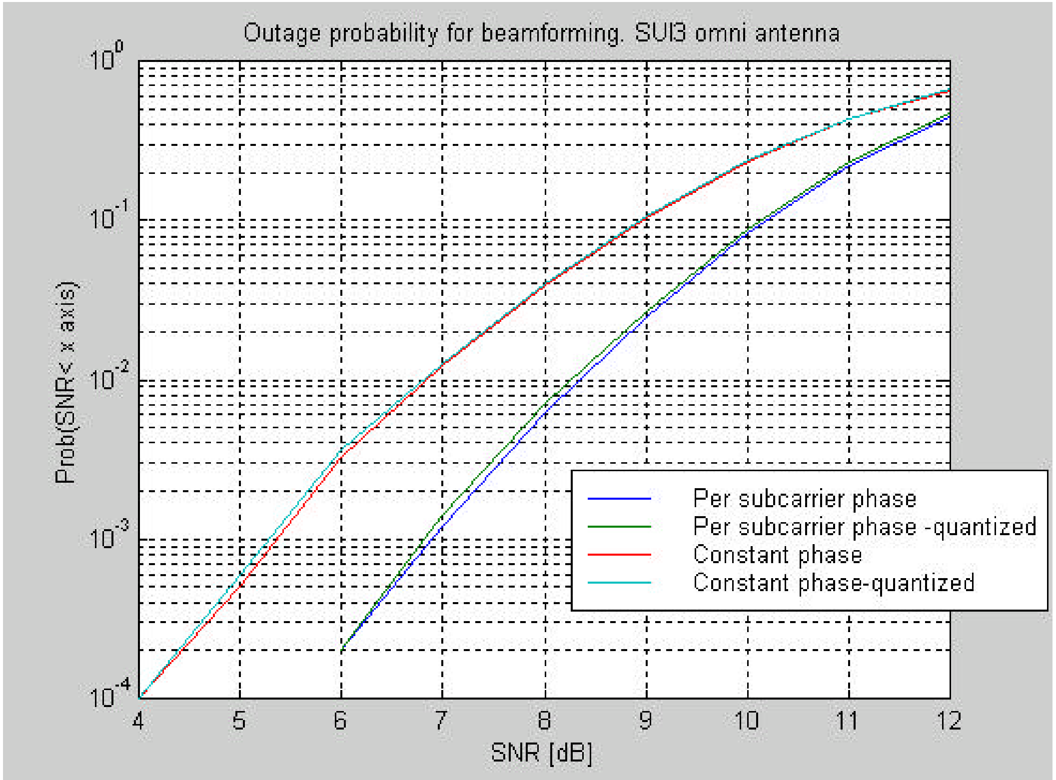
[2] IEEE P802.16-REVd/ D2-2003

Appendix A - Simulation results

In this appendix we compare the performance loss using constant phase beamforming, compared to using optimal beamforming per subcarrier. In particular we compare the outage probability when:

1. The transmitter knows the optimal phase offset per subcarrier.
2. The transmitter knows the optimal phase offset per subcarrier, quantized to a resolution of $360^o/16$.
3. The transmitter knows the optimal phase offset optimal for the entire bandwidth, The transmitter knows the optimal phase offset optimal for the entire bandwidth, quantized to a resolution of $360^o/16$.

The simulation assumed a SUI-3 model with omni-directional antennas at the CPE. 4 antenna were used with independent impulse response in each antenna. The channel response were normalized per ensemble, thus the effects of fading are taken into account. The indicate results take into account both the diversity gain and the array gain.



As can be seen for the difference between per-subcarrier and constant phase, @Poutage=10^{-3} are about 1.5dB.