Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**MAC and PHY Support for AAS**
Date Submitted	**2002-05-10**
Source(s)	Yigal Leiba Yossi Segal Itzik Kitroser Dr. Zion Hadad Moshe Levinson Runcom Technologies LTD. 2 Ahcoma St. 75655, Rishon Lezion Israel Voice: 972-3-9528440 Fax: 972-3-9528805 mailto:yigall@runcom.co.il mailto:yossis@runcom.co.il mailto:itzikk@runcom.co.il mailto:zionh@runcom.co.il mailto:moshel@runcom.co.il Phil Kelly Amir Sarajedini Huanchun Ye Randall Schwartz BeamReach Networks 755 N. Mathilda Ave Sunnyvale, CA 94086 USA Voice: 408-869-8700 Fax: 408-869-8701 mailto:pkelly@beamreachnetworks.com Paul Struhsaker Raze Technologies 2540 East Plano Parkway Brian Eidson Conexant Anader Benyamin-Seeyar 657 Orly Avenue Dorval, Quebec Remi Chayer Harris
Re:	Call for Contributions on P802.16a Mergers and Consolidation Document Number: IEEE 802.16a-02/22, April 15, 2002. URL: < http://ieee802.org/16/docs/02/80216-02_22.pdf >
Abstract	Describes procedures for MAC and PHY support for AAS, and provides specific changes to P802.16a/D3
Purpose	Make proposed changes to P802.16a/D3.
Notice	

MAC and PHY Support for AAS

Yigal Leiba, Yossi Segal, Itzik Kitroser, Dr. Zion Hadad, Moshe Levinson, Phil Kelly, Amir Sarajedini, Huanchun Ye, Randall Schwartz, Paul Struhsaker, Brian Eidson, Anader Benyamin-Seeyar, Remi Chayer

Introduction

Incorporating design considerations into the MAC and PHY designs supports realizing benefits from advanced antenna systems. Specific PHY modifications for adaptive antenna implementations can be addressed in the appropriate PHY sections. Regardless of the PHY, support in the MAC is required to enable adaptive antenna solutions.

This section describes the support required from the MAC layer to support any AAS, regardless of PHY mode. Section 2 addresses specific PHY concerns. Section 3 provides suggested changes to P802.16a/D3.

Basic Assumptions

An operator may provide incremental improvements in system performance by adding AAS-enabled base stations to existing deployments, or initially deploy AAS-enabled base stations. In the former situation, there will naturally be a mix of standard subscriber stations (non AAS-enabled) and AAS-enabled subscriber stations. In the latter case, there is an assumption that the subscriber stations are, or should be, AAS-enabled. In either case, there must be a defined procedure for establishing communication between BS and SS units. This is fundamentally a MAC issue.

An AAS-enabled base station will use multiple antennas. On the uplink, the beamforming algorithms are able to use a training signal to form a beam without a priori information about the direction of the SS. The same results can be used to form a downlink transmit beam for TDD systems, whereas a channel estimation algorithm is also required to form a downlink transmit beam for FDD systems. Because of cost considerations, an AAS-enabled SS will use very few antennas, typically one, but will support AAS MAC messages.

MAC Support for AAS

The 802.16 MAC model is based on an assumption that there is a bi-directional broadcast channel between a BS and SS. This assumption does not universally hold in the case of adaptive antenna systems because the benefits of these systems are based on an ability to create directional signal gains.

From a traffic flow perspective, the lack of a broadcast channel is not a problem as long as the MAC supports communication with AAS-enabled and standard SS units. Specifically, the BS MAC needs to define opportunities where AAS-enabled SS units communicate with the BS. This is inherently supported for standard SS units in the base MAC design via the broadcast DL-MAP, as this informs standard SS units when they are able to transmit. This same concept can be used for AAS communications if the DL-MAP provides separate opportunities for AAS-enabled SS units as described in Section 6.2.7.7 (P802.16a/D3).

Network entry for standard SS units is naturally supported using a broadcast message. Providing a mechanism for AAS-enabled SS units to enter a network requires additional definition. This is described next.

Network Entry Process

The network entry procedure can be divided into the following stages:

- Synchronize with the BS
- Obtain downlink parameters
- Obtain uplink parameters

- Perform initial ranging
- Provide logical network entry (negotiate basic capabilities, authorize SS, registration, establish IP connectivity, establish time of day (time synchronization), transfer operational parameters, set up connections).

