

A Novel MIMO detection method for Mobile IPTV

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Abstract—For converged technology both broadcasting and communication, currently mobile IPTV is focused on portable broadcasting system with users' feedback. To implement mobile IPTV based on mobile communication, the MIMO technique is necessary due to increasing capacity and applying different modulation ratio. In this paper, we proposed decision vector. The decision vector improves system performance by selecting reliable layer and isolating unacceptable layer. We prove performance improvement by computer simulation.

Keywords—Broadcasting, Multicast, MIMO, mobile IPTV, Decision vector

I. INTRODUCTION

Recently, broadcasting and communication technologies have been converged each other. One of the good examples of converged technologies is IPTV. An IPTV technology provides broadcasting service based on wired network. Nowadays network supports unicast service basically, also supports multicast and broadcast service to use network effectively. In the conventional broadcasting, multimedia stream is transmitted to multi users at once without feedback. Conventional IPTV service uses communication network. Therefore the multimedia stream is transmitted by multicast or broadcast service. Also the users' feedback is transmitted by unicast service.

On the other hand, the portable broadcasting system has been evolved such as digital multimedia broadcasting (DMB) in Korea. Currently the DMB system has same weak point as conventional broadcasting system that the system provide multimedia stream without feedback. Thereby the users of DMB service always are restricted to select desired multimedia. To overcome a shortcoming in DMB, the mobile IPTV has come into the spotlight. The mobile IPTV is mostly same as wired based IPTV but it supports mobility. There are some ways to realize mobile IPTV [1]. One of candidates to implement is to use next generation mobile communication technology on broadcasting.

For applying broadcasting in mobile communication, mobile communication standards for instance [2]-[5] have been defined optional terms for multicast and broadcasting protocol such as multicast and broadcast service (MBS) or multimedia broadcast / multicast service (MBMS). However, those of communication standards are not optimized on

multimedia stream transmission. When the base station (BS) transmit stream to the subscriber stations (SS), each SS receives stream with different signal power. It means that the signals at each SS has different signal to noise ratio (SNR). Unicast stream transmission is not problem due to applying different modulation and coding scheme (MCS) each SS. However multicast stream transmission can not apply different MCS level since all users should receive same stream at once. Thereby BS should transmit stream using low MCS level to receive stream successfully for all users. The low MCS level is not sufficient to provide multimedia stream. For broadcasting without a hitch, the communication system has to support transmission bandwidth and differential data rate for each user. To optimize broadcasting transmission, one of good solutions is spatially multiplexed multiple-input multiple-output (SM-MIMO) based approach [6]. SM-MIMO system guarantees transmission bandwidth due to increasing capacity. Also, recent research for SM-MIMO has been considering multi-user MIMO system with differentially modulated each antenna [7]-[9].

In this paper, we propose a novel detection method to provide multimedia stream differently using decision vector. The decision vector selects simply acceptable layer using received SNR information. Also the decision vector isolates potentially unacceptable layer so that it reduce probability of error occurrences.

The organization of this paper is as follows. In Section II, we depicted basic MIMO system model. In Section III, we simply review conventional MIMO detection method. In Section IV, we proposed details about a weighting matrix generation and detection method for broadcasting using differentially modulated MIMO system. In Section V, we verify proposed method by computer simulation result, and conclude our paper in Section VI.

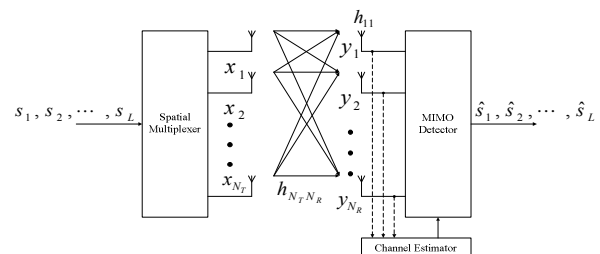


Fig. 1. Conventional MIMO system model

II. MIMO SYSTEM MODEL

The basic MIMO system model is shown in Fig. 1. The system has N_T transmission antennas and N_R receive antennas. We assume that $\mathbf{x} = [x_1, x_2, \dots, x_{N_T}]$ is transmitted symbol vector, $\mathbf{y} = [y_1, y_2, \dots, y_{N_R}]$ is received symbol vector, $\mathbf{s} = [s_1, s_2, \dots, s_L]$ is transmitted bit stream where L is the number of elements in bit stream, $\hat{\mathbf{s}} = [\hat{s}_1, \hat{s}_2, \dots, \hat{s}_L]$ is received bit stream. The transmitted bit stream is converted transmission symbol by some modulation techniques such as PSK or QAM. After modulation, the converted symbols may be modulated again for multicarrier communication such as orthogonal frequency division multiplexing (OFDM) depending on system. The transmission signal passes from transmitter to receiver. The signal is possibly distorted by fading channel and additive white Gaussian noise (AWGN) channel. The fading channel can be modeled by $N_R \times N_T$ matrix which has Rayleigh coefficient with uniform phase distribution. The AWGN channel has zero mean and variance σ_n^2 . A process of transmitting channels is described as below equations.

