HARQ in a Closed Loop MIMO System

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Venue:

IEEE 802.16m-08/016r1, “Call for SDD Comments and Contributions,” on the topic of Hybrid ARQ

Base Contribution:

[ ]

Purpose:

Adoption of the proposed text into SDD

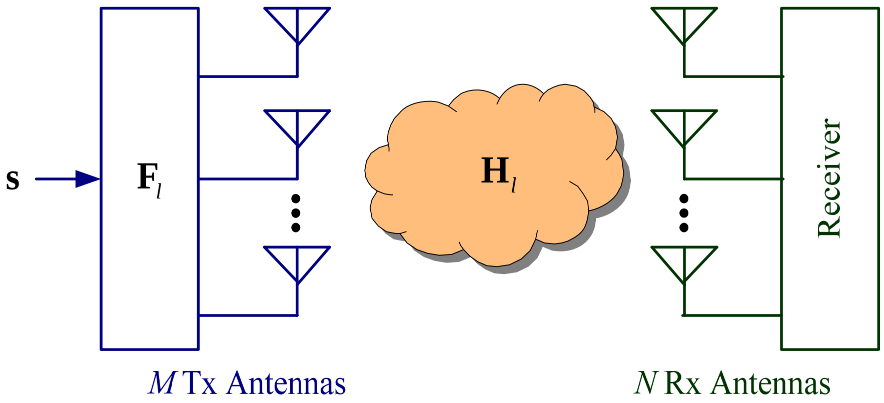
Motivation

- In the conventional closed-loop MIMO system, e.g., the codebook-based approach in IEEE 802.16e specification, the typical underlying assumption is that a precoding matrix is not updated even when the multiple reception of the same signal is available under the HARQ process.

- In the proposed approach, a precoding matrix is updated for every retransmission by taking a symbol level combining gain obtained with the previous receptions into account.

HARQ in a Closed-loop MIMO System (1)

- **Overall System Model**



- Received signal for the l-th transmission

$$\mathbf{r}_l = \mathbf{H}_l \mathbf{F}_l \mathbf{s} + \mathbf{w}_l = \tilde{\mathbf{H}}_l \mathbf{s} + \mathbf{w}_l$$

where $\mathbf{H}_l$: Channel matrix for the l-th transmission

$\mathbf{F}_l$: Precoding matrix for the l-th transmission

- Received signal associated with L retransmissions under a *concatenated combining* scheme

$$\mathbf{r} = \begin{bmatrix} \mathbf{r}_1 \\ \mathbf{r}_2 \\ \vdots \\ \mathbf{r}_L \end{bmatrix} = \begin{bmatrix} \mathbf{H}_1 \mathbf{F}_1 \\ \mathbf{H}_2 \mathbf{F}_2 \\ \vdots \\ \mathbf{H}_L \mathbf{F}_L \end{bmatrix} \mathbf{s} + \begin{bmatrix} \mathbf{w}_1 \\ \mathbf{w}_2 \\ \vdots \\ \mathbf{w}_L \end{bmatrix}$$

HARQ in a Closed-loop MIMO System (2)

- **Progressive Linear Precoder (PLP) & Decoder Design [1]**

  - Detection for the initial transmission

$$\hat{\mathbf{s}} = \mathbf{G}_1\mathbf{H}_1\mathbf{F}_1\mathbf{s} + \mathbf{G}_1\mathbf{w}_1$$

  where $\mathbf{F}$ and $\mathbf{G}$ are determined by the following MMSE criterion:

$$\mathbf{F}_1^{MMSE}, \mathbf{G}_1^{MMSE} = \arg\min_{\mathbf{F}_1,\, \mathbf{G}_1} E\left\{\left\|\hat{\mathbf{s}} - \mathbf{s}\right\|^2\right\}$$

  - Detection for l-th transmission

$$\hat{\mathbf{s}} = \mathbf{G}_l\mathbf{r} = \mathbf{G}_l\begin{bmatrix}\mathbf{r}_1 \\ \mathbf{r}_2 \\ \vdots \\ \mathbf{r}_l\end{bmatrix} = \mathbf{G}_l\begin{bmatrix}\mathbf{H}_1\mathbf{F}_1 \\ \vdots \\ \mathbf{H}_{l-1}\mathbf{F}_{l-1} \\ \mathbf{H}_l\mathbf{F}_l\end{bmatrix}\mathbf{s} + \mathbf{G}_l\begin{bmatrix}\mathbf{w}_1 \\ \vdots \\ \mathbf{w}_{l-1} \\ \mathbf{w}_l\end{bmatrix}$$

