Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	New Adaptive Antenna MAC Section (substitute for section 6.2.7.13)
Date Submitted	**2001-9-6**
Source(s)	Einan Regev Wavion Hacarmel St. Yoqneam 20692 Israel Voice: +972-4-9097331 Fax: +972-4-9594122 mailto: einan@wavion.com Huanchun Ye BeamReach Networks 755 North Mathilda Avenue Sunnyvale, CA 94086 Voice: 408-869-8748 Fax: 408-869-8701 mailto: hye@beamreachnetworks.com
Re:	
Abstract	This document purpose is to replace the entire section 6.2.7.13 of working document IEEE 802.16ab-01/01r1 named: “sub-11 Ghz support for advanced antenna technology”, in order to improve, clarify and provide a more accurate and specific text. The content of this new text is based on the same concept and architecture as the original section with modifications. The text reflects a consolidation of the two main contributors to MAC group in the field of Advanced Antenna Techniques.
Purpose	Replace the section 6.2.7.13 of working document IEEE 802.16ab-01/01r1 with an improved version.
Notice	
Release	

Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

New Adaptive Antenna MAC Section (substitute for section 6.2.7.13)

General

This document purpose is to replace the entire section 6.2.7.13 of working document IEEE 802.16ab-01/01r1 named: **"sub-11 Ghz support for advanced antenna technology"** from July 2001. It is proposed to substitute the entire section as a whole in order to improve, clarify and provide a more accurate and specific text. The content of this new text is based on the same concept and architecture as the original section with modifications. The main reason for the need to substitute the original text is the consolidation of two contributors to MAC group in the field of Advanced Antenna Techniques, to generate a single text that reflects both contributions [1] and [2].

In the IEEE 802.16.3 meeting #13 there were 2 contributions on the subject of Advanced Antenna Techniques [1], which was entered into the MAC document as section 6.2.7.13 and [2] which was submitted separately. By request of the TG3 MAC chair the contributors of these two documents had consolidated and generated a new document.

We recommend using the following text (with properly adjusted subsection numbering), under section 6.2.7.13 of the sub-11 air interface document.

Architectural overview

Adaptive Antenna Arrays are elements of the BWA system that are used in conjunction with the PHY and MAC, to enhance the performance of the system. Adaptive Arrays can improve range and system capacity, and enable a system deployment in Non-Line-Of-Sight (NLOS) conditions. This section specifies the general architecture and the detailed mechanism in the MAC by which Adaptive Array enhancements can be added to the system. A general concept of "Adaptive Array Supportive" (AAS) system is defined in this chapter. The AAS system is capable of delivering the benefits of Adaptive Arrays and may also be compatible with non-AAS systems. The implementation of Adaptive Array in a BWA system requires both MAC and PHY to be AAS compliant, therefore it is assumed in this section that the AAS compliant MAC is operating in conjunction with an AAS compliant PHY.

MAC services in AAS systems

The use of Adaptive Array in the system shall not affect the definition of MAC services at the MAC service access point. When interfacing with higher layers, the AAS MAC appears exactly the same as non-AAS MAC does.

Transition from non-AAS to AAS systems

The architecture of AAS option provides a way to migrate from non-AAS system to AAS system by changing parts of the system first. During the migration phase the system may not be able to gain all AAS benefits, however as the mixture between AAS and non-AAS improves, the system capacity, range and inter-cell interference performance will significantly increase. The first change in the transition path should be to replace the base-station with an AAS base-station. By enabling coexistence of AAS and non-AAS subscriber stations in the same base-station service area, any mixture of AAS/non-AAS subscriber units can be deployed. At the end, if a system becomes full-AAS system, with all its components being AAS compatible (including base-station and all subscriber stations), it can be operated with the AAS option only, thus some of the MAC components that are used in non-AAS base-stations can be omitted. For example, the broadcast MAP used in non-AAS systems to indicate transmission scheduling can be omitted in a full-AAS system, since the AAS MAC uses private MAP messages designated to subscriber stations instead of the broadcast MAP.

