

Project	<b>IEEE 802.16 Broadband Wireless Access Working Group</b> < <a href="http://ieee802.org/16">http://ieee802.org/16</a> >
Title	<b>Progressive Feedback Scheme for High Resolution MIMO Codebook</b>
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Re:	IEEE 802.16m-08/016r1: Call for Contributions on Project 802.16m System Description Document (SDD). Target topic: “Downlink MIMO Schemes” and “Uplink control Structures”.
Abstract	This contribution proposes a progressive feedback scheme for downlink MIMO, especially for multi-user scenario.
Purpose	For discussion and approval by TGm
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# Introduction

- This contribution proposes a high level design of progressive feedback for large size codebook, aiming for high resolution and low overhead feedback in single and multi user MIMO transmissions in 16m standard.
- The proposal consists of
  - A method for progressively quantizing channel state information using a non-localized base codebook and a localized codebook that shrinks with each successive refinement of the quantization step.
  - The operations on base station and subscriber station, as well as the feedback message containing the quantized channel state information.

# Background

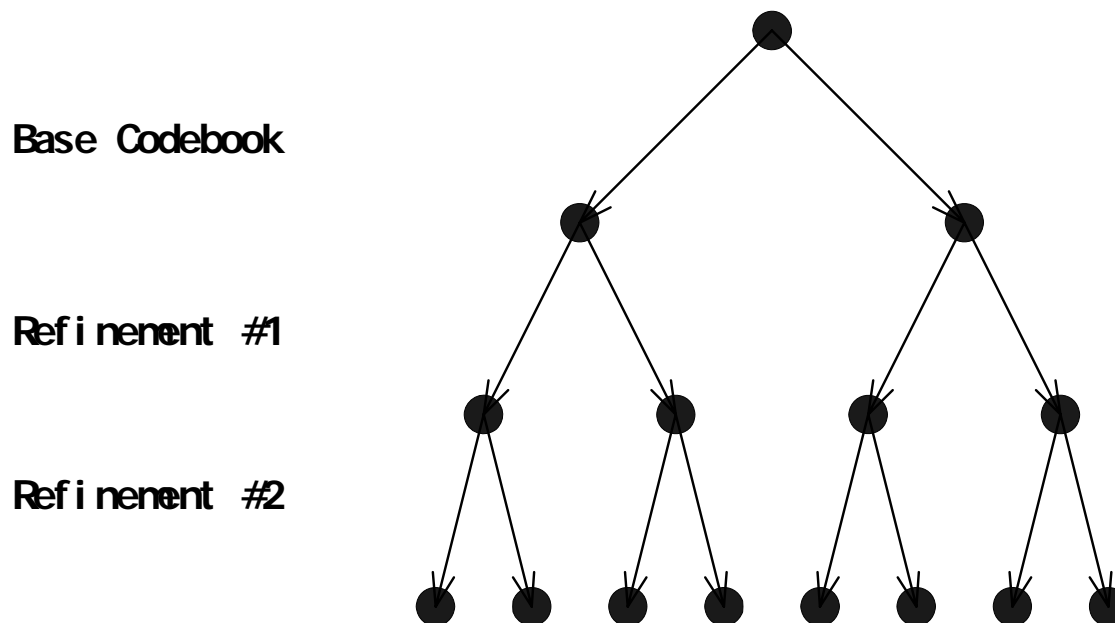
- MU-MIMO is considered to increasing system capacity
- Unfortunately, codebook based MU-MIMO requires large codebooks
  - Feedback scales as  $(M_t-1)\log_2 \text{SNR} + c$  [Jindal06]
  - Codebook sizes of 18-25 bits may be required per user in the four antenna case
- Many challenges to implement large codebook designs
  - How to find these codebooks?
  - How to search the codebook with low complexity?
  - How to store these codebooks?
  - How to support both single user and multi user beamforming?
  - How to exploit spatial/temporal correlation to reduce feedback?
- New codebook designs needed especially for MU-MIMO