SS Synchronization with the BS

Synchronization with the BS in time and frequency is accomplished using the downlink preamble. Standard SS units search for the preamble signal based on an understanding of where in time and frequency this message occurs. The same is true with AAS-enabled SS units. It is possible to provide array gain by sweeping the direction of array gain over 360 degrees. This effectively creates a low rate broadcast capability, which is acceptable for network entry. If array gain is not used, then the AAS-enabled SS units will rely solely on signal-processing gain to extract the preamble. This is possible because the DL preamble is repetitive.

Obtaining Downlink Parameters

Downlink parameters are obtained from the DL-MAP and DCD messages. If a standard SS cannot decode these messages, it abandons the downlink channel and searches for a better downlink channel. An alternate mechanism is required for an AAS-enabled SS, as it will not be able to receive the DL-MAP and DCD messages without array gain. Establishing the array gain requires that an AAS-enabled SS notify the BS of its presence. In the absence of any prior communication of link parameters, this alert message must be implemented using a defined contention oriented entry mechanism. With this mechanism, the size and position of the contention interval is defined and understood by all AAS-enabled SS units. The actual number of contention slots and their location in the frame is PHY specific, and is therefore defined in each PHY section. These contention slots are called AAS-alert-slots. Although this procedure is not intended for initial ranging, it is recommended that a similar procedure be used by an AAS-enabled SS to alert the BS so that the BS can adapt the adaptive array to the SS.

Once an AAS-enabled SS has synchronized to the downlink, it can alert the BS of its presence using a defined AAS-alert-slot opportunity. After transmitting the alert message, the SS waits for private DL-MAP and DCD messages from the BS, and continues the network entry process just like a standard SS. If an AAS-enabled SS has synchronized to the downlink but is still unable to obtain the downlink parameters because it cannot decode the DL-MAP and DCD messages, it assumes that the alert message failed to reach the BS due to a collision. In this case the SS uses an exponential back-off algorithm for selecting the next frame in which to attempt alerting the BS of its presence. At the appropriate time, it again uses the AAS-alert-slot to send the alert message.

This procedure addresses most of the problems associated with the ability of the AAS-enabled SS to initially decode the DL_MAP, UL-MAP, DCD and UCD messages. For FDD systems the uplink channel to use for the alert message still needs to be defined. The problem can be solved either by setting in advance the channel to use, or by relying on the fact that the duplex separation between DL and UL is fixed and known in advance.

Obtaining Uplink Parameters

Once the downlink parameters have been obtained, either from the broadcast channel or as a result of using an alert message, an AAS-enabled SS can behave like a standard SS.

Initial Ranging

Initial ranging procedures are the same for a standard and AAS-enabled SS. The BS may request the AAS-enabled SS to send as many ranging codes as it requires to fine-tune the adaptive array's beamforming weights.

Logical Network Entry

The only difference between a standard and AAS-enabled SS is that the AAS-enabled SS receives a private version of the DL-MAP, UL-MAP, DCD and UCD messages. In all other respects they behave identically.

PHY Specific Issues

The discussion above addresses MAC domain issues. As mentioned above, there are some PHY specific issues that need to be addressed to support AAS services.

SC PHY Mode

The SC PHY mode of 802.16a was specifically designed to allow synchronization and processing on a burst-by-burst basis. The use of CAZAC start-of-message (SOM) sequences and general organization of the framing structure in both FDD and TDD modes of operation fully support AAS features. The burst structure based of SC is identical in function to OFDM use of cyclic prefix but adapted for highly efficient Block Frequency Domain equalization. The CAZAC SOM sequences have the benefit of nearly 20 dB of processing gain for synchronization and detection.

The SC PHY mode, like all other modes, shares the common 802.16 MAC which the AAS extensions are a part.

OFDM PHY Mode

The OFDM PHY mode of 802.16a can fully support AAS. AAS operation is supported on a burst-by-burst basis, where the uplink and downlink preambles are used for synchronization. The OFDM downlink preamble is composed of two OFDM symbols, and the uplink preamble is composed of one OFDM symbol. These preambles provide about 20dB of processing gain for synchronization and detection.

OFDMA PHY Mode

A goal is to have one OFDMA mode, which incorporates options for AAS support. Specific comments to achieve this are provided below.

