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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]

2. Basic Principles

2.1. Signals for channel estimation

The concept is to transmit orthogonal waveforms from each of the BST antennas/beams. 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 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.

[1] Here we replace the term AAS NW entry preamble with AAS preamble

In each AAS network entry preamble, up to eight orthogonal signals can be transmitted, each from a different beam. 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 thus be supported.

The orthogonality is achieved by using different subset of subcarriers. In particular, the m^{th} antenna signal is transmitted on subcarriers $k_{\mathrm{mod}4} = m, k = -100:100$.

2.2. Network entry

In AAS mode the network entry procedure is as follows:

1. The SS detects the network entry preamble and computes the SHORT-FBCK-IE from it. (See Table 4).

2. The SS selects at random an AAS network entry slot and a 4 bit network entry code. The SS appends the network entry code to the SHORT-FBCK-IE and creates the AAS_NETWORK_ENTRY_REQ, as shown in Table 1.

3. In the selected AAS alert slot, the SS 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. The AAS_NETWORK_ENTRY_REQ message, defined below, which contains the random network entry code and the estimated phase offsets. The AAS_NETWORK_ENTRY_REQ is transmitted on the allocated subchannel using the most robust rate.

4. The BS detects the signal, extracts ranging information and decodes the message.

5. The BS responds to the network entry request by transmitting a RNG-RSP message indicating the required changes to their ranging parameters. The SS is identified by specifying the transmit opportunity and the entry code of the AAS_NETWORK_ENTRY_REQ message. When transmitting the response, the BS may use the phaseoffset information to direct the beam to the SS, embedded in the SHORT-FBCK-IE.

6. The SS corrects the ranging parameters and the process of 1-5 is repeated until the ranging parameters are corrected accordingly.

7. After the ranging parameters have been corrected, the BS allocates an UL transmit opportunity. The SS is identified by the relative frame index in which the network entry was transmitted and the network entry code, using the AAS_NW_Entry_Response_IE (

Field	**Length, bits**	**Comments**
Phase offset 1	4	The mean phase offset of beam 1 relative to beam 0. 4 bit signed number, in units of 360o/16.
Phase offset 2	4	The mean phase offset of beam 2 relative to beam 0. 4 bit signed number, in units of 360o/16.
Phase offset 3	4	The mean phase offset of beam 3 relative to beam 0. 4 bit signed number, in units of 360o/16.
Symbol Index CINR	1 5	0: Phase information corresponds to beams in first symbol of AAS preamble 1: Phase information corresponds to beams in second symbol of AAS preamble The CINR value of the last transmission formed to this SS.
Total	18	

8. Table 2. SHORT_FBCK_IE format).

2.2.1. SHORT_AAS_FBCK_IE

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 of $360^o/16$.

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.

Table 1. AAS_NETWORK_ENTRY_REQ format

Field	Length, bits	Comments
Network entry code	4	A randomly selected code.
SHORT_FBCK_IE	18	Channel feedback information IE.
Total	22	

Table 2 SHORT_FBCK_IE format

Field	Length, bits	Comments
Phase offset 1	4	The mean phase offset of beam 1 relative to beam 0. 4 bit signed number, in units of 360o/16.
Phase offset 2	4	The mean phase offset of beam 2 relative to beam 0. 4 bit signed number, in units of 360o/16.
Phase offset 3	4	The mean phase offset of beam 3 relative to beam 0. 4 bit signed number, in units of 360o/16.
Symbol Index	1	0: Phase information corresponds to beams in first symbol of AAS preamble 1: Phase information corresponds to beams in second symbol of AAS preamble
CINR	5	The CINR value of the last transmission formed to this SS.
Total	18	

Table 2. SHORT_FBCK_IE format.

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 NW entry 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	~~24~~ 8 bits	
Measurement data type	1 bit	0 = measure on downlink preamble only 1 = measure on downlink data (for this SS) only.
Number of frames	7 bits	
Feedback request counter	3 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
Reserved	3 bits	Shall be set to zero

…

Frame Number

The 8 least significant bits of the Frame Number in which to start the measurement.

Feedback Request Counter

Every time an AAS-FBCK-REQ is sent to the SS. Individual counters shall be maintained for each SS. The value 0 shall not be used.

…

Syntax	Size	Notes
AAS_FBCK_REQ_message-format(){		
Management message type=45	8bits	

Measurement data type Feedback request number Frequency measurement resolution Reserved for (i=0; i<**NumberOfFrequencies**; i++) {	1 bits 3 bits 2 bits 2 bits	
Re (Frequency_value[I])		
Im(Frequency_value[i])		
}		
RSSI mean value	8bits	
CINR mean value	8bits	

…

Feedback Request Counter
Counter from the AAS-FBCK-REQ messages to which this is the response. The value 0 indicates that the response is unsolicited. In this case the measurement corresponds to the preceding frame.

