Importance of Dedicated Pilots for the Downlink in IEEE 802.16m

Document Number:

IEEE C802.16m-08/122

Date Submitted:

2008-03-10

Source:

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Venue:

TGm Call for contributions on 802.16m System Description Document, IEEE 802.16m-08/005.

Topic: “Downlink Physical Resource Allocation Unit” and “Pilot Structures as relevant to downlink MIMO”

Abstract:

This contribution describes the importance supporting dedicated pilots in the downlink resource allocation units.

Purpose:

Adoption of recommendations into the 802.16m System Description Document

Importance of Dedicated Pilots for the downlink of IEEE 802.16m

- The IEEE 802.16e downlink supports both broadcast pilots and dedicated pilots
  - STC Zone IE specifies either Broadcast pilots or Dedicated pilots in a zone
  - Broadcast pilots – support open-loop STC/MIMO and closed-loop (codebook) precoding
  - Dedicated pilots – support TDD-reciprocity-based beamforming and MIMO+BF
- Key Message for 802.16m from this contribution:
  - The **downlink data channels must support dedicated pilots** for a variety of reasons that we will outline in this contribution
    - Critical for more than 2TX antennas
  - The downlink data channels must also support broadcast pilots
    - Reasonable for 2 transmit antennas at the BS and for legacy base stations

Why the concern over dedicated pilots vs. broadcast pilots?

- Support of Advanced Antenna Techniques is vital for 802.16m
- Need to efficiently support high-performance Closed-Loop MIMO / MIMO+BF transmission methods:
  - Beamforming
  - Single-User MIMO (SU-MIMO)
  - Multi-User MIMO (MU-MIMO)
- Support up to rank 4 transmission
  - 2-stream SU-MIMO for handsets
  - 4-stream SU-MIMO for CPEs / Laptops
  - 4-user MU-MIMO for all MS classes
- **The performance of advanced antenna techniques is highly dependent on the choice of whether the pilots are dedicated or broadcast**.

Terminology: Dedicated vs Broadcast Pilots

- **Broadcast Pilots** (sometimes called Common Pilots)
  - Pilot symbols that can be used by any MS for estimating the DL channel
    - Pilot symbols are not beamformed / precoded with the data and *are specific to a transmit antenna* (or virtual transmit antenna)
    - When beamforming / precoding is used on the data and the pilots are broadcast (not beamformed/precoded), then the MS requires knowledge of (or must determine) the beamforming/precoding vector/matrix being used
- **Dedicated Pilots**
  - Pilot symbols that are specific to the data allocation and cannot be used by other MSs (those not assigned to the data allocation) to estimate the channel
    - *Pilot symbols that are typically beamformed along with the data*
    - MS does not need to know the beamforming/precoding vector/matrix
  - Definition from P802.16Rev2/D2 (Dec 2007) – Section 8.4.5.3.4 (STC Zone IE Switch)
    - "The optional Dedicated Pilots fields are used to support the use of open-loop precoding or closed-loop transmissions in which the MS has no knowledge of the precoding / beamforming matrix."
    - "When the data allocations are precoded/beamformed, then setting the Dedicated Pilots bit to 1 means the pilot symbols are precoded / beamformed in the same way as are the corresponding data subcarriers."
      - "In this case, an MS should use only the pilots that are specific to its allocation for channel estimations."

