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Number of pilots in OFDM FFT=256 mode with UL subchannelization.
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Base Document:
Purpose:
Present the deficiencies of current text for uplink subchannelization in 802.16a in FFT=256 mode and provide an improved solution.
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802.16a OFDM # of pilots and its relation to subchannelization

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Comment (1)

- This comment addresses the issue of number of pilots in the OFDM mode.

- Between 802.16a/D5 and 802.16a/D6 a major technical change has occurred, by introduction of the subchannelized uplink option in the OFDM mode. I welcome this change - it is a significant improvement of the OFDM mode. Nevertheless, it calls for review of the whole OFDM clause.
Comment (2)

- In my view, the subchannelized operation will become "de facto mandatory" in all 802.16a point-to-multipoint equipment. Therefore we have to give appropriate weight to its performance and to its implementation aspects.
Comment (3)

- The current implementation of the subchannelization is both awkward and carries a performance penalty in that in subchannelized mode each subchannel has only two pilots. The use of just two pilots creates a situation in which the diversity order of phase tracking is less than of the data, and the channel estimate cannot be maintained adequately in larger Doppler spreads.
Comment (4)

- The awkwardness usually translates to implementation complexity and to performance reduction. Here we have clusters of irregular size (some 12, some 13 subcarriers); some contain pilots, some not; the pilots are in irregular locations within the clusters. These irregularities complicate channel estimation, phase tracking, separation of data subcarriers etc. The subchannelized mode just looks as OFDM divided by a butcher's knife, rather than design for performance and for implementation.
Comment (5)

- For all the reasons above I recommend to implement the OFDM mode with 16 pilots rather than with 8. Documents 802.16a-02/35 shows that the increase in the number of pilots does not violate the regulatory masks and does not penalize the data rate. Documents 802.16a-02/36r1,37 document the changes needed to implement a regular, high performance OFDM mode.
802.16a timeline implications

- Adoption of a change carries additional time penalty on 802.16a only if appealed in recirculation stage.

- If an agreement is achieved at this stage, there is little danger of time slip

- No additional time penalty
Subchannelized UL for the OFDM mode is a great achievement

• Provides 6 dB link budget advantage on UL
  – Allows better CPE economics, especially in licensed bands

• Improved granularity and reduced training overhead

• Implements clustered subcarrier allocation
  – Improved ACI and training performance
History of subchannelized UL

• Promoted by Alvarion for more than a year
• Finally, gained support by Nokia and WiLAN, and introduced in HIPERMAN
  – Disagreements on details
• Repeatedly rejected in 802.16
  – Opposition from both OFDMA and SC camps
• Introduced as a part of the Ballot Resolution Committee in the 802.16a/D6
  – Included some last-minute changes
Subchannelized uplink – a de-facto mandatory feature in licensed bands

• The subchannelized uplink is not just for short packets – it provides performance advantages across the board, and should be implemented in the best way possible.

  – Adequate phase tracking performance for long packets
  – Convenient and high performance training
Regularity implications

• Processing of upstream subchannelization composed of clusters calls for per-cluster processing

• In current structure each cluster is built differently
  – Some clusters contain a pilot, some don’t
  – Some contain 13 pilots, some 12
  – Those with 13 each contains pilots at different location
  – Those with 13 contain some 6 training subcarriers at even locations, some 7 subcarriers at odd locations

• Implementer’s nightmare

• Performance implications
• 3:{-100, ..., -89}, T.T.T.T.T.T.T.
• 1:{-88, ..., -76}, p@-84 T.T.P.T.T.T.T
• 4:{-75, ..., -64}, .T.T.T.T.T.T.T.
• 2:{-63, ..., -51}, p@-60 .T.P.T.T.T.T.T.
• 1:{-50, ..., -39}, T.T.T.T.T.T.T.
• 3:{-38, ..., -26}, p@-36 T.P.T.T.T.T.T.
• 1:{ 1, ..., 13}, p@12 .T.T.T.T.T.P.
• 3:{ 14, ..., 25}, T.T.T.T.T.T.T.
• 2:{ 26, ..., 38}, p@36 T.T.T.T.T.P.T
• 3:{ 51, ..., 63}, p@60 .T.P.T.T.T.T.T.
• 1:{ 64, ..., 75}, T.T.T.T.T.T.T.
• 4:{ 76, ..., 88}, p@80 T.T.P.T.T.T.T.T.
• 2:{ 89, ..., 100}, .T.T.T.T.T.T.T.
The proposed pilot structure