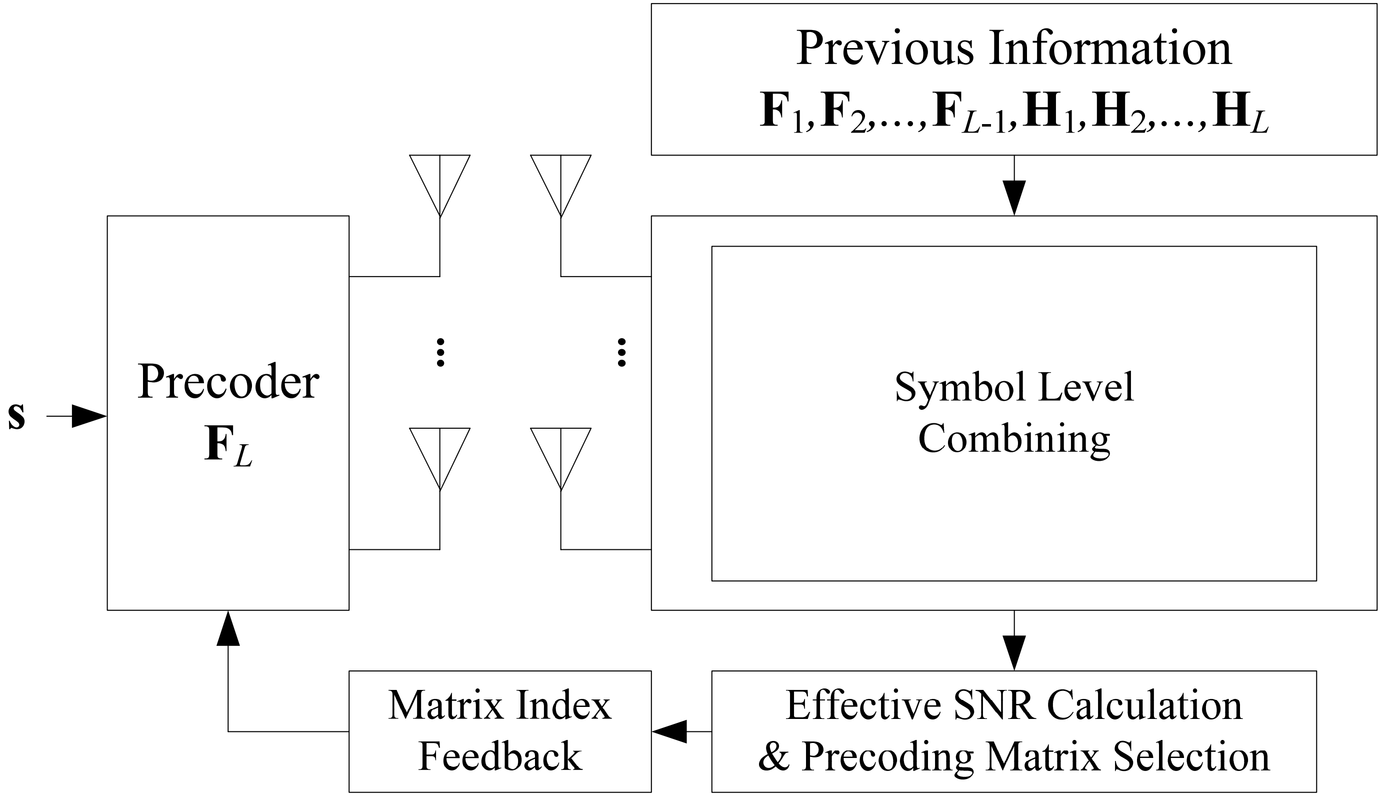
  where $\mathbf{F}$ and $\mathbf{G}$ are determined by the following MMSE criterion:

$$\mathbf{F}_l^{MMSE}, \mathbf{G}_l^{MMSE} = \arg\min_{\mathbf{F}_l,\, \mathbf{G}_l} E\left\{\left\|\hat{\mathbf{s}} - \mathbf{s}\right\|^2\right\}$$

[1] Haitong Sun, Jonathan H. Manton, and Zhi Ding, "Progressive Linear Precoder Optimization for MIMO Packet Retransmissions," *IEEE Journal on Selected Areas in Communications*, vol. 24, no. 3, March 2006.

HARQ in a Closed-loop MIMO System (3)

- **PLP for Codebook-based Precoding**
  - For L retransmitted signals



HARQ in a Closed-loop MIMO System (4)

- **Basic Operation**

  - To use the different pre-coding matrix (selected from a codebook) in the course of retransmission, so as to fully utilize the multiple receptions of MIMO signals subject to the given type of retransmission combining scheme.