Many Reasons for Supporting Dedicated Pilots

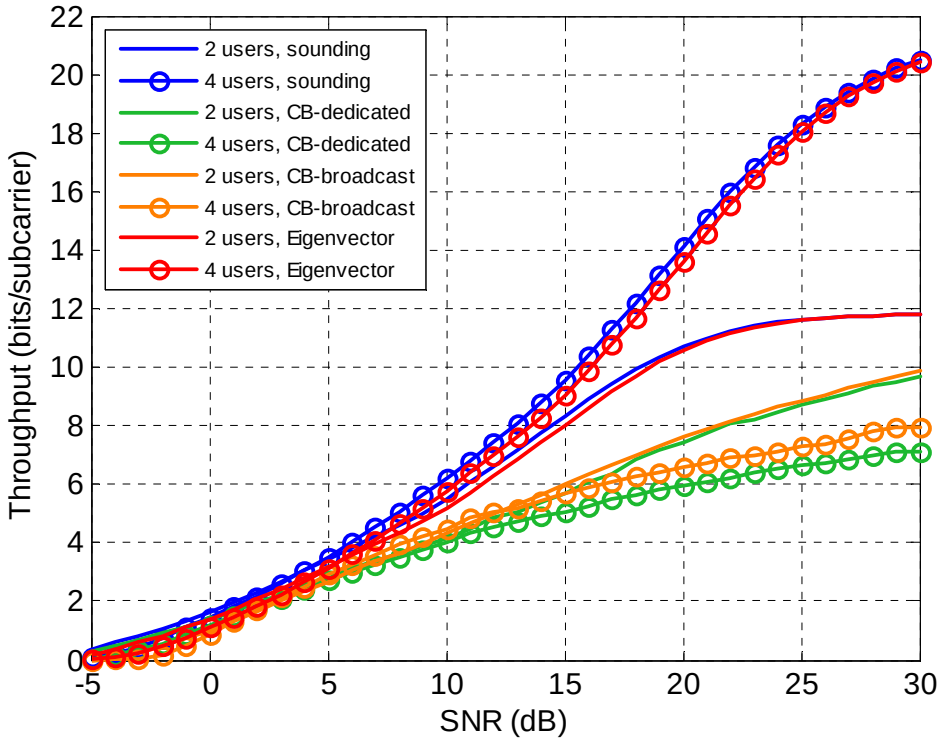
- Need 16m to support Beamforming (BF) and MIMO+BF methods that leverage TDD reciprocity
  - These methods require dedicated pilots
  - Reciprocity-based Closed-Loop MIMO methods are very efficient in terms of the required feedback
  - Field-proven techniques
  - Continuity from 16e
- Dedicated pilots are often more efficient than Broadcast Pilots in terms of pilot overhead for 4 or more transmit antennas:
  - Broadcast pilot overhead is fixed for a given number of *transmit* antennas
  - Dedicated pilot overhead increases with transmission rank
    - Note that transmission with rank 3 or 4 is not used as often as rank 1 or 2 transmission
    - For example: with dedicated pilots, there is no need to *always* have a 4-source pilot format when your BS has 4 Tx antennas.
- Power boosting more efficient with dedicated pilots
- Dedicated pilots more efficient with Fractional Frequency Reuse (FFR) scenarios
- Dedicated pilots are essential for supporting an arbitrary number of Tx antennas at the BS
  - Eliminates need for antenna aggregation methods which don't fully exploit coherent processing capability of higher numbers of transmit antennas
- Dedicated pilots allows more freedom for the BS to compute transmit weights
  - TX weights are not limited to a finite codebook (important for MU-MIMO)
  - Enable upgrades to the BS transmit weight computation strategy

