Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Reuse / AAS enhancements for IEEE 802.16-REVd**
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Re:	Working Group re-circulation Ballot #13a Announcement
Abstract	Reuse / Enhancements for AAS support, to enable operation in high interference environments
Purpose	Adoption of proposed enhancement into P802.16-REVd/D3-2003
Notice	
Release	
Patent Policy and Procedures	

Reuse/AAS Enhancements for IEEE 802.16d

Problem Definition

In order for adaptive arrays to effectively benefit 802.16d, the benefits must be brought in equal measure to both broadcast and unicast channels. In particular, there are two major issues that must be addressed:

Link Budget

Coherent beamforming with a basestation antenna array can effectively increase the transmission range of unicast channels, since there exists an optimum beampattern to serve the intended SU, but it cannot directly increase the range of the broadcast channels – most crucially, broadcast MAP bursts do not enjoy this extended range. An SU who cannot receive DL MAP is cut-off from receiving downlink unicast data, even though it has the link budget for the unicast transmission itself. The same problem occurs in the uplink – an SS that cannot receive the UL MAP message will not use the uplink channel, even though the basestation can use coherent combining techniques to receive its weak signal.

The present standard attempts to circumvent this problem in the 'AAS' mode by redefining several of the broadcast messages, in particular the MAP messages, to be unicast instead of broadcast. This strategy incurs potentially expensive penalties – large overhead, the inability to support genuine broadcast-type services, and the practical problem that it may not work – AAS systems cannot unicast messages to terminals that have been idle and whose locations have not recently been determined. Period ranging, though it can furnish location information, may be overwhelmed in a large cell with many SUs if relied upon to update AAS location information frequently in dynamic channel environments. It would be preferable if AAS mode could support true broadcast functionality.

Interference

In a network that has made effective use of adaptive array technology, the unicast channels will operate with great spectral efficiency, possibly supporting operation where each basestation sector has the same frequency allocation (re-use 1). In networks with only one UL/DL resource available, this may in fact be the only option. This is achieved by each basestation both focusing energy onto a 'desired' SUs while sending very little energy (nulling) 'undesired'users for whom these transmissions cause interference.

While the unicast transmissions can accomplish nulling, broadcast transmissions cannot. In such a high re-use network, these broadcast transmissions are received by SUs from their 'own' basestations together with the transmissions of all other basestations, and are thus at significant risk of being buried by interference. Such at-risk transmissions include the 2-128 symbol of the long preamble, which is important to train the SU equilizer and needs to be 'clean', the MAP messages, DCD, UCD, etc…

Even in the case of unicast channels, there remains the problem that if occasional channel conditions cause 'nulling' to fail, SUs can receive a burst from a different basestation than the one intended. If this burst has the same timing as the anticipated burst, it will be demodulated correctly and pass CRC checksum, since bit scrambling, which in other standards is derived from the BSID, is in the present system derived from the same parameters for each basestation. The problem is even worse in the uplink direction, since the basestation will receive bursts from many SUs, only one of which is its 'own'. The AAS BS may correctly demodulate the signal from an SU, but the PHY cannot determine if the burst came from its own SU or that of another BS, since the same scrambling was applied to each.

The problem becomes particularly bad in synchronized networks where all the basestations use the fixed slot sizes to bear the DL bursts, fixed slot sizes for the UL bursts, and the same DL/UL transition time. This is the preferred operating mode for networks of AAS basestations operating with nulling capability.

Proposed Solutions

The solutions fall into three categories:

BSID-based Scrambling

The current randomization (scrambling) process for the 802.16 OFDM PHY is performed by a modulo-2 addition to each uplink or downlink data burst with a pseudo-random binary sequence output from a linear feedback shift register as described in 8.3.3.1 of [1].

The shift register is 15 bits long, with a seed value that is initialized at the beginning of each frame on the downlink, and again at the beginning of each downlink burst (not including burst #1). On uplink, the randomizer seed is initialized at the beginning of each burst. Preambles are not scrambled.