…

RSSI mean value
The mean RSSI as measured on the element pointed to by *data measurement type*, *frame number* and *number of frames* in the corresponding request. The RSSI is quantized as described in corresponding PHY sections. When the AAS feedback response is unsolicited, this value corresponds to preceding frame.

CINR mean value
The mean CINR as measured on the element pointed to by *data measurement type*, *frame number* and *number of frames* in the corresponding request. The RSSI is quantized as described in corresponding PHY sections. When the AAS feedback response is unsolicited, this value corresponds to preceding frame.

3.3. AAS-BEAM-REQ/RSP 6.4.2.3.40

The AAS Beam Request/Response messages shall be used by a system supporting AAS This message serves to request channel measurement that will help in adjusting the direction of the adaptive array. Shall be used for OFDM mode only in conjunction with the AAS preamble.

Table –XX AAS Beam Request

Syntax	Size	Notes
AAS_BEAM_REQ_message-format(){		
Management message type= XX	8bits	
Frame number	8 bits	
Feedback request number	3 bits	
Measurement Report Type	2 bits	0b00: BEAM_REP_IE Otherwise: reserved.
Resolution parameter	3 bits	
Beam bit mask	8 bit	A bit corresponds to a requested report on the beam

Frame Number
The 8 least significant bits of the Frame Number in which to start the measurement.

Feedback Request Counter
Every time an AAS-FBCK-REQ is sent to the SS. Individual counters shall be maintained for each SS. The value 0 shall not be used.

Measurement report type
The report type to be used.

Beam Bit Mask
A 1 in a bit signifies that the corresponding beam is to be reported on

Table –XX AAS Beam Response

Syntax	Size	Notes
AAS_BEAM_RSP_message-format(){		
Management message type=XX	8bits	
Frame number	8 bits	
Feedback request number	3 bits	
Measurement Report Type	2 bits	0b00 BEAM_REP_IE otherwise reserved
Resolution parameter	3 bits	
Beam bit mask	8 bit	A bit corresponds to a requested report on the beam
if (Measurement Report Type==0)		
AAS_BEAM_REP_IE()		
}		
RSSI mean value	8bits	
CINR mean value	8bits	

Frame Number
The 8 least significant bits of the Frame Number in which to start the measurement. If the message is unsolicited corresponds to the previous frame.

Feedback Request Counter
Counter from the AAS-BEAM-REQ messages to which this is the response. The value 0 indicates that the response is unsolicited.

Measurement report type
The report type to be used.

Beam Bit Mask
A 1 in a bit signifies that the corresponding beam is to be reported on

RSSI mean value
The mean RSSI as measured on the element pointed to by *data measurement type*, *frame number* and *number of frames* in the corresponding request. The RSSI is quantized as described in corresponding PHY sections. When the AAS feedback response is unsolicited, this value corresponds to preceding frame.

CINR mean value
The mean CINR as measured on the element pointed to by *data measurement type*, *frame number* and *number of frames* in the corresponding request. The RSSI is quantized as described in corresponding PHY sections. When the AAS feedback response is unsolicited, this value corresponds to preceding frame.

The AAS beam pattern report IE shall be used in conjunction with the AAS_BEAM_REQ/RSP messages. This report IE contain the frequency response of the beams transmitted during the AAS_preamble of the corresponding frame. only the beams which corresponds to the Beam Bit mask are reported. The resolution parameter is interpreted as follows:

resolution parameter ==0b000 => report every 4th subcarrier
resolution parameter ==0b001 => report every 8th subcarrier
resolution parameter ==0b010 => report every 16th subcarrier

resolution parameter ==0b011 => report every 32th subcarrier
resolution parameter ==0b100 => report every 64th subcarrier

Table –XX AAS Beam Response

Syntax	Size	Notes
AAS_BEAM_REP_IE_message-format(){		
for m=1 to NumberOfBeams {		
for n=1 to NumberOfFrequencies{		
Re {Frequency_value_beam[m,n] }		
Im{Frequency_value_beam[m,n] }		
}		
}		

Re(**Frequency_value_beam[m,n]**) and Im(**Frequency_value_beam[m,n]**)
The real (Re) and imaginary (Im) part of the measured amplitude on the frequency measurement point n (low to high frequency) from beam m in signed integer fixed point fo rmat ([±][2 bits].[5 bits].

3.4. Changes to preamble section 8.3.3.6

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

The AAS preamble shall be transmitted during two OFDM symbols. Each symbol shall be transmitted from up to 4 beams. This preamble shall be used to mark the AAS alert slots and to perform channel estimation. If the BST support more than eight antennas the subset that is transmitted on a single AAS preamble may be varied from frame to frame. The preamble from beam m, $m=0\ldots3$, 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 $m=1..3$

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

3.5. 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 R anging. 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.

A BS supporting the AAS option may allocate in the uplink subframe an AAS alert slot for AAS SSs that have to initially alert the BS of their presence. This period shall be marked 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. Additionally this period shall be marked using AAS map (see XXX).