AAS framing

It is envisioned that AAS is most beneficial for burst-mode PHYs, in particular systems using TDD as the duplexing scheme. During the migration from non-AAS to AAS, each part of the TDD time frame (UL part and DL part) is sub-divided into two logical parts. The first part is used for non-AAS subscriber stations, while the second part is used for AAS subscriber stations. For a non-AAS subscriber station, the TDD time frame appears like the expected frame, starting with the frame synchronization and control packets (MAP, UCD, DCD, etc.). The downlink burst modes and scheduling is received via DCD and DL-MAP, in the same way as in the non-AAS system. Thus a non-AAS subscriber station can be completely unaware of the fact that it is communicating with an AAS base-station. On the other hand, AAS subscriber stations use a different part of the downlink frame, starting immediately after the first part. The MAC sub-layer within these AAS stations has a special mechanism to schedule transmissions in the uplink and downlink, without using the regular broadcast MAP and DCD messages. The method by which an AAS subscriber station achieves time and frequency synchronization is dependent on the property of the underline AAS PHY, and is beyond the scope of this section.

In order to be able to perform all MAC services, the AAS MAC should have some additional packets in the air interface time frame. These packets are transmitted during the fixed service slot within the AAS part of the frame, and are ignored by non-AAS subscriber stations.

Figure 1 is an illustration of the logical division of the physical frames into non-AAS and AAS parts. For single carrier and OFDM systems, the division is based on time. For OFDMA systems, the division is based on both time and frequency, where the mapping is specified in the relevant sections on PHY.

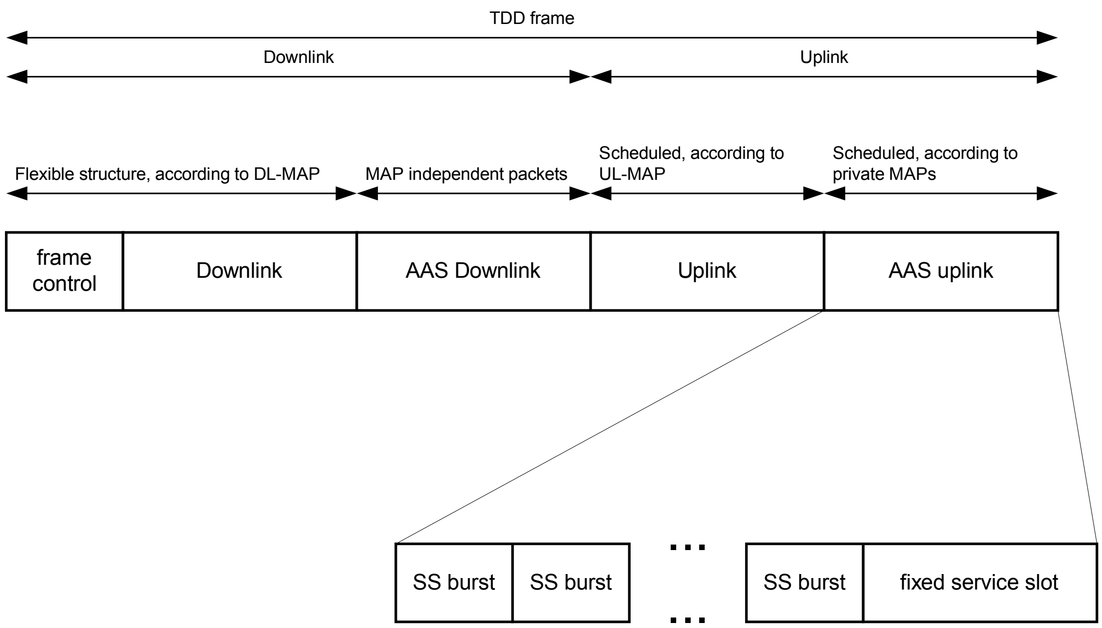

Figure 1- AAS/non AAS frame division

Supporting various duplexing schemes

The framing structure shown previously is based on a TDD duplexing scheme. In general, AAS can be applied to all burst-mode air interface schemes, including Time-Division Multiplexing with Time-Division Duplexing (TDM/TDD) and Frequency-Division Duplexing TDM/FDD. When operating in FDD mode, the AAS system cannot rely on the reciprocity of the RF channel (as it is with TDD systems, where the PHY can rely on receiver channel estimations to estimate the transmit channel). Therefore, AAS in FDD systems uses an additional feedback message to support the PHY in performing transmit channel estimation. The additional functions required to support FDD will be described in detail later.