In order to create a randomization that is dependent on both base station and the user (or connection), we introduce modifications to this seed value. For the preambles and broadcast portion of the downlink frame (FCH and burst #1) we recommend maintaining the fixed constant seed value as currently defined. For all other downlink bursts and all uplink bursts, we recommend that a combination of base station ID, connection ID, and frame number determine the seed value for the shift register, rather than the current combination of DIUC/UIUC and symbol number.

The base station ID is a 48-bit value, the connection ID (CID) is 16 bits, and the frame number is 24 bits; these can be combined together with a simple hashing function to produce the seed for both uplink and downlink transmissions. The CID is included since at sector boundaries, different SUs communicating with different sectors of the same basestation may interfere, and the frame number is included in order to ensure that retransmissions are differently scrambled and are not distorted with the same peak-power nonlinearities.

Creation of Re-use for Preamble and Broadcast transmissions

The second symbol of the long preamble transmitted by nearby basestations, and the broadcast MAC messages, need to be as ‘orthogonal’ as possible. The most direct way to do this is to allocate a different set of subcarriers to each basestation for these transmissions. For instance, a re-use of 4 can be created by forming one preamble symbol from only the subcarriers of section 8.3.3.6 numbered k=0 (mod 4), a second preamble from the subcarriers numbered k=1 (mod 4), etc… to create four distinct, orthogonal preambles. The same subcarrier allocation can be used for the other broadcast messages of a given basestation’s frame.

The penalty for creating re-use in this manner is that the broadcast messages would use four times the resources that they presently do. The benefit is greatly reduced interference, and this may in fact be required to create a viable wide-area network. In fact, a yet more aggressive re-use than 4 may be required for wide-area deployment. A further benefit is that these symbols may be transmit with higher power than symbols using all subcarriers; this gives a significant boost to the link budget for broadcast bursts in AAS systems.

In order to cope with this increased expense for broadcast burst transmission, the broadcast bursts themselves should be compressed to the maximum extent possible. Strategies of this kind are already present in the OFDMA variant of the standard, and these should serve as examples.

Note that subchannelization is introduced as well in [2] without the penalty of a much more MAP overhead by allowing traffic data concurrent with broadcast burst (MAP) transmission. This, however, offers incomplete interference suppression, since the traffic data will interfere with the broadcast data of neighboring basestations (although this might be controlled by transmitting the broadcast subcarriers with more power, as suggested by N. Chayat).

Beampattern Diversity

A major component of the link budget gain in unicast AAS is the diversity gain resulting from the use of many basestation antennas simultaneously -- in channels were some of these fade, others might not. This same advantage can be brought to broadcast AAS by repeating broadcast bursts but transmitting them with different antenna beampatterns each time. For a well-chosen sequence of beampatterns, the diversity order that can be created in this way is equal to the number of repetitions of the burst.

Coherent gain can be created as well if the SUs soft-combine the repeated broadcast burst transmissions, although this may offer insufficient benefits to justify its implementation complexity.

The cost of this strategy is the overhead for repeating broadcast bursts. If, however, this method is combined with the subchannelization strategy described above, the penalty need not be multiplicative. This is because subchannelized symbols, for instance using k = j mod 4 numbered subcarriers, will in the time domain consist of four repetitions of the same waveform. If each of these waveforms were transmit with a different antenna beampattern, the result would be pattern diversity. Functionally, each of these waveforms needs to be preceded with its own cycle prefix and these become ‘microsymbols’ defined by 64-point FFTs.

References

[1]. IEEE P802.16-REVd/D2-2003 Draft IEEE Standard for local and metropolitan area networks part 16: Air Interface for Fixed Broadband Wireless Access Systems.

[2]. IEEE C802.16d-03/20 Subchannelization for OFDM AAS Mode by Yanover et al.