Survey of Massive MIMO Detectors

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Abstract: Massive multiple-input multiple-output is a novel digital technique; it can be proposed the different types of detectors in the MIMO. In this paper it can be perform the bit error rate and the spectral efficiency for the performance analysis of the massive MIMO systems. Maximum Likelihood (ML), Near Maximum Likelihood (N-ML), Log-Likelihood Ratio (LLR), Ordered Successive Interference Cancellation (OSIC), Minimum Mean Square Error (MMSE), Zero Forcing (ZF), detectors is proposed and investigated the theoretical performance. It can be provides the better error performance in massive MIMO under the realistic conditions.

Keywords: MIMO systems, Maximum Likelihood (ML), Near Maximum Likelihood (N-ML), Log-Likelihood Ratio (LLR), Ordered Successive Interference Cancellation (OSIC), Minimum Mean Square Error (MMSE), Zero Forcing (ZF).

I. INTRODUCTION

Multiple-input multiple-output is a digital modulation techniques, its transmission having their advantages over a single system antenna can be improved the data rate and efficiency. MIMO having the modulation process of spatial and index modulations [3]. This multicarrier transmission can be increasing the high data rate in the communication systems. Spatial modulation (SM) is based on the transmission of information bits by means of indices of the active transmission antenna of the system. It can be attracted the attention of significant for researchers in the communication side.

Index modulation is a technique for the subcarrier indices available in massive MIMO systems. The only subset of the subcarrier available in the active information bits, it remains their inactive subcarriers are set as zero [2]. It can be achieve a potential to better performance of error and efficiency. It can be communicate through the machine to machine (M2M) systems, requires less power consumption. High data rate in wireless access can be demanded in many applications and they having high bandwidth for transmission required for higher rate of data. Their limitations in the spectral it will often the very expensive to increase their bandwidth. Transmit in multiple antenna can used to transceiver the multiple channels of the MIMO systems. The challenge in realization practical of the MIMO system in wireless lies the efficient implementation of the detector can be needs to separate the multiplexed data streams in spatially modulation.

It can be offering the various trade-offs in between the complexity computation and the performance.

II. MIMO DETECTORS

The data of reception is transmitted over serially in the dispersive medium of complex of channel presence to induce the interference. Many techniques reducing the complexity of the optimal reception in a receiver. In a 4x4 MIMO channel [1], input data can be transmitted in the sequence.

In the first time slot, M1 and M2 can be sending from the first and the second antenna. In second time slot, M3 and M4 can be send from the first and the second antenna, and M5 and M6 the third time slot and so on.

A variety of these techniques are evaluated using different predetermined performance and complexity [5]. MIMO detection techniques are categorized into linear schemes, successive interference cancellation, and tree-search techniques. Linear schemes are easy to implement but leads to high degradation in performance. Successive interference cancellation schemes transmitted the extract symbol according to a certain permutation depending on channel matrix.
III. SIGNAL DETECTORS

Several algorithms offering various trade-offs between performance and computational complexity have been discussed in literature [10]. Linear detection schemes provide inferior error performance with much reduced complexity while Maximum Likelihood Detector (MLD), Log-Likelihood ratio (LLR), Near-Maximum Likelihood detector (N-ML), minimum Mean Square Error (MMSE) algorithm provides optimum performance with high complexity.

A. Maximum Likelihood (ML)

The signal detection techniques include spatial and successive interference cancellation for the maximum likelihood (ML) detectors. In the spatial system pre-whitening inputs, interferer detection joint the multiple users or inputs is optimal [6]. This detection is forbidding complexity in computations. The maximum likelihood decoding for spatial pre-whitening for massive multiple input multiple output (MIMO)-orthogonal frequency division multiplexing (OFDM), it can be reduce the complexity detection.

In successive interference cancellation can be introduced pre-whitening for the space-time codes for MIMO-OFDM

\[ X_{ML} = \arg \min \| r - \sqrt{P/N} H X \|_2 \]  

Where \(\| a \|_2\) is the norm of vector \( a \).

The use of ML detector which can be realized for each sub-blocks \( g \) as

\[ (X^g_1, ..., X^g_T)_{ML} = \arg \min \sum_{t=1}^{T} \| Y_t^g - \sum_{i=1}^{T} \text{diag}(X^g_t) h_r^g t \|_2^2 \]  

\[ Y^g = H^g X^g + W^g \]  

Probability of error given by

\[ P(X^g \rightarrow e^g | H^g) = \frac{1}{2} \int_{0}^{\pi} \exp \left( - \left\| H^g (X^g_{\text{eq}} - e^g) \right\|_2^2 \right) \, d\theta \]  

B. Near-Maximum Likelihood (N-ML)

The detector is higher order modulation and critical. At the receiver, the ML solution is the number of transmitted symbols per block. A brute-force solution to is prohibitively complex and hence, low-complexity solutions are of interest [7]. For OFDM, orthogonality in the frequency domain (FD) allows to block diagonalize \( H \) by the FT, so that decouples into problems of dimension \( T \). For each of these problems, the ML solution can be found with the help of a SD. The proposed algorithm is given by

While

\[ \text{length}(y) > 0 \]

\[ dS = SD(Y_s, R_{SS}) \times \text{Jointly detect last S streams}. \]

\[ y \leftarrow Y_s, R \leftarrow R_{SS} \times \text{Reduce system size.} \]

end while.

