Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Channel Estimation and feedback report for OFDM AAS**
Date Submitted	
Source(s)	Tal Kaitz Naftali Chayat Vladimir Yanover Alvarion Ltd. Radu Selea and Bogdan Franovici, RedLine Communications Adam Kerr and Paul Petrus, ArrayComm Hassan Yaghoobi Atul Salvekar, Intel Raja Banerjea , Proxim Voice: +972-36456273 mailto: tal.kaitz@alvarion.com Voice: +972-36456801 mailto: naftali.chayat@alvarion.com Voice: +972-36457834 Fax: +972-36456290 mailto: vladimir.yanover@alvarion.com
Re:	
Abstract	
Purpose	
Notice	
Release	
Patent Policy and Procedures	

Channel Estimation and Feedback Report for AAS OFDM mode

Tal Kaitz, Naftali Chayat and Vladimir Yanover, Alvarion

Radu Selea and Bogdan Franovici, RedLine Communications

Adam Kerr and Paul Petrus, ArrayComm

Hassan Yaghoobi and Atul Salveka, Intel

Raja Banerjea, Proxim

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 utlized.
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.

In each AAS network entry preamble, up to four 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 $k_{\mathrm{mod}4} = m, k = -100:100$.

New feedback are defined that support feedback report of channel response measured from the AAS preamble. Additionally, changes are proposed to support unsolicited report.

2.2. Network entry

In AAS mode the network entry procedure is as follows:

1. The SS detects the AAS preamble and computes the response, and prepares the feedback information.

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 feedback message and creates the AAS_NW_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_NW_ENTRY_REQ message, transmitted 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 channel feedback information to direct the beam to the SS, embedded in the AAS_NW_ENTRY_REQ.

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).

Table 1. AAS_NW_ENTRY _REQ format

Field	Length, bits	Comments
Network entry code	4bits	A randomly selected code.
Measurement frame index	4bits	The 4 LSB of the frame number for which the beam measurements refer to.
for m=1 to 4{		
Real (beam_value[m])	8 bits	
Imag(beam_value[m])	8 bits	
}		
RSSI	8 bits	

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

HCS	8 bits	
Total	11 byte	

The BST may allocate also subchannelized AAS network entry opportunities for SS supporting subchannelization. In this case the network entry burst is composed as follows:

a. A 4x64 preamble transmitted on the entire BW
b. A 2x128 preamble transmitted on the entire BW
c. The SBCH_AAS_NW_ENTRY_REQ message, defined below, which contains the random network entry code and a short feed back message.

Table 2. SBCH_AAS_NW_ENTRY_REQ

Field	**Length, bits**	**Comments**
Network entry code	4	A randomly selected code.
Phase offset 1	4	The mean phase offset of beam 1 relative to beam 0. 4 bit signed number, in units of $360^{o}/16$.
Phase offset 2	4	The mean phase offset of beam 2 relative to beam 0. 4 bit signed number, in units of $360^{o}/16$.
Phase offset 3	4	The mean phase offset of beam 3 relative to beam 0. 4 bit signed number, in units of $360^{o}/16$.
Measurement frame index	1	0: Phase information corresponds to beams in previous frame 1: Phase information corresponds to beams in one before previous frame.
RSSI	5	
Total	22bits	

The SBCH_AAS_NE_REQ 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.

3. Proposed text

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

3.1. 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_RSP_message-format(){		
Management message type=45	8bits	
Measurement data type	1 bits	
Feedback request number	3 bits	
Frequency measurement resolution	2 bits	
Reserved	2 bits	
for (i=0; i<**NumberOfFrequencies**; i++) {		
Re (Frequency_value[I])	8bits	
Im(Frequency_value[i])	8bits	
}		
RSSI mean value	8bits	
CINR mean value	8bits	

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 i (low to high frequency) in signed integer fixed point format ([±][2 bits].[5 bits].

…

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.

3.2. 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= 46	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	4 bit	A bit corresponds to a requested report on the beam
Resreved	4bit	Shall be set to zero

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

Feedback Request Counter
Every time an AAS-BEAM-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=47	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	4 bit	A bit corresponds to a requested report on the beam
reserved	4bit	Shall be set to zero
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 perform 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 the set
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

Measurement points shall be on the frequencies corresponding to the negative subcarrier offset indices $-N_{used}/2$ plus n times the indicated subcarrier resolution and corresponding to the positive subcarrier offset indices $N_{used}/2$ minus n times the indicated subcarrier resolution where n is a positive integer.

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] }	8bits	
Im{Frequency_value_beam[m,n] }	8bits	
}		
}		

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 format ([±][2 bits].[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 preamble shall be composed of two identical OFDM symbols. Each symbol shall be transmitted from up to 4 beams. The same beams shall be used in the first and second symbols. This preamble shall be used to mark AAS DL zoone. slots and to perform channel estimation. If the BST support more than four 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…3, shall be transmitted on subcarriers m mod 4 and shall use the sequence $P_{AAS}^{(m)}$ given by:

For m=0

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

For m=1..3

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

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.~~

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 a burst carrying the AAS_NW_ENTRY_REQ message (See XXX). This burst shall use the most robust mandatory rate.