# Proposed Scheme

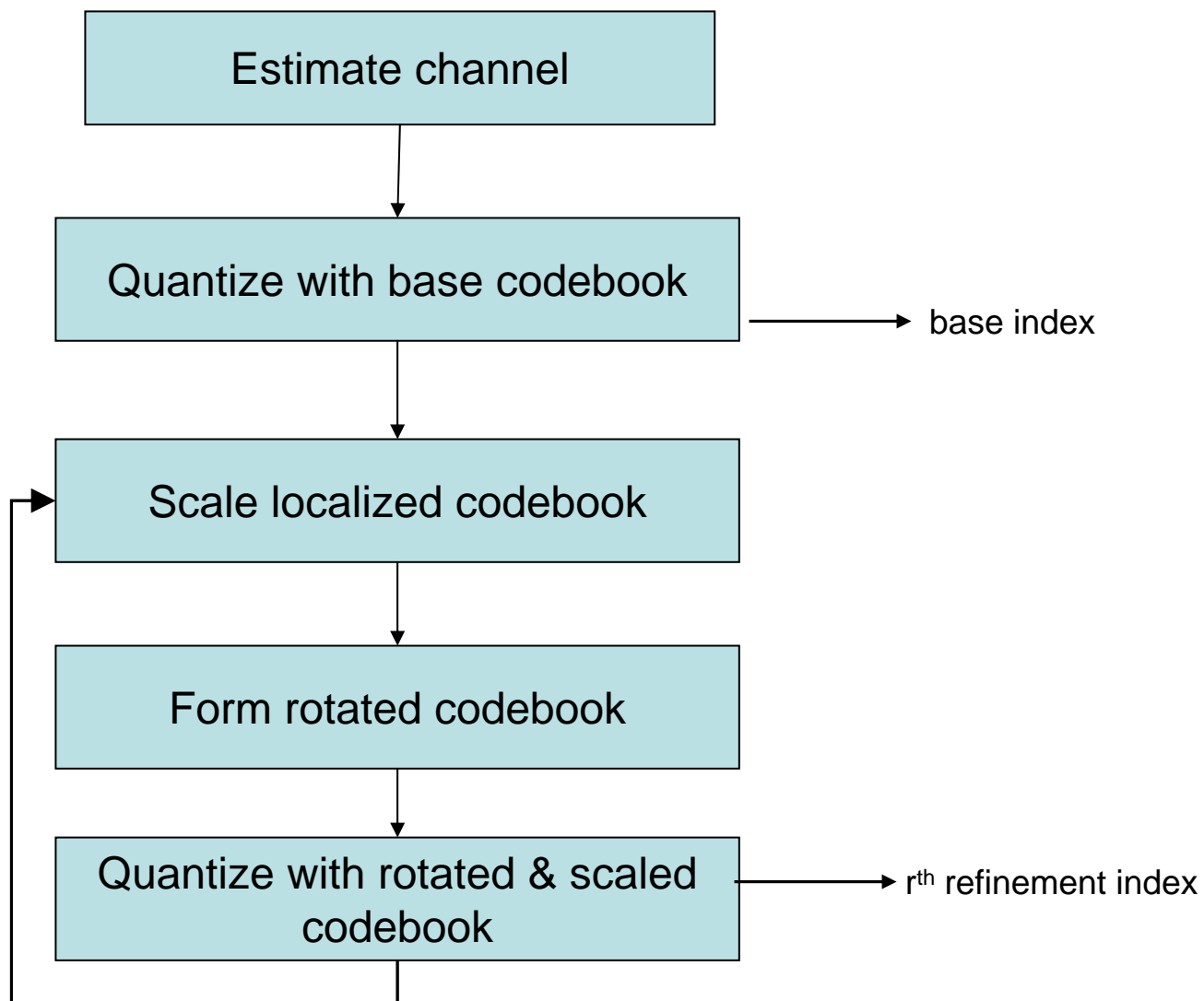
- We propose a progressive feedback scheme for any hierarchical codebook structure, for both single user and multi-user MIMO systems.
- Using a specially designed codebook or quantization method, a receiver progressively quantizes the channel state information and conveys the results back to the transmitter. The transmitter can then reconstruct the quantized information with high precision.
- As an example, the codebook consists of two sub-codebooks: a base codebook and a localized codebook. Each codebook consists of  $N_t \times 1$  unit norm vectors which correspond to a one-dimensional subspace that is to be quantized.
- The base codebook is the first step in the quantization process. As such, it should be as uniform as possible.
- The concept of a localized codebook is to generate a codebook that is localized around a center of mass. Localized codebooks have several applications such as refinement of quantization or dealing with time variations. They have been shown to be useful in dealing with spatial correlation [RagHeaSay07] and in adaptive algorithms [SamHea05].