• Each cluster contains a pilot
  – Pilots and data have same diversity order

• Pilot always at cluster’s center
  – location most representative of cluster’s channel

• Each cluster is processed same way in the receiver
  – Pilot gathering for phase estimation
  – Data-pilot separation
• 1: \{-104, \ldots, -92\}, p@-98  TTTTTTPTTTTTTT
• 3: \{-91, \ldots, -79\}, p@-85  TTTTTTPTTTTTTT
• 2: \{-78, \ldots, -66\}, p@-72  TTTTTTPTTTTTTT
• 4: \{-65, \ldots, -53\}, p@-59  TTTTTTPTTTTTTT
• 1: \{-52, \ldots, -40\}, p@-46  TTTTTTPTTTTTTT
• 3: \{-39, \ldots, -27\}, p@-33  TTTTTTPTTTTTTT
• 2: \{-26, \ldots, -14\}, p@-20  TTTTTTPTTTTTTT
• 4: \{-13, \ldots, -1\}, p@ -7  TTTTTTPTTTTTTT
• 1: \{ 1, \ldots, 13\}, p@  7  TTTTTTPTTTTTTT
• 3: \{ 14, \ldots, 26\}, p@ 20  TTTTTTPTTTTTTT
• 2: \{ 27, \ldots, 39\}, p@ 33  TTTTTTPTTTTTTT
• 4: \{ 40, \ldots, 52\}, p@ 46  TTTTTTPTTTTTTT
• 1: \{ 53, \ldots, 65\}, p@ 59  TTTTTTPTTTTTTT
• 3: \{ 66, \ldots, 78\}, p@ 72  TTTTTTPTTTTTTT
• 2: \{ 79, \ldots, 91\}, p@ 85  TTTTTTPTTTTTTT
• 4: \{ 92, \ldots, 104\}, p@ 98  TTTTTTPTTTTTTT
The proposed training structure

• All subcarriers are used for training

• There is no need for using odd carriers only, since stations transmit with a small frequency error.

• Less interpolation side effects
• Better smoothing performance
• Uniform processing of all clusters
Simple construction, good PAPR

- The training sequences proposed are algorithmically constructed
  - Use two seed length-13 QPSK sequences
- No need for separate 1/4, 2/4, and 4/4 training sequences
- PAPR of 3 dB in all (1/4, 2/4, 4/4, short and long downlink) modes
Spectral masks

• Spectral masks of ETSI
  – OK both before and after the change

• The 802.16a masks for WirelessHUMAN
  – OK both before and after the change

• MMDS masks
  – FFT size 256 with Fs=7/6 BW does not pass the mask even before the change
    • The flattop fits, the edges cut the mask
ETSI spectral masks

OFDM spectra vs. ETSI masks

- 200 active subcarriers
- 208 active subcarriers
- ETS1E
- ETS1F
- ETS1G

Frequency [Hz]

PSD [dB]
WirelessHUMAN mask

OFDM spectra vs. WirelessHuman mask

200 active subcarriers
208 active subcarriers
WirelessHuman
MMDS mask

OFDM spectra vs. MMDS mask

200 active subcarriers
208 active subcarriers
MMDS mask
The upcoming Mobility support

- The next phase of 802.16 is supporting mobility
- Mobility calls for supporting higher Doppler spreads, training information maintenance
- Availability of adequate amount of pilots is crucial for future support of mobility
Recommendations

• Adopt the 208 subcarrier structure
  – 16 pilots, 4 pilots per subchannel

• The text is available
  – Doc 80216a-02/37 (parts 4.2, 4.3, 4.7)
    • subchannelization, pilots, focused contention
  – Document 802.16a-02/36r1 part 4
    • Preamble structure

• We have a last chance to do it right!