Supporting continuous mode PHY

The AAS option is required to support TDM/FDD and TDM TDD in the burst mode only. Supporting continuous modes is not required.

Supporting different PHY modulation schemes

In general, AAS is independent of the PHY modulation scheme in use. The only condition for MAC AAS to be effective is the presence of necessary AAS functions in the PHY. Thus AAS MAC can be used in conjunction with single-carrier, OFDM, and OFDMA. When working with an OFDM PHY, either one of the 3 modes can be used. However, each one of these modes may require specific additions to the MAC/PHY interfaces.

AAS specific functions

From the MAC point of view, the PHY can be equipped with an Adaptive Array element or not, depending on the system implementation. In the context of this standard, AAS in the MAC sub-layer is defined by MAC protocol functions. The main functions affected by AAS can be divided into three groups as follows:

a) MAC control functions---Uplink/Downlink MAP distribution, Channel Description

b) MAC utility function---PHY related information provided by MAC

c) Registration functions---Initial Synchronization/Ranging

AAS can be implemented in the subscriber station (SS) MAC (which then will be able to interoperate with the MAC of any BS that have AAS at the MAC layer), or in the base-station (BS) MAC.

Compatability model

AAS is an optional component of the IEEE 802.16ab standard. The AAS option, if present, must comply with the normative clauses specified in this section.
According to the logical division described earlier, non-AAS subscriber stations must be able to operate normally whether or not they receive any signal in the AAS part of the frame, and AAS subscriber stations must be able to operate normally whether or not they receive any signal in the non-AAS part of the frame.

Logical channels with mapping to physical channels

For the purpose of specification in this section, and in order to support multiple PHY modes, we identify the following logical channels for the operation of the MAC. The mapping of the logical channels to the actual physical channels is specified in the sections on the respective PHY. For single carrier and OFDM systems, the logical channels are mapped to fixed time and duration. For OFDMA systems, the mapping will specify both time and frequencies.

The following logical channels exist in non-AAS systems:

1. Broadcast Frame Control Channel: This channel is used for frame control, carrying DL-MAP, UL-MAP, DCD, and UCD
2. Downlink Traffic Channels: This is the part of the physical channel that carries downlink user traffic, as scheduled by the BS
3. Uplink Contention Channel: This channel is used for SS initiated random access, including ranging and bandwidth request
4. Uplink Traffic Channels: This is the part of the physical channel that carries uplink user traffic, as scheduled by the BS

The following logical channels are required for AAS systems:
Downlink Synchronization Channel: This channel is used for time and frequency synchronization by AAS subscriber stations

1. Downlink Polling Channel: This channel is required only for AAS with OFDMA systems, where the array adaptation using signals received in the Uplink Contention Channel may be inadequate to open a Downlink Traffic Channel to a subscriber station, due to frequency displacement

2. Downlink Traffic Channels: This is the part of the physical channel that carries downlink user traffic, as scheduled by the BS. Their availability requires array training. In contrast to similar channels in the non-AAS systems, multiple simultaneous Downlink Traffic Channels can be open to spatially separated subscriber stations.
3. Uplink Contention Channel: This channel is used for SS initiated random access, including ranging and bandwidth request. Its availability does not require array adaptation.
4. Uplink Traffic Channels: This is the part of the physical channel that carries uplink user traffic, as scheduled by the BS. Their availability requires array adaptation.

In a pure AAS system where all subscriber stations are AAS enabled, only AAS channels shall be required.

MAC control functions

The DCD, UCD, UL-MAP, and DL-MAP messages for non AAS subscriber stations are broadcast using the broadcast CID. 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. Non AAS subscriber stations shall ignore the intervals associated with these DIUC and UIUC values.