# Successive Refinement Procedure

- A successive refinement procedure is employed to enable several levels of more refined quantization than the base codebook. At each step, the localized codebook rotates and shrinks to obtain higher precision.
  - The number of refinements determines the effective resolution.
  - The number of refinements can vary for different users.

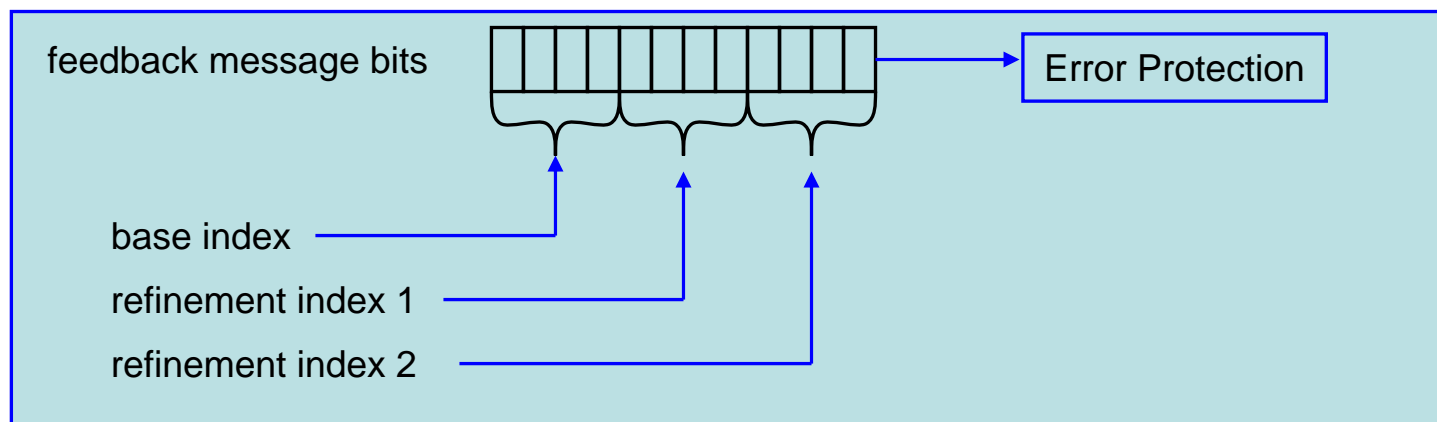


# Subscriber Station Procedure Flow Chart

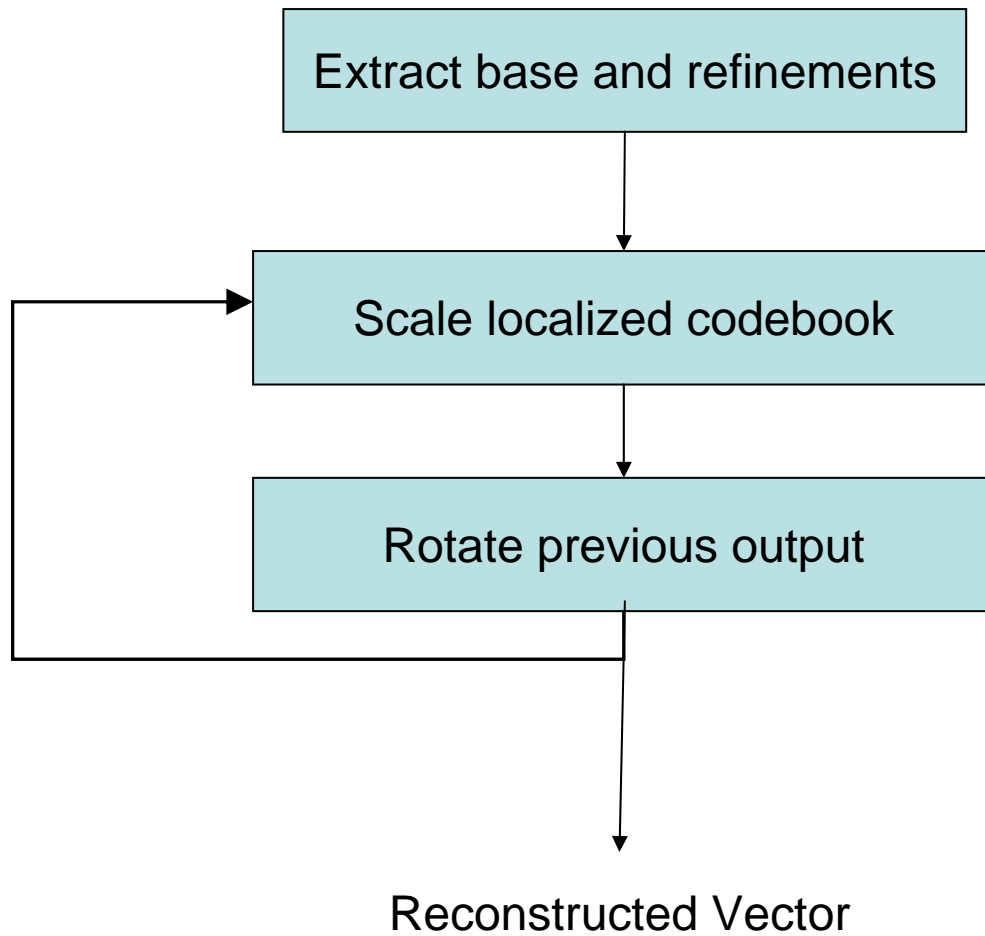


# Feedback Message

- The feedback message consists of base and refinement indices which can be allocated in the same or different channels.
- Different indices can have different level of error protections.
- A generic feedback message is shown below.