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n} \quad (1)$$

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_{N_R} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1N_T} \\ h_{21} & h_{22} & \dots & h_{2N_T} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_R1} & h_{N_R2} & \dots & h_{N_RN_T} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{N_T} \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_{N_T} \end{bmatrix} \quad (2)$$

III. CONVENTIONAL MIMO DETECTION METHOD

A. QRM-ML

QRM-ML detection method is a fundamental MIMO detection method. Approximately, QRM-ML detection method holds good performance also reduces computational complexity comparing with ML detection. At first, decompose channel matrix $\mathbf{H} = \mathbf{Q}\mathbf{R}$ by QR decomposition where $\mathbf{Q}$ is unitary matrix and $\mathbf{R}$ is upper triangular matrix, and then replace the channel matrix in equation (1).

$$\mathbf{y} = \mathbf{Q}\mathbf{R}\mathbf{x} + \mathbf{n} \quad (3)$$

$\mathbf{Q}$ is simply converted to inverse matrix due to $\mathbf{Q}^{-1} = \mathbf{Q}^H$. To make simple system equation, multiply $\mathbf{Q}^{-1}$ each side.

$$\mathbf{Q}^H\mathbf{y} = \mathbf{R}\mathbf{x} + \mathbf{Q}^H\mathbf{n} \quad (4)$$

Finally we derive the system equation approximately as equation (5).

$$\mathbf{R}\hat{\mathbf{x}} \cong \mathbf{Q}^H\mathbf{y} = \tilde{\mathbf{y}} \quad (5)$$

where $\hat{\mathbf{x}}$ is estimated transmission symbol. To estimate $\hat{\mathbf{x}}$ as precise as possible, calculate minimum cost inserting all candidate constellation points. After obtained minimum cost,

select M candidate points, calculate upper layer candidates using selected M candidates. Finally, select the least cost points. Overall detection procedures are described following table 1.

Table 1. QRM-ML detection process

Function $\hat{\mathbf{x}} = \text{QRM-MLD}(\mathbf{R}, \tilde{\mathbf{y}})$
M = number of candidate constellation points
N = number of elements in $\mathbf{C}_i$
$\mathbf{C}_i$ = All constellation points i -th layer
$\mathbf{m}$ = ML metric vector
$\mathbf{e}$ = M numbers of minimum ML metrics
for $i = N_R : -1 : 1$
for $j = 1 : N$
$\mathbf{m}(j) = \ \mathbf{Q}^H\tilde{\mathbf{y}}(i:\text{end}) - \mathbf{Q}^H\mathbf{R}(i:\text{end}, :)\ \cdot \ \mathbf{Q}^H\mathbf{C}_i(j)\ ^2$
end
$\mathbf{q} = \text{sort}(\mathbf{m})$
$\mathbf{e} = \mathbf{C}_i(\mathbf{q}(1:M))$
end
$\hat{\mathbf{x}} = \mathbf{e}(1)$

B. Channel Matrix Ordering

To obtain better performance, we must reduce error propagation explicitly. A property of QR decomposition based MIMO detection is most reliable the first layer. On the other hand, the last layer is least reliable due to cumulated error. Thereby we can effectively reduce error propagation in case that reliable symbol is allocated from first to last layer in sequence. One of the channel matrix ordering methods is SNR based ordering. Even though the transmission power is normalized, the power at the receiver changes randomly due to distortion by MIMO channel. The variation affects system performance. For example, the system performance might be degraded in low power receiving case. To avoid performance degradation, channels which have low power have to allocate around last layer. Ordering procedure is starting from pseudo inverse calculation. We assume that $\mathbf{G}$ is a pseudo inverse matrix, then

$$\mathbf{G} = (\mathbf{H}^H\mathbf{H})^{-1}\mathbf{H}^H \quad (6)$$

Using equation (6), ordering index is decided by sort function. Basically, the sort function reallocates norms of row vectors $\mathbf{g}_1, \mathbf{g}_2, \dots, \mathbf{g}_{N_T}$ for matrix $\mathbf{G}$ descent way.

$$\mathbf{q} = \text{sort}([\|\mathbf{g}_1\|, \|\mathbf{g}_2\|, \dots, \|\mathbf{g}_{N_T}\|]) \quad (7)$$

