IEEE 802.16 Presentation Submission Template (Rev. 8)

Document Number:
IEEE S802.16a-02/39

Date Submitted:
2002-03-12

Source:
Randall Schwartz, Phil Kelly
BeamReach Networks
755 N. Mathilda Ave
Sunnyvale, CA 94086

Venue:
802.16, Session 18

Base Document:
Refers to P80216a_D2.pdf at URL <http://ieee802.org/16/…>.]

Purpose:
AAS Ad-hoc Report

Notice:
This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.

Release:
The contributor grants a free, irrevocable license to the IEEE to incorporate text contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE’s name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE’s sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.

IEEE 802.16 Patent Policy:
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/letter>. 
Output of the 802.16 AAS Ad Hoc

March 11-15, 2002

Randall Schwartz, Chairman
Goals of the AAS Ad-hoc

- Reply to AAS PHY and MAC comments from Finland meeting
- Present data demonstrating the comparative performance of AAS with Mode C and other Modes.
- Flesh out text of the Mode C PHY and MAC sections
- Propose structure for adding AAS to other modes
Participants in the Ad Hoc

- BeamReach
- Raze
- Conexant
- Harris
- WiLAN
- Runcom
- Intersil
- Marvel
- Vectrad
- IOSpan
- Hexagon
- Transcom
- TI
- Arraycom
- WPI
Actions of the Ad Hoc

• Conference calls held to review goals of the ad hoc, set action plan of the ad hoc, review results of the ad hoc
• Call made for inputs to both MAC and PHY text
• Call for simulation testing of all modes

Actions Taken
• Test simulation undertaken for comparison of Mode B vs. Mode C for implementation of adaptive antenna system
• Capacity analysis performed comparing diversity techniques with adaptive antenna arrays
• White paper written outlining the performance gains using adaptive antenna arrays
• Review and update of PHY text in document
• Review and update of MAC text in document
• Review comments from last meeting
• Models are the outcome of the IEEE 802.16 working group's efforts to define channel models in the 2 to 11 GHz bands for evaluation of physical layer design considerations.

• Based in part on Stanford University Interim (SUI) channel models

• SUI models intended to model typical conditions in the continental U.S. They encompass three terrain types:
  • A: hilly with moderate-to-heavy tree densities
  • B: intermediate path loss conditions
  • C: mostly flat terrain with light tree densities

• Models include rms delay spread, based on a 3-tap delay line. The gain associated with each tap is characterized by a Ricean or Rayleigh distribution and Doppler frequency.

• Models are based on the following scenario: cell radius equal to 7 km, base station antenna height equal to 30 m, and 90% cell coverage with 99.9% reliability at each location covered.
IEEE 802.16 Channel Models

Power Delay Profiles

- SUI-1, Type C (flat, light trees), \( \tau_{rms} = 0.111, K=3.3 \)
- SUI-2, Type C (flat, light trees)
- SUI-3, Type B (intermediate), \( \tau_{rms} = 0.26, K=0.5 \)
- SUI-4, Type B (intermediate)
- SUI-5, Type A (hilly, moderate trees), \( \tau_{rms} = 2.8, K=1.0 \)
- SUI-6, Type A (hilly, moderate trees)

Sample Fading Envelope

- SUI-1
- SUI-3
- SUI-5
- SUI-6
- SUI-2
802.16 AAS
Ad Hoc

Adaptive Antenna Arrays

• **Attributes**
  – Increased signal power through beamforming gain
  – Reduced interference through null steering
  – Spectral reuse through spatial multiple access
  – Robustness to multipath fading through spatial diversity

• **Benefits**
  – Higher data rates (improved system capacity, spectral efficiency)
  – Increased cell radius
  – Increased coverage
  – Increased link reliability, or lower multipath fade margin
Without Adaptive Antenna Array

Out-of-cell Interference

Non Adaptive Array System (Non-AAS) Cell
802.16 AAS
Ad Hoc

Desired Coverage

Multiple antennas are placed at the Base Station
Single antenna at the Subscriber Station

Out-of-cell Interference

Cell Extension

AAS Cell

Non Adaptive Array System (Non-AAS) Cell
With Adaptive Antenna Array

AAS provides beamforming gain, interference rejection, and multipath isolation.
802.16 AAS Ad Hoc

With Adaptive Antenna Array

Subscriber 1
Subscriber 2
Subscriber 3

Out-of-cell Interference
Non AAS Cell
AAS Cell

New links acquired without harm to existing links
802.16 AAS
Ad Hoc

With Adaptive Antenna Array

Subscriber 1

Subscriber 2

Subscriber 3

Out-of-cell Interference

AAS Cell

Non AAS Cell

Multiple users on the same frequency (each with high link quality)
## AAS Gains

- **Signal Gain** – large (Implementation/Mode dependent)
- **Interference Rejection** – Deep nulls (40 to 80 dB)
- **Diversity Gain** – 20+ dB in Rayleigh fading
- **Link Capacity** (bps/Hz) – $\log_2(M)$
- **System Capacity** – 15 dB
  
  (multiple access and interference limited)

- Provided by adaptive antenna arrays
- Provided by space-time block codes
- Provided by diversity processing
Implementation Details

• **Nomenclature**
  – OFDMA subchannel = 48 data carriers
  – M = number of antennas
  – S = number of symbols based on time-bandwidth product considerations
    • S = 2 x adaptive degrees of freedom
  – C = complexity (floating point operations)
  – OFDMA symbol duration is on the order of 0.1 to 1.0 ms