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

The control of AAS part of the frame is done by unicast Private DCD, UCD, UL-MAP and DL-MAP messages to individual subscriber stations, using the basic CID assigned to that SS. AAS subscriber stations shall ignore all messages associated with the broadcast CID.

The format of Private DCD and UCD messages are the same as broadcast messages, except that the CID must be the basic CID assigned to that AAS subscriber station.

The format of Private DL-MAP and UL-MAP is the same, as shown in the table below:

Field	**Size**	Notes
Generic MAC Header	6 bytes	Use Basic CID
MAC Message Type	1 byte	
PHY Synchronization	2 bytes	
No. of MAP IE	1 byte	
List of MAP IE		
{		
Channel ID	1 byte	Required for OFDMA only, specifying which set of frequencies to be used for this MAP IE
DIUC or UIUC	4 bits	
Start Time	6 bits	
End Time	6 bits	
}		

Table 1 Private DL-MAP and UP-MAP

Subscriber Station Registration Process

The process of registration in AAS systems is different from the regular registration process. This is because the Adaptive Array operating in the PHY cannot be effective until the MAC and PHY of the base-station identify the registering subscriber station. The adaptation of base-station Antenna Array can be accomplished only after the base-station has identified the subscriber-station. On the other hand, if the base-station cannot adapt the array to the new subscriber, there is a chance that the subscriber station will not receive any valid signal from the base station at all. Since the regular registration process requires that the SS receive a valid message first, it is not always possible to rely on this process.

The Uplink Contention Channel and Downlink Polling Channel are designed to solve this problem. The process of registration of a SS to a base-station, where both the SS and the BS use AAS in the MAC is based on the following steps:

SS MAC waits for an indication from PHY that initial synchronization with BS is achieved.

After receiving initial synchronization indication from PHY, SS MAC transmits a registration message TBD using the AAS registration channel (a logical channel that is mapped to a fixed physical slot).

BS PHY receives the registration message and performs channel estimation and delay measurement.

BS MAC receives the registration message from PHY and the corresponding delay. In OFDMA systems, BS needs to send a signal to SS using the Downlink Polling Channel. SS then responds with a training sequence to allow BS to perform array adaptation in the correct tones, and thus opens a Downlink Traffic Channel.

BS MAC sends a registration response message containing ranging information, and a private MAP message with an uplink bandwidth allocation to enable SS complete registration sequence.

SS proceeds with the standard process as required to complete all registration operations (power adjustment, rate adaptation, authentication, encryption etc…).

Broadcast services

FDD support

Adaptive Arrays use channel state information in the PHY at both downlink and uplink. When channel state of the downlink is required at the BS, there are two ways to obtain it:

1. By relying on reciprocity, thus using the uplink channel state estimation as the downlink channel state.
2. By using feedback, thus transmitting the estimated channel state from the SS to BS.

The first method is more simple and is well suited for TDD systems, The second method is more suitable for FDD systems, where reciprocity does not apply (due to the large frequency separation between uplink and downlink channels). In this section the special MAC functions that support the second type of channel estimation is described.

Adaptive Array Support for FDD systems contains two MAC control messages: Request for estimation and a reply. The reply contains channel state information, obtained at the SS. The channel state information shall be computed periodically during Channel Estimation Interval (CEI). The CEI is the time allowed from the arrival of the signal that the SS uses for channel estimation, to the reply send by the SS. The value of CEI shall be determined by the BS and broadcasted to all SSs at registration.

CSF-REQ message

The Channel State Feedback Request (CSF-REQ) message shall be sent by the BS from time to time, to signal the SS that channel state information should be updated. The time between requests is an internal parameter of the BS MAC, and should not be limited to any specific value. The SS should perform channel estimations on a regular time basis, in order to be able to provide up-to-date estimations upon request.