After ordering, $\mathbf{H}$ and $\mathbf{x}$ are reallocated to $\mathbf{H}_o$ and $\mathbf{x}_o$ by ordering index $\mathbf{q}$. Finally decomposed channel matrix is separated $\mathbf{Q}_o$ and $\mathbf{R}_o$.

$$\mathbf{H}_o = [\mathbf{h}_{q(1)}, \mathbf{h}_{q(2)}, \dots, \mathbf{h}_{q(N_T)}] \quad (8)$$

$$\mathbf{x}_o = [\mathbf{x}_{q(1)}, \mathbf{x}_{q(2)}, \dots, \mathbf{x}_{q(N_T)}]^T \quad (9)$$

$$\mathbf{H}_o = \mathbf{Q}_o\mathbf{R}_o \quad (10)$$

C. QR-MRL (Most Reliable Layer)

QR-MRL allocates most reliable layer to the first layer. To make priority order, QR-MRL sorts channel matrix as descent way using equation (7). With the result of equation (8) and (9), we apply similar procedure in table 1.

At first, QR-MRL considers all constellation points for the first layer. Usually the last element in the received symbol $\mathbf{x}_{q(N_T)}$ uses for the first layer. ML metric is calculated for all constellation points. After the second layer, calculate ML metric repeatedly using result of previous layer until final layer. Finally the least cost ML metric is selected an estimated transmitted symbol vector.

D. QR-LRL (Least Reliable Layer)

The QR decomposition can be implemented various way. One of possible implementations is Gram-Schmidt procedure that uses projection. Basically, QR decomposition separates matrix Q and R that is orthogonal matrix and its coefficient matrix respectively.

The first layer of QR-MRL looks like independent channel such as SISO system since each layer holds orthogonality. Therefore, allocation MRL on the first layer does not affect error propagation. To transmit effectively, QR-LRL loads a least reliable layer on the first layer. Remaining detection procedure is same as QR-MRL.

E. Modified QR-LRL

Modified QR-LRL method proposed to apply MIMO detection with differentially modulated layer. In this case system performance of QR-LRL is degraded than ML detection method due to wrong LRL selection. To prevent mistake, modified QR-LRL normalized channel matrix by their average power before ordering. It proposed weighting based ordering and reduced error propagation effectively. There are several steps to detect MIMO symbols, however the key idea is generating weighting matrix. The weighting matrix $\mathbf{W}$ is described as follow.

$$\mathbf{W} = \begin{bmatrix} w_1 & 0 & \dots & 0 \\ 0 & w_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & w_{N_T} \end{bmatrix} \quad (11)$$

where $w_i, i = 1, 2, \dots, N_T$ is inverse of average power for i -th layer. After generating, multiply weighting matrix to channel matrix to make duplicated channel matrix $\mathbf{H}_d$ for ordering.

$$\mathbf{H}_d = \mathbf{H} \cdot \mathbf{W} \quad (12)$$

Then sort layers by ordering index using duplicated matrix.

$$\mathbf{G}_d = (\mathbf{H}_d^H \mathbf{H}_d)^{-1} \mathbf{H}_d^H \quad (13)$$

where $\mathbf{G}_d$ is duplicated pseudo inverse matrix for $\mathbf{H}_d$. Finally, the first layer is allocated LRL and the second layer is allocated MRL (Most Reliable Layer). The rest detection procedure is same as QR-MRL.

IV. PROPOSED MIMO DETECTION METHOD

In the mobile communication environment which is support broadcasting, a data stream usually applied low level modulation and coding scheme (MCS) for offering stable data communication to the cell edge users. Thereby all users in the cell receive broadcasting data with same transmission rate. In this situation, the central users only receive same rate of broadcasting data even though they can receive high-quality data. It is a main reason to waste transmission bandwidth. To make better, we can apply MIMO technique such as modified QR-LRL. However, modified QR-LRL suffers from significant performance degradation at the cell edge due to detecting least reliable layer first. To prevent from reducing performance degradation, we propose enhanced detection method. Proposed detection method use decision vector. The decision vector percolates through unacceptable layer. Consequently each user can detect available layer. Details for detection procedure are explained as following three steps.

Step 1. Selection

Receive SNR is different each receiver. To prevent from detecting high level MCS at the cell edge, we need to separate desired layers. To guarantee QoS, we assume each receiver has threshold variance th each modulation level. In Step 1, we only select desired layer information and generate decision vector $\mathbf{d}$ as table 2.

Table 2. Decision vector generation

Function $[\mathbf{d}]$ = decision vector (var)
var = variance vector of each layer
for $i = 1 : N_R$
if (var > th)
$d(i) = 0$
else
$d(i) = 1$
end
end

Step 2. Ordering and Decision

Ordering process is similar with equation (6)-(10) using weighting matrix equation (11). Using decision vector, reordering is needed for channel matrix $\mathbf{H}_d$ and received symbol vector $\mathbf{x}_d$ generated by modified QR-LRL process. The number of zeros in decision vector means the number of forward shift for $\mathbf{H}_d$ and $\mathbf{x}_d$. Forward shift is cyclic moving from first layer to last layer as shown in Fig. 2.