The substantial difference between OFDMA modes is how logical carriers are mapped to physical carriers. OFDMA2 uses sub-channels that are composed of adjacent sub-carriers. A separate permutation mapping can represent this. Using this permutation in conjunction with adaptive array makes the array implementation simpler, and is therefore justified.

OFDMA2 currently provides a superframe structure. The BS is fully capable of enabling this structure, since it has control on where in time and frequency control and data transmit opportunities occur. As such, this information may be informational.

Specific comments

These comments are in reference to P802.16a/D3. Comments for pages 88 to 91 refer to the MAC. Comments for pages 142 – 152 refer to the SC2 PHY. Comments for pages 171 to 185 refer to the OFDM PHY. The remaining comments refer to the OFDMA PHY.

Page	Line	Section
88	45	6.2.7.7.1
Comment		
The section says nothing useful about framing (see also another comment from myself regarding this issue)		
Remedy		
Change section name to "AAS MAC services"		

Page	Line	Section
88	65	6.2.7.7.1
Comment		
The TDD case shown is too much a private case to be helpful and does not mention the fact that frame structure is dynamic		
Remedy		

Delete the sentence beginning "This is achieved by...." and lines 1-39 from page 89.
Replace with the following text:
"This is achieved by dedicating part of any frame to AAS traffic, and part to non-AAS traffic. This allocation is performed dynamically by the BS. Non-AAS SS are informed through the DL-MAP/UL-MAP messages where the AAS traffic resides, and therefore can ignore it. AAS enabled SS use dedicated private DL-MAP/UL-MAP messages, and are therefore prevented from colliding with non-AAS traffic.
Special considerations apply to these parts of the frame that are not scheduled, e.g. initial-ranging and BW-request, as discussed in sections <insert reference>."

Page	Line	Section
89	41	6.2.7.7.2

Comment

Section 6.2.7.7.2 contains no useful normative information.

Remedy

Remove section 6.2.7.7.2

Page	Line	Section
90	3	6.2.7.7.3

Comment

The CLK-CMP message is transmitted on the broadcast management connection

Remedy

Change the first sentence to read:
"The CLK-CMP, DCD, UCD, UL-MAP, and DL-MAP messages for non-AAS subscriber stations are broadcast using the Broadcast CID.

Page	Line	Section
90	4	6.2.7.7.3

Comment

Currently there is no specific DIUC/UIUC for AAS

Remedy

Replace the sentences:
"Their formats are unchanged by the AAS option, except for the presence of a special value for DIUC and UIUC that mark the AAS part of the frame."
By the following:
"Allocations for AAS subscribers are marked by usage of the extended DIUC/UIUC with sub-code=1."

Page	Line	Section
90	9	6.2.7.7.3

Comment

The BS has no way to know in advance whether a new SS attempting to join the system supports AAS or not.

Remedy

Remove the sentence "In systems that support only AAS subscriber stations, the use of broadcast messages is not required."

Page	Line	Section
90	21	6.2.7.7.4

Comment

Currently it is unclear how initial synchronization is achieved when using adaptive antenna

Remedy

Remove lines 21 to 28 to and insert instead a new section called "6.2.7.7.4 AAS synchronization to the downlink" that contains these lines as modified below:
"The process of initial synchronization to the downlink in AAS systems is different from the non-AAS process. This is because the adaptive array operating in the PHY cannot be effective until the MAC and PHY of the BS identify the new SS. The adaptation of BS antenna array can be accomplished only after the BS has identified the SS.
When the SS first attempts to synchronize to the downlink transmission, the BS is unaware of its presence, and therefore is not aiming the adaptive array at its direction. Nevertheless, the frame start preamble is a repetitive well-known pattern, and SS may utilize the inherent processing gain associated with it in order to synchronize timing and frequency parameters with the BS."

Page	Line	Section
90	30	6.2.7.7.4

Comment

The process where the BS becomes aware of a new SS trying to enter the network is currently undefined for SC, OFDM and OFDMA PHY modes.