The SS shall transmit the long preamble as defined in 8.3.3.6. This shall be followed by subchannelized burst carrying the AAS_NETWORK_ENTRY_REQ message (See XXX). This message shall be sent on the subchannel indicated by the uplink map information element used to allocate the ranging period.

Table 3. AAS_NETWORK_ENTRY_REQ format

Field	Length, bits	Comments
Network entry code	4	A randomly selected code.
SHORT_FBCK_IE	18	Channel feedback information IE. Refers to the AAS preamble in the preceding frame.
Total	22	

The BS may respond by allocating a single subchannel identifying the SS by the Transmit Opportunity and Frame Number in which the transmission was received. The allocation is accomplished by sending an UL-MAP IE containing am AAS_NW_Entry_Response_IE (see xxx.) The allocated bandwidth shall be big enough as to contain at least one RNG-REQ message. The BST may use the phase information embedded in the SHORT_FBCK_IE.

Note that a BST supporting AAS is required to be capable of receiving a single subchannelized transmission. However, it is not required to receive simultaneous subchannelized transmissions. A SS supporting AAS is required to be capable of sending a transmission on a single subchannel.

Table 4. SHORT_FBCK_IE format.

Field	Length, bits	Comments
Phase offset 1	4	The mean phase offset of beam 1 relative to beam 0. 4 bit signed number, in units of 360o/16.
Phase offset 2	4	The mean phase offset of beam 2 relative to beam 0. 4 bit signed number, in units of 360o/16.
Phase offset 3	4	The mean phase offset of beam 3 relative to beam 0. 4 bit signed number, in units of 360o/16.
Symbol Index	1	0: Phase information corresponds to beams in first symbol of AAS preamble 1: Phase information corresponds to beams in second symbol of AAS preamble
CINR	5	The CINR value of the last transmission formed to this SS.
Total	18	

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 AAS preamble and are given relative to the first beam.

Symbol Index
Indicates whether the phase information corresponds to the first or second symbol in the AAS preamble.

CINR
The CINR value of the last transmission formed to this SS. Quantized in 1dB units. 0x00 corresponds to 0dB.

4. References

[1] Map formats in AAS 3-March03, Arraycomm, Alvarion

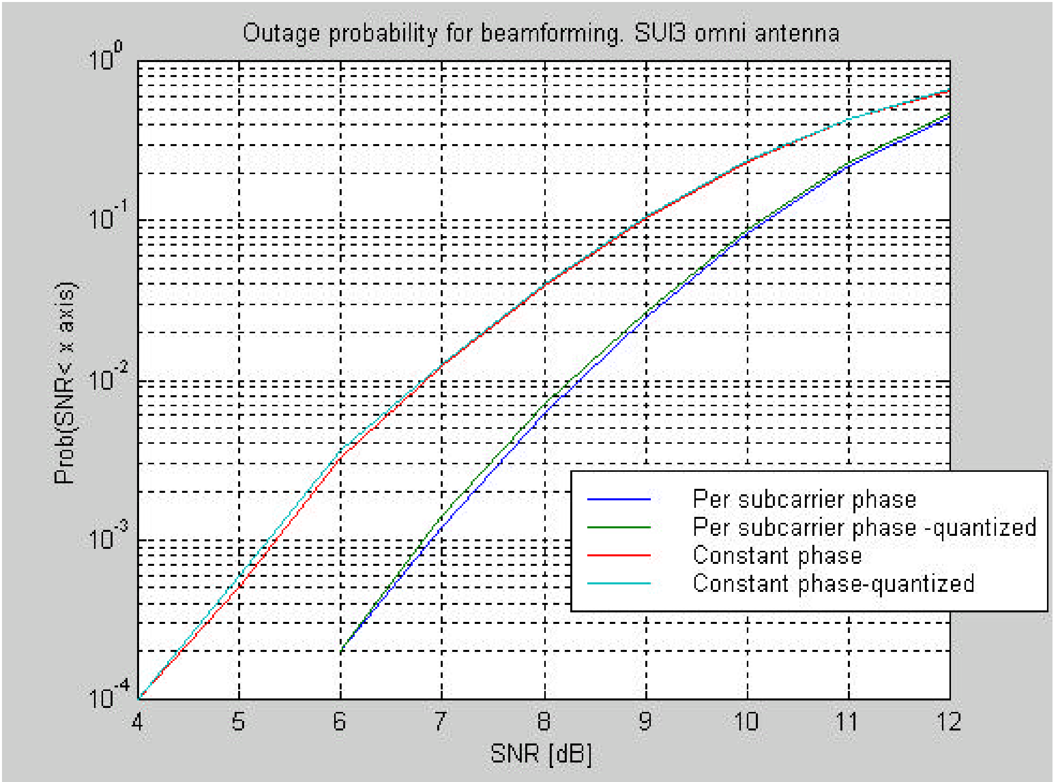
[2] IEEE P802.16-REVd/ D3-2003

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 .