# Base Station Procedure Flow Chart



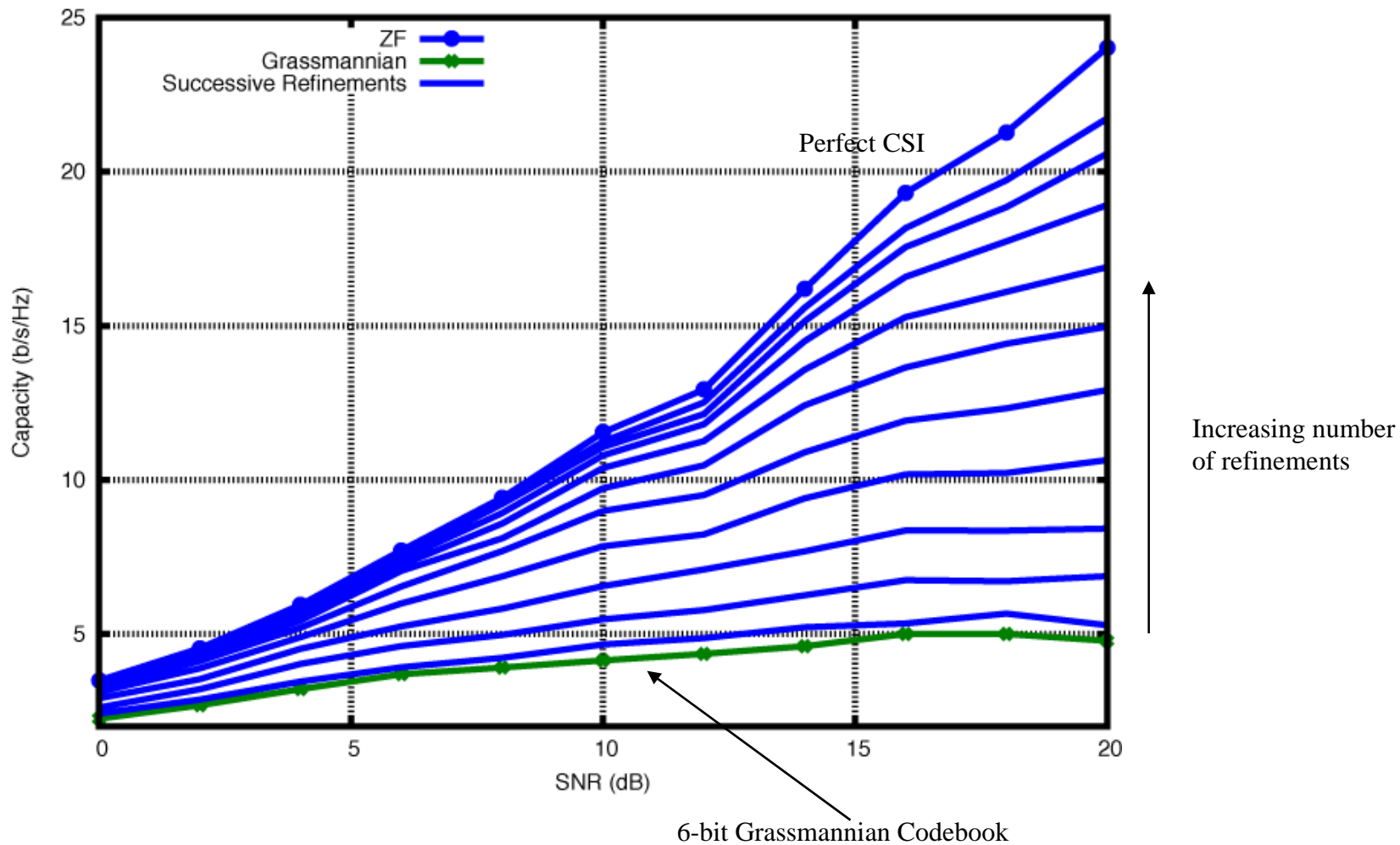


# Performance Example

- Consider MU-MIMO with zero forcing transmit precoding
- Quantize direction and assume perfect SINR
- 4 TX @ BTS, 1 RX @ subscriber
- Uncorrelated Rayleigh channels
- Use sum rate measure of performance

$$R(\rho) = \sum_{u=1}^U \log 2 \left( 1 + \frac{\rho |h_u^T w_u|^2}{1 + \rho \sum_{k \neq u} |h_u^T w_k|^2} \right)$$

# Performance Example (cont.)



# Benefits of Proposed Scheme

- Allows efficient large codebook quantization with 10+bits
  - Essential for implementing multiuser MIMO systems
- Requires very low storage, compared to a typical large codebook
  - Only small base and localized codebooks need to be stored
- Simplifies the codeword search process for large codebooks
  - For example, two 5-bit codebook searches (64 entries) are much better than one search over a 10-bit codebook (1024 entries).
- Supports variable feedback allocation
  - Scheduled users may be allocated more refinements while other users may be allocated fewer refinements. In general with scheduling, less feedback per user will be required.
- Number of refinement levels may be adjusted based on the users' channel conditions or other system dependent parameters
  - For example, it is known that for larger SNR, users require a larger codebook size while for smaller operating SNR, smaller codebooks may work.
- Supports adaptive feedback techniques
  - When a users channel is varying slowly, instead of sending back all the refinements, progressive refinement might initialize on the previous quantized value and only search over a few refinements. This further reduces the feedback required.