Remedy

Remove lines 30 to 53 and add a new section with the following text:
"6.2.7.7.5 Alerting the BS about presence of a new SS in an AAS system
In a non-AAS system, after synchronizing to the downlink a SS attempts to obtain the downlink parameters by decoding the DL-MAP and DCD messages. In an AAS system a SS may be able to obtain the downlink parameters if it receives the broadcast channel with enough energy so it can decode the DL-MAP and DCD messages. If this is the case, the SS continues with the network entry process just like in the non-AAS case, and the BS will get the chance to tune the adaptive array to it during the ranging process.
For AAS SS that are not able to initially decode the broadcast messages, a procedure is defined for them to alert the BS to their presence, so the BS can adapt the adaptive array to their position.
An AAS BS shall reserve a fixed, pre-defined part of the frame as initial-ranging contention slots for this alert procedure. These contention slots shall be located at a well-known location relative downlink preamble, so even an SS that can only identify the DL preamble will be able to locate it. The number of contention slots and their location in the frame is PHY specific and is defined in PHY section. These contention slots shall be called AAS-alert-slots.
When an AAS SS has synchronized to the downlink, yet is unable to obtain the downlink parameters because it cannot decode the DL-MAP and DCD messages, it shall attempt initial ranging on the AAS-alert-slots. 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. After such an attempt the SS shall wait for a private DL-MAP and private DCD messages from the BS, and shall continue the network entry process line a non-AAS SS.
If the private DL-MAP and DCD messages fail to arrive, the SS shall use an exponential backoff algorithm for selecting the next frame in which to attempt alerting the BS to its presence."

Page	Line	Section
90	56	6.2.7.7.5

Comment

No text in the section

Remedy

Remove the section

Page	Line	Section
91	11	6.2.7.7.6

Comment

It is better to transmit CEI as a TLV on the DCD message. This way it may be dynamically updated.

Remedy

Change the sentence "The value of CEI shall be determined by the BS and broadcast to all SS at registration" to read "The value of CEI shall be determined by the BS and broadcast to all SS using the DCD message"

Page	Line	Section
91	16	6.2.7.7.6

Comment

BW request mechanisms when using adaptive antennas are not clearly defined

Remedy

Add a new section with the following text:
"6.2.7.7.7 Requesting BW
AAS subscribers may not be able to request BW using the usual contention mechanism. This happens because the adaptive array may not have a beam directed at the SS when it is requesting BW, and the BW request will be lost. In order to avoid this situation an AAS is directed by the BS as to whether or not it may use broadcast allocations for requesting BW. The BS may change its direction dynamically using a TLV called ALLOW_BROADCAST_REQ, which is carried by the RNG-RSP message.
When a SS is directed not to use the broadcast CID to request BW, it is the responsibility of the BS to provide a polling mechanism to learn about the SS BW requirements.
Note that base stations in adaptive array systems are capable of receiving BW requests from simultaneous AAS-enabled SS, because multiple beams can be simultaneously formed."

Page	Line	Section
142	7	8.3.3.1.4.1.1.1

Comment

Provide a PHY definition of contention slots that enable operation of an adaptive array system with the SC2 PHY

Remedy

Add the following text:
"A BS supporting the optional AAS mode shall allocate at the end of the UL frame N = 1-8 (normative value is N=2) physical slots for AAS SS that have to initially alert the BS to their presence. This period will be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but will be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance."

Page	Line	Section
151	28	8.3.3.1.4.5.1.3

Comment

Currently there is no possibility to mark AAS traffic when adaptive antennas are used with SC2 PHY

Remedy

Add the following text at the end of the section:
"AAS traffic is marked by using the extended DIUC = 15 with the sub-code 0x01, followed by the DL-MAP IE as defined in table 207."

Page	Line	Section
152	57	8.3.3.1.4.5.2.2

Comment

Currently there is no possibility to mark AAS traffic when adaptive antennas are used with SC2 PHY

Remedy

Add the following text at the end of the section:
"AAS traffic is marked by using the extended UIUC = 15 with the sub-code 0x01, followed by the UL-MAP IE as defined in table 209."

Page	Line	Section
171	51	8.3.4.2.5
Comment		
Provide a PHY definition of contention slots that enable operation of an adaptive array system with the OFDM PHY		
Remedy		
Add the following text: "A BS supporting the optional AAS mode shall allocate at the end of the UL frame N = 1-8 (normative value is N=2) OFDM symbols for AAS SS that have to initially alert the BS to their presence. This period will be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but will be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance."		

Page	Line	Section
184	47	8.3.4.3.2.3
Comment		
Currently there is no possibility to mark AAS traffic when adaptive antennas are used with OFDM PHY		
Remedy		
Add the following text at the end of the section: "AAS traffic is marked by using the extended DIUC = 15 with the sub-code 0x01, followed by the DL-MAP IE as defined in table 221."		