• **Option 1: Compute single beamforming weight per subchannel**
  – S = 2 x M
  – C = order (M)^3
  – Overhead is S tones per frame
  – Example: M = 8, S = 16; Overhead contained within one OFDMA symbol, so overhead is 2 to 20% in a 5 ms frame

• **Option 2: Compute beamforming weight for each individual tone within a subchannel (i.e., 48 beamforming weights)**
  – S = 2 x M for each carrier => 2 x 48 x M
  – C = order (48M)^3
  – Example: M = 8, S = 48 x 16, Overhead requires 16 OFDMA symbols, so overhead is 32 to 320% in a 5 ms frame
Implementation Summary

- Given 48 data tone subchannel (OFDMA)

  Option 1: Compute single beamforming weight per subchannel
  - Reasonable complexity
  - Weight training overhead is 2% to 20% in a 5 ms frame
  **Achievable**

  Option 2: Compute beamforming weight for each individual tone within a subchannel (i.e., 48 beamforming weights)
  - Complexity is up to \((48)^3\) times greater to achieve similar performance
  - Weight training overhead is 32% to 320% in a 5 ms frame
  **Not practical**
Consider (for example) \( \text{BW} = 3.5 \text{ MHz} \), \( N_{\text{FFT}} = 2048 \), \( \Delta f = 1.95 \text{ kHz} \)

- \( N_{\text{FFT}} = 2048 \)
- Mode B Subchannel (48 data tones) \( \Delta f \approx 3.5 \text{ MHz} \)
- Mode C Subchannel (48 data tones) \( B = 48 \times \Delta f \approx 94 \text{ kHz} \)

The processing bandwidth impacts performance.

In the analysis, all other factors (coding, FFT size, channel bandwidth) are identical.
Impact of Processing Bandwidth (Mode C vs. Mode B)

Output SINR vs. Processing Bandwidth

SINR performance for narrow processing bandwidth (Mode C)
SINR performance for wider processing bandwidth (Mode B)

SINR Improvement Using Narrow Processing Bandwidth

Mode C
Mode B

(50 ~ 100 kHz) (3.5 MHz)

Processing Bandwidth (kHz)

500 1000 1500 2000 2500 3000 3500

SINR (dB)

(500 1000 1500 2000 2500 3000 3500)
Mode C provides 12 dB more SINR than mode B for 3.5 MHz channel bandwidth.
Mode C provides 14 dB more SINR than mode B for 3.5 MHz channel bandwidth.
SUI-5

802.16 AAS Ad Hoc

SUI 5 30° Sectorized Antennae
16 Antennae
12 Emitters
15 dB Receive SNR
200 Trials

Mode B

7 dB
MAC Support for AAS

- **Objectives**
  - Allow evolution toward AAS for range and capacity improvement
  - Support co-existence of AAS and non-AAS subscriber stations
  - Support multiple PHY modes
  - Exploit available MAC mechanisms

- **Main Issue is Lack of Broadcast Capability**
  - AAS extends cell coverage beyond broadcast range
  - Spatial multiplexing increases system capacity through frequency reuse by simultaneous P-to-P links

Multiple users on the same frequency (each with high link quality)
AAS parts are distinguished by special DIUC and UIUC

AAS boundary is defined by DL/UL MAPS
- “standard” broadcast MAPS for non-AAS subscriber stations
- “private” (unicast) MAPS for AAS subscriber stations
  - Use the same format, but contains only information for a designated subscriber station
This figure illustrates the current text:

<table>
<thead>
<tr>
<th>SYN</th>
<th>Frame Control</th>
<th>Non-AAS Downlink</th>
<th>AAS Downlink</th>
<th>AAS DL Polling</th>
<th>Non-AAS Uplink</th>
<th>AAS Uplink</th>
<th>AAS BW Request</th>
<th>AAS Ranging</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>User N</td>
<td>User 2</td>
<td></td>
<td>User N</td>
<td>User 2</td>
<td></td>
</tr>
</tbody>
</table>

DIUC = 15/X

UIUC = 15/X

802.16 AAS
Ad Hoc

Additional AAS Detail
Network Entry and Initiation

- **Network Entry**
  - Subscriber station uses the same SYN sequence for frequency and time synchronization
  - AAS ranging and BW request interval have a known relationship with SYN

- **Downlink Initiation**
  - Subscriber station transmits its unique code to BS. BS detects it and forms a beam using the unique code. This establishes a link. BS then sends a private map.

- **Uplink Initiation**
  - DL polling channel has a known relationship with SYN
  - BS transmits a unique code in the DL polling channel. SS detects it and sends its unique code in the BW request channel. The subsequent steps are the same as downlink initiation.
Conclusions

- Results assume 2k FFT for OFDMA (Mode B and C)
- Mode C provides 12-16 db improved performance for the implementation of adaptive antenna solutions vs. Mode B for single weighting coefficient implementations.
- Mode B can reach performance levels near Mode C if a scheme of individual weightings are used. But the computation burden would be significant.
- MAC should be able to send message to identify an AAS mode. Would need implementation for each PHY mode. Should allow initialization in AAS or non-AAS mode
- PHY for AAS modes can be implemented with minimum additional updates, as proposed.
Spatial diversity means the required fade margin is reduced, and this excess gain can be applied to higher data rates, increased range, or to support indoor installations.