# References

- N. Jindal, MIMO Broadcast Channels with Finite Rate Feedback, IEEE Trans. Information Theory, Vol. 52, No. 11, pp. 5045-5059, Nov. 2006.
- V. Raghavan, R. W. Heath, Jr., and A. Sayeed, "Systematic Codebook Designs for Quantized Beamforming in Correlated MIMO Channels," IEEE Journal on Sel. Areas in Comm., Special Issue on Optimization of MIMO Transceivers for Realistic Communication Networks: Challenges and Opportunities, vol. 25, no. 7. pp. 1298-1310, Sept. 2007.
- R. Samanta and R. W. Heath, Jr., "Codebook Adaptation for Quantized MIMO Beamforming Systems" Proc. of the IEEE Asilomar Conf. on Signals, Systems, and Computers, pp. 376-380, Pacific Grove, CA, USA, Oct. 30 - Nov. 2, 2005.

# Text Proposal

***Insert the following text in Chapter 11 (Physical Layer):***

## 11.X Hierarchical Codebook

The system shall support a base codebook and a localized codebook. The base codebook shall be applied to single user MIMO, while both base and localized codebooks may be used for multi user MIMO.

### 11.X.1 Base Codebook

### 11.X.2 Localized Codebook

### 11.X.3 Progressive Refinement Procedure

The system shall follow the progressive refinement procedure to generate and reconstruct the channel state information.

## 11.Y Control Channel

### 11.Y.1 Codebook Size Assignment

The forward control channel shall include a field of codebook size which assigns codebook size to a subscriber station.

### 11.Y.2 CSI Feedback Mode

The forward control channel shall include a field of CSI feedback mode which indicates a full CSI feedback or adaptive CSI feedback from the subscriber station.

## 11.Z CSI Feedback Channel

The CSI feedback channel shall support variable CSI feedback bits, which is a function of number of progressive refinements and feedback mode.