Page	Line	Section
185	60	8.3.4.3.2.4
Comment		
Currently there is no possibility to mark AAS traffic when adaptive antennas are used with OFDM PHY		
Remedy		
Add the following text at the end of the section: "AAS traffic is marked by using the extended UIUC = 15 with the sub-code 0x01, followed by the UL-MAP IE as defined in table 222."		

Page	Line	Section
200	19	8.3.4.4.2.4
Comment		
Currently there is no possibility to mark AAS traffic when adaptive antennas are used with OFDMA PHY		
Remedy		
Add the following text at the end of the section: "AAS traffic is marked by using the extended DIUC = 15 with the sub-code 0x01, followed by the DL-MAP IE as defined in table 235."		

Page	Line	Section
201	24	8.3.4.4.2.5
Comment		
Currently there is no possibility to mark AAS traffic when adaptive antennas are used with OFDMA PHY		
Remedy		

Add the following text at the end of the section: "AAS traffic is marked by using the extended UIUC = 15 with the sub-code 0x01, followed by the UL-MAP IE as defined in table 236."

Page	Line	Section
201	24	8.3.4.4.2.5

Comment
Provide a PHY definition of contention slots that enable operation of an adaptive array system with the OFDMA PHY

Remedy
Add the following text: "A BS supporting the optional AAS mode shall allocate sub-channels 30 and 31, during the last 4 symbols of the UL frame for AAS SS that have to initially alert the BS to their presence. This period will be marked in the UL-MAP as Initial-Maintenance (UIUC=2), but will be marked by a non-used CID such that no non-AAS subscriber (or AAS subscriber that can decode the UL-MAP message) uses this interval for initial maintenance."

Page	Line	Section
212	55	8.3.4.5

Comment

Merge the OFDMA2 mode into the OFDMA mode

Remedy

Move (with editorial modifications) the text from line 57 down to line 30 in page 213 to a new section. The modified text should read:

8.3.4.4.3.3 Optional permutation for AAS

AAS systems may use the distributed carrier permutations or the adjacent carrier permutation specified in this clause. With the adjacent carrier permutation, symbol data within a subchannel is assigned to adjacent carriers and the pilot and data carriers are assigned fixed positions in the frequency domain within an OFDM symbol.

Table ?: Optional AAS permutation Carrier Allocations

Parameter	Value
Number of dc carriers	1
Number of Guard Carriers, Left	176
Number of Guard Carriers, Right	175
Nused Number of Used Carriers N	1696
Total Number of Carriers	2048
Number of Variable-Location Pilots	0
Number of Fixed-location Pilots	160
Number of Variable-Location Pilots which coincide with Fixed-Location Pilots	0
Total Number of Pilots	160
Number of data carriers	1536
Nsubchannels	32
Nsubcarriers	53
Number of data carriers per subchannel	48
BasicFixedLocationPilots	{5,16,27,38,49} within each subchannel

"

Page	Line	Section
213	41	8.3.4.5.3

Comment

The section contains no normative information. The description of the DL and UL frane in section 8.3.4.4.2 covers the AAS situation as well

Remedy

Remove section 8.3.4.5.3

Page	Line	Section
213	49	8.3.4.5.4

Comment

The objectives of the superframe can be achieved by appropriate scheduling in the BS, therefore there is no need to define in advance a specific structure
Remedy
Remove section 8.3.4.5.4

Page	Line	Section
228	41	11.1.2.1

Comment
A TLV is required to transmit AAS CEI value
Remedy
Add a line to table 251 where NAME = CEI TYPE = 12 LENGTH = 4 VALUE = The period of time allowed from the arrival of the signal that the an AAS SS uses for channel estimation, to the reply send by the SS. The period is measured in physical slots (PS) PHY scope = SC2, OFDM, OFDMA

Page	Line	Section
234	52	11.1.4

Comment
BW request mechanisms when using adaptive antennas are not clearly defined
Remedy
Add to table 253 the following line: "NAME = ALLOW_BROADCAST_REQ TYPE = 21 LENGTH = 1 VALUE = This parameter applies to SS supporting the optional AAS mode, 0 = SS may use uplink intervals marked by the broadcast CID (=0xffff) for requesting BW, 1 = SS may not request BW on uplink intervals marked by the broadcast CID