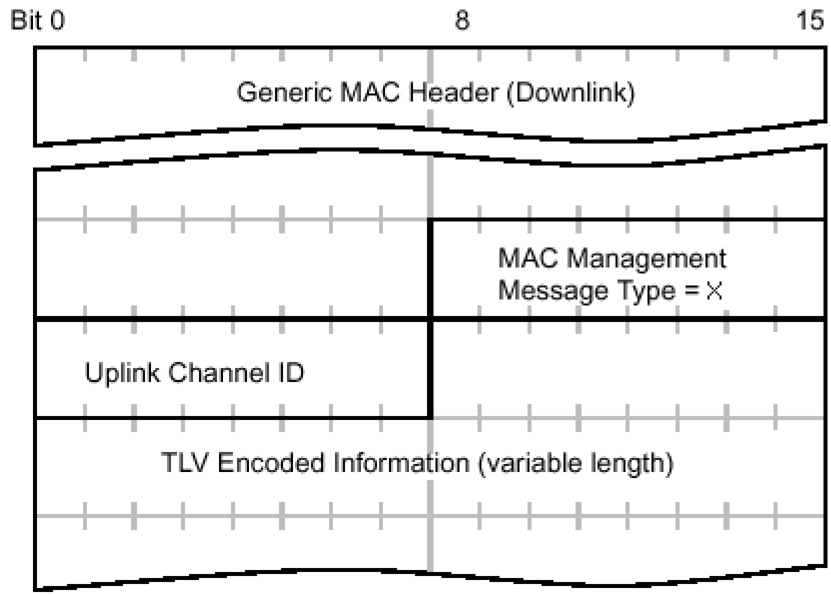

Figure 2: CSF-REQ message

The CID used in the header will be the basic CID of the SS that is addressed.

The following parameters may be included in the TLV encoded information of the message:

- Frequency adjust information
- Power adjust information
- Timing adjust information

CSF-REP message

The Channel State Feedback Reply (CSF-REP) message shall be sent by the SS as a response to a CSF-REQ sent by the BS. The SS reply shall be the most up-to-date estimation of the channel, obtained during a **Channel Estimation Interval** (CEI). The Channel Estimation Age field shall be used to indicate the number of CEI periods elapsed since the channel estimation was performed. Any value of Channel Estimation Age field, greater then zero, indicates to the BS that the channel information send by SS is not up to date.

Note:

The value of CEI shall be predefined according to channel stability over time (a typical value is 20 msec), The BS is responsible to determine the actual value of CEI, and for the distribution of this value to all SSs.

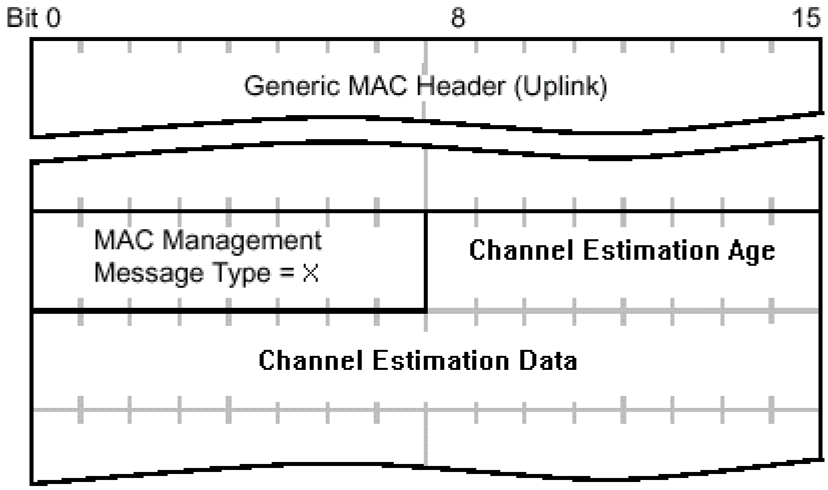

Figure 3: CSF-REP message

The Channel Estimation Data is a stream of data bits captured by the SS PHY. The definition of this stream is left to the PHY, since it may be different for different PHY types. As an example only, this data stream may represent 64 consecutive complex samples (of 8 bits I and Q) of the received preamble or synchronization signal.

References

[2] Einan Regev, Proposed MAC Enhancements to support adaptive antenna array processing in 802.16.3, IEEE document number 802.16c-01/45.

[1] Huanchun Ye, TG3 MAC Support for Advanced Antenna Technologies, IEEE document 802.16c-01/64