- **Design Consideration**

  - To design the pre-coding matrix selection criterion
  - To design the pre-coding matrix to be suited to the HARQ in a closed-loop MIMO

Precoding Matrix Selection Procedure

- **Example: Effective SNR-based Criterion**

STEP 1:
For each matrix in codebook

Combining

$\mathbf{F}_L +$ Previous Information $\mathbf{F}_1, \mathbf{F}_2, \ldots, \mathbf{F}_{L\text{-}1}, \mathbf{H}_1, \mathbf{H}_2, \ldots, \mathbf{H}_L$

STEP 2:
Post-Detection SNR Calculation after Combining

$$\gamma_i = \frac{\left|\mathbf{g}_i \tilde{\mathbf{h}}_i\right|^2 \sigma_{\mathbf{s}}^2}{\sum_{j \neq i}^{N_T} \left|\mathbf{g}_j \tilde{\mathbf{h}}_i\right|^2 \sigma_{\mathbf{s}}^2 + \left\|\mathbf{g}_i\right\|^2 \sigma_{\mathbf{w}}^2}$$

STEP 3:
Effective SNR Calculation after Combining

MIESM, EESM, etc.

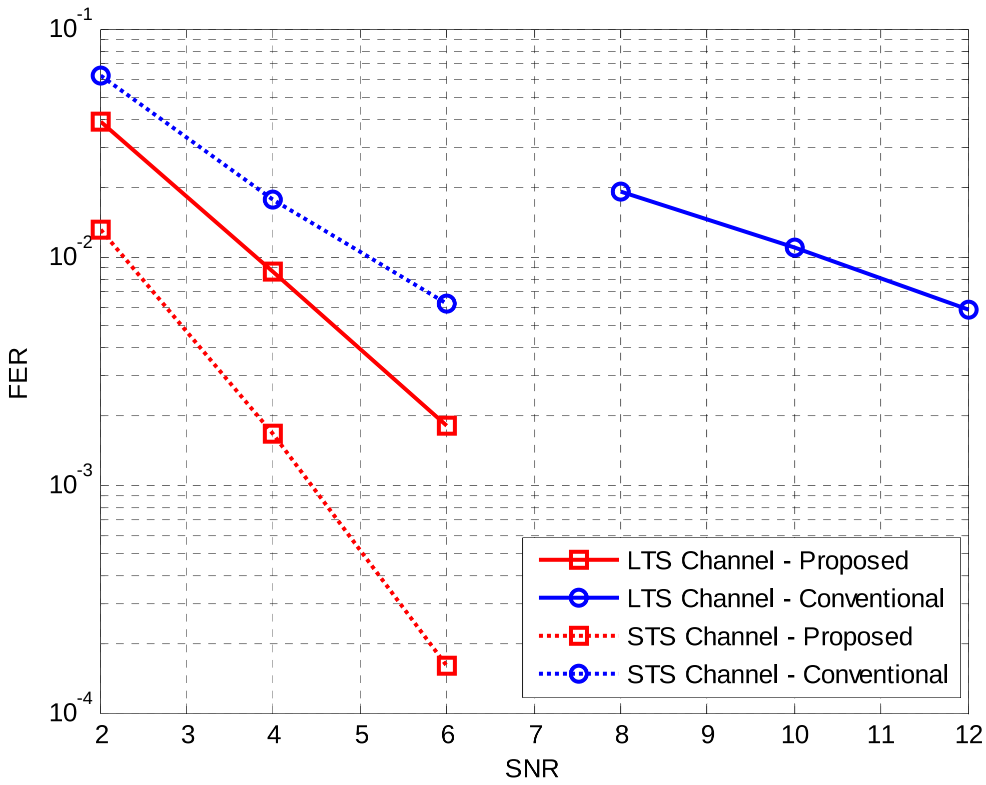
STEP 4:
Select the matrix which maximize effective SNR

$$\mathbf{F}_L^* = \arg\max_{\mathbf{F}_L \in S} \underline{f\left(\mathbf{H}_1, \ldots, \mathbf{H}_L, \mathbf{F}_1, \ldots, \mathbf{F}_{L-1}; \mathbf{F}_L\right)}$$

Objective Function

Performance Comparison

- **Frame Error Rate for 2nd Transmission**



Parameters	Value
Channel	Short-Term-Static (STS) or Long-Term-Static (LTS)
Codebook	IEEE 802.16e 3bit codebook
Antenna	4 Tx & 2 Rx antennas
Spatial Correlation	Urban macro in 16m EMD
Subcarrier Allocation	Localized mode (14 subcarriers)

Proposed Texts for SDD

- 11.x Hybrid ARQ

  In a codebook-based closed-loop MIMO system, linear precoding matrix for retransmission can be selected by taking symbol level combining gain with previous reception into account. In this HARQ process, NAK message and the corresponding precoding matrix index must be jointly signaled in the uplink control channel. Therefore, the message which is not received successfully in the initial transmission is retransmitted by using the precoding matrix reported along with NAK.