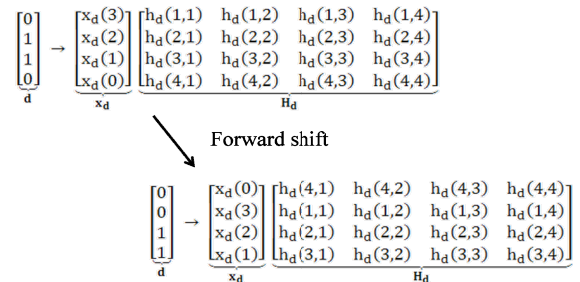


Fig. 1 An example of forward shift process (4x4 case)

Step 3. Detection

By Step 2, unacceptable layers move around last layer. Those of layers calculated mostly final detection step, however we only detect reliable layer for holding performance. We summarized proposed method in Table 3.

Table 3. An example of proposed detection process

Function $\hat{\mathbf{x}} = \text{proposed}(\mathbf{R}, \tilde{\mathbf{y}}, \tilde{\mathbf{d}})$

M = number of candidate constellation points

N = number of elements in C_i

C_i = All constellation points i-th layer

m = ML metric vector

e = M numbers of minimum ML metrics

$\tilde{\mathbf{d}}$ = Shifted decision vector

for i = $N_R : -1 : 1$

 if $\tilde{\mathbf{d}}(i)$ is not zero

 for j = 1 : N

$m(j) = \|\mathbf{0}; \tilde{\mathbf{y}}(i:\text{end})\| - \|\mathbf{0}; \mathbf{R}(i:\text{end}, :)\| \cdot \|\mathbf{0}; C_i(j)\|^2$

 end

 q=sort(m)

 e = $C_i(q(1:M))$

 end

end

$\hat{\mathbf{x}} = e(1)$

V. SIMULATION RESULT

In this section, we prove relevance to proposed MIMO detection method by simulation result. Simulation result shows as throughput. For verifying proposed method, we assume perfect channel and receive SNR estimation. Detail of simulation parameters is in Table 4.

Table 4. Simulation Parameters

Number of transmit antennas	4
Number of receive antennas	4
Modulation	4, 4, 16, 64 QAM
Coding rate	1 (Uncoded)
Bandwidth	10 MHz
Fading channel	Flat fading
Pathloss model	Urban macro cell
BS transmit power	100 W
Carrier frequency	2.3 GHz
Temperature	27 °C
Number of transmitted frames	100
Number of bits per one frame	1024

Fig. 3 shows throughput performance for the QR-MRL, QR-LRL, Modified QR-LRL, proposed QR-LRL with decision vector under 4x4 MIMO environment. Distance is radius from BS to each SS. System performance is yielded by relative throughput for each SS. Relative throughput is defined by a ratio of receive data rate per maximum data rate. We assume all detectors have same data rate around BS.

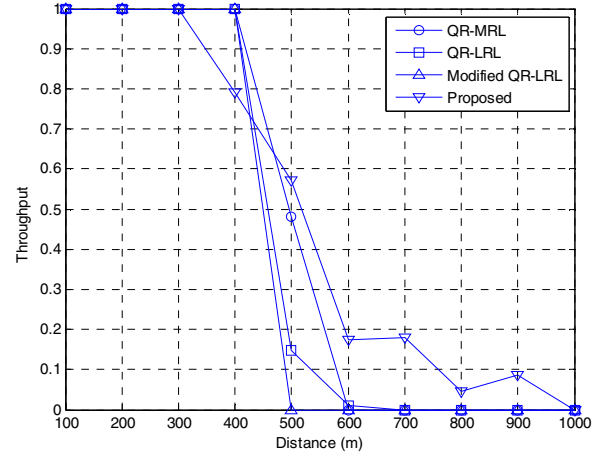


Fig. 3 Relative throughput comparison for MIMO detectors

As shown in Fig. 3, performance of conventional detectors is dramatically decreased from 400 m. Over 600 m, only proposed detector can receive data. Therefore, proposed detection method is available at the cell edge in contrast with other detection method.

VI. CONCLUSIONS

In this paper, we proposed novel MIMO detection method for mobile IPTV system. Proposed decision vector improve receiving performance at the cell edge for multicast and broadcasting stream transmission with MIMO systems. Proposed detection method helps to provide multimedia stream to multi-users by different data rate at the same time. In the future, we can realize differential quality broadcasting service using proposed detection method with particular video encoding method such as scalable video coding (SVC).

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