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

BS may additionally assign subchannelized AAS alert slot for SSs supporting subchannelization. AAS SSs which have attempted initial ranging with the maximum power level using AAS_NW_ENTRY_REQ may attempt initial ranging in the subchannelized AAS alert slot.

The SS shall transmit the long preamble as defined in 8.3.3.6. This shall be followed by subchannelized burst carrying the AAS_SBCH_NW_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_NW_ ENTRY_REQ format

Field	Length, bits	Comments
Network entry code	4bits	A randomly selected code.
Measurement frame index	4bits	The 4 LSB of the frame number for which the beam measurements refer to.
for m=1 to 4{		
Real (beam_value[m])	8 bits	
Imag(beam_value[m])	8 bits	
}		
RSSI	8 bits	
HCS	8 bits	
Total	11 byte	

Network entry code
A 4 bit number selected at random

Measurement frame index
The 4 LSB of the frame number for which the beam measurements refer to.

Re(**Value_beam[m]**) and Im(**Value_beam[m]**)
The real (Re) and imaginary (Im) part of the measured amplitude of beam m in signed integer fixed point format ([±][2 bits].[5 bits]. These values are measured on the AAS preamble pointed to by measurement frame index. A single value shall be used for the entire bandwidth.

RSSI
The RSSI of the AAS preamble information pointed to by measurement fram e index. This value is averaged over the 4 beams. The RSSI value shall be quantized as in 8.3.8.2.

Table 4. SBCH_AAS_NW_ENTRY_REQ

Field	Length, bits	Comments
Network entry code	4	A randomly selected code.
Phase offset 1	4	The mean phase offset of beam 1 relative to beam 0. 4 bit signed number, in units of $360^o/16$.
Phase offset 2	4	The mean phase offset of beam 2 relative to beam 0. 4 bit signed number, in units of $360^o/16$.
Phase offset 3	4	The mean phase offset of beam 3 relative to beam 0. 4 bit signed number, in units of $360^o/16$.
Measurement frame index	1	0: Phase information corresponds to beams in previous frame 1: Phase information corresponds to beams in one before previous frame.
RSSI	5	
Total	22bits	

Network entry code
A 4 bit number selected at random

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 previous frame or to the one before previous frame.

RSSI
The RSSI of the AAS preamble information pointed to by measurement frame index. This value is averaged over the 4 beams. This value shall be quantized in 2 dB increments, ranging from –110 dBm (encoded 0x00) to –48 dBm (encoded 0x1F). Values outside this range shall be assigned the closest extreme value within the scale.

4. References

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

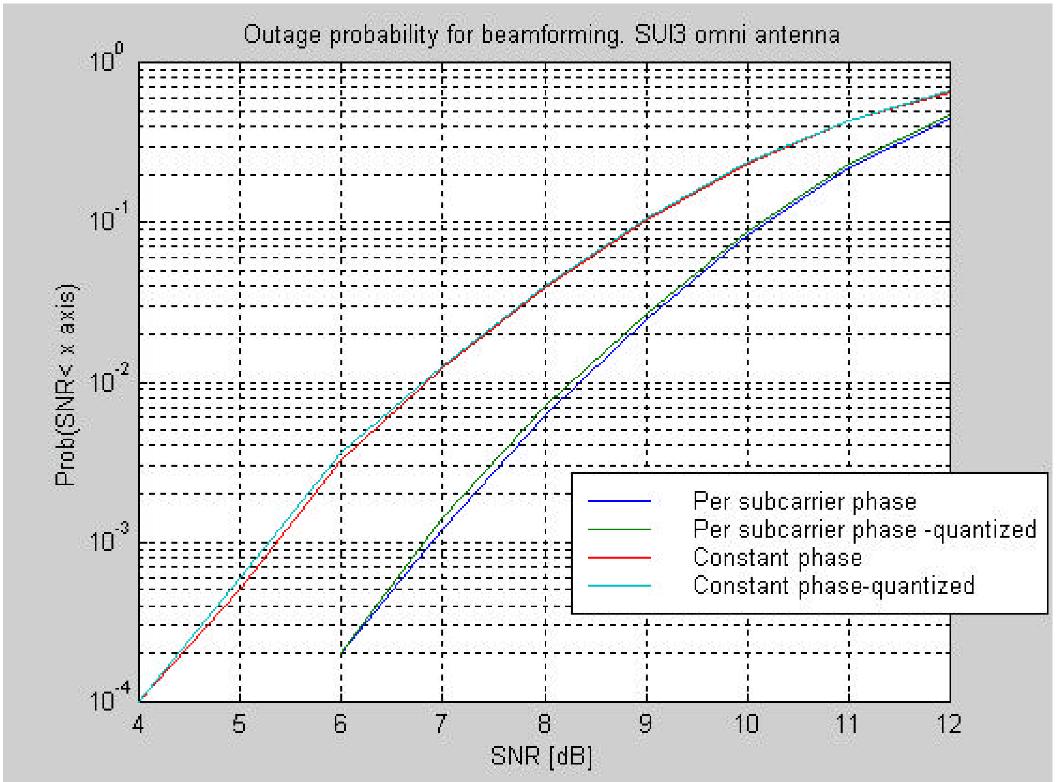
[2] IEEE P802.16-REVd/ D3-2003

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.