Dedicated Pilots enable the use of better-performing MU-MIMO Methods

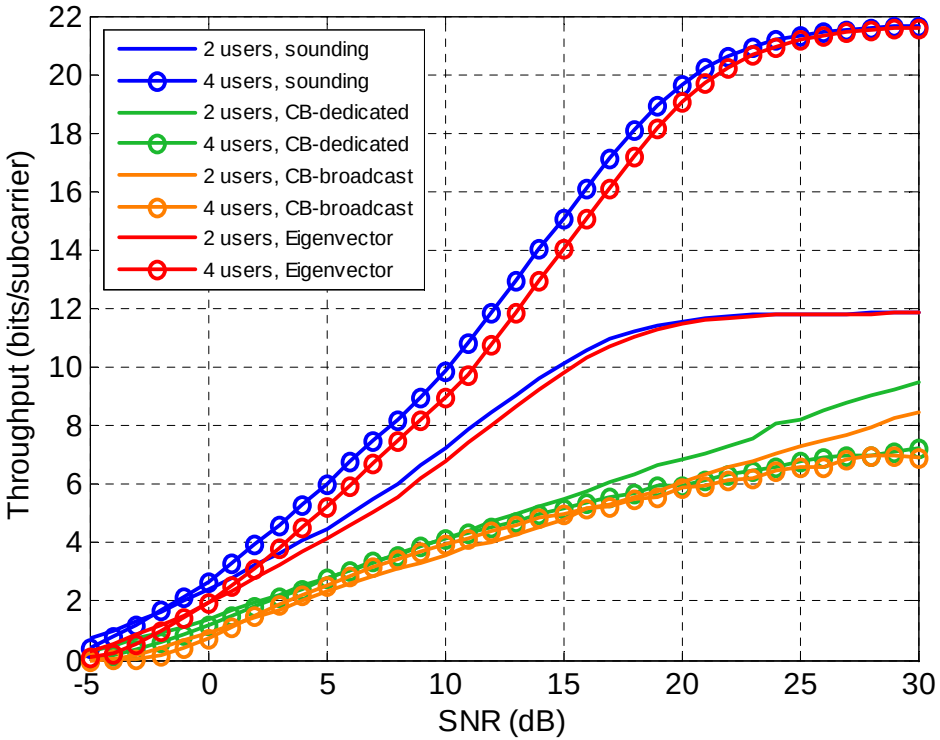
- Supporting DL MU-MIMO methods provide a significant opportunity for increased capacity over the MIMO & advanced antenna methods in IEEE 802.16e
- Choice of enablers for DL MU-MIMO:
  - Leveraging TDD reciprocity via UL Sounding or regular UL transmission (*requires dedicated pilots*)
  - Codebook feedback (*requires broadcast* or *dedicated pilots*)
  - Direct/Analog Covariance/Eigenvector feedback (*require dedicated pilots*)
- DL MU-MIMO methods that are enabled with TDD-reciprocity (e.g., UL Sounding) or Covariance / Eigenvector Feedback provide much better performance than codebook feedback
  - See graph on next slide and C80216m-08/123 for the details
- Therefore need to enable ULCS and/or Covariance /Eigenvector Feedback to provide better performance for MU-MIMO
- **Therefore need dedicated pilots to enable the higher performing MU-MIMO methods (critical for 4 or more TX antennas)**

Performance Comparisons for MU-MIMO

4 Tx, 2 Rx antennas



8 Tx, 2 Rx antennas



- For Sounding (TDD) and Eigenvector feedback (FDD), MU-MIMO provides large throughput gains over SU-MIMO in this channel (at SNRs>5 dB)
- UL Sounding (TDD)/Eigenvector feedback (FDD) & dedicated pilots is better than codebook (CB) feedback for this scenario
- For Codebook methods: Dedicated pilots provide some advantages with 8 Tx
  - For 4Tx, broadcast pilots are marginally better, but require feed-forward of interferers' codebook entries

NOTE: pilot overhead is accounted for in the throughput results

Broadcast Pilots are also needed in the System

- Broadcast pilots are a reasonable option for 2TX antennas at the BS
  - For 2TX antennas at the BS, MU-MIMO may not provide compelling gains over SU-MIMO
    - However, MU-MIMO vs SU-MIMO performance will need to be quantified as more features of the 16m system become defined
    - Expect similar performance amongst the various enablers for SU-MIMO with 2TX
  - Continuity with 16e deployments having 2TX BS antennas employing open-loop MIMO&STC

Specific Text Recommendations for the SDD

- Section 11 – PHY Layer
  - The DL Resource Allocation Units shall support the use of dedicated pilots
  - The DL Resource Allocation Units shall support the use of broadcast pilots