C. Zero Forcing (ZF)

Zero Forcing is a linear equalization algorithm. It can be used in communication systems, which inverts the response of the channel frequency. The Zero-Forcing Equalizer applies the inverse of the channel to the received signal, to restore the signal before the channel [9]. A zero-forcing equalizer can uses an inverse filter to compensate the channel for response function. The equalizer, it has an overall response function equal for the symbol that is being detected and a zero response for other symbols. The removal of the interference from all other symbols in the noise of their absence. Zero forcing is a linear equalization method that does not consider the effects of noise. In fact, the noise may be enhanced in the process of eliminating the interference.

\[ W_{ZF} H = 1 \]

\[ W_{ZF} = (H^H H)^{-1} H^H (5) \]

Channel matrix \( H \) to produce the estimate of transmitted vector \( X \) because the pseudo-inverse of the matrix channel may have high power when the channel matrix is ill conditioned, the noise variance is consequently increased and the performance is degraded. The noise enhancement introduced by the ZF detector, the MMSE detector was proposed, where the noise variance is considered in the construction of the filtering matrix.

Effect of channel as

\[ X_{ZF} = W_{ZF} + Y \]

\[ = X + (H^H H)^{-1} n (6) \]

D. Minimum Mean Square Error (MMSE)

Proves the BER characteristics and maintains a good SNR. It can be minimizes the total power of the noise. Reduce decoding complexity [4]. If the mean square error between the transmitted data symbols and the outputs of the detected symbols, or equivalently, the SNR received is taken as the performance criteria, the MMSE detector is the optimal detection that seeks to balance between cancellation of the interference and reduction of noise.

\[ E[(X-W_{MMSE})^H (X-W_{MMSE})] \]

\[ W_{MMSE} = (H^H H + \sigma^2 I)^{-1} H^H (7) \]

Where \( X \) is combination of the inverted channel matrix and the unknown noise vector. \( \sigma^2 \) is the noise variance. \( 1/SNR = \)
\[ \sigma^2 \text{trade-off between the residual interference and the noise enhancement.} \]

**E. Log-Likelihood Ratio (LLR)**

The LLR detector of the OFDM-IM scheme provides the logarithm of the ratio of probabilities of the frequency domain symbols by considering the fact that their values can be either non-zero or zero [4]. A simple hypothesis test has completely specified models under both the null and alternative hypotheses.

\[ Y = h_1X_1 + h_2X_2 + Z(8) \]

**IV. PROPOSED SYSTEM**

In this proposed system, the bit error rate can be perform by the massive MIMO detectors, that is Maximum Likelihood (ML) detector, to get the better bit error performance and spectral efficiency analysis of the massive MIMO-OFDM with IM for the fifth generation networks. This system can perform by the digital modulation of quadrature amplitude modulation is the combine of phase shift key and amplitude shift key with the M-ary modulation of the signal constellation. The frequency selective Rayleigh fading techniques and then concentrated in both the transmitter (TX) and the receiver (RX) side can be used to get the error performs and the efficiency.

Generalized orthogonal frequency division multiplexing with index modulation (GOOFDM-IM) is combined with MIMO transmission to take the advantages of the benefits of these techniques. The implementation and error performance analysis of the massive multiple-input multiple-output (MIMO) Generalized OFDM-IM scheme for 5G networks [8]. The detector is provided the error performance and spectral efficiency.

In digital transmission, the number of bit errors is the number of received bits of a data stream over a channel communication that have been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors per unit time. The number of bit errors divided by the total number of transferred bits during a studied time interval of bit error rate. BER is a unit-less performance measure, often expressed as a percentage. The probability of bit error \( p_e \) is the expectation value of the bit error ratio. The bit error ratio can be considered as an approximate estimate of the bit error probability. This accurate for a long time interval and a high number of bit errors. The analytical expression for M-ary QAM signalling in Rayleigh channels are respectively given as

\[ P_e = \frac{M-1}{\log_2 M} \left( 1 - \frac{3y\log_2 M/(M^2-1)}{3y\log_2 M/(M^2-1)+1} \right) \]  

(9)

Where \( y \) and \( M \) denote \( E_b/N_0 \) and  

\[ Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-t^2/2} dt \]  

(10)

\[ \text{SNR}_{r} = \text{SNR}_{t} + 10 \log\frac{N_{\text{int}}}{N} \text{[dB]} \]  

(11)

Maximum likelihood is a estimating the parameters of a statistical model given observations, by finding the parameter values that maximize the likelihood of making the observations given the parameters. ML can be seen as a special case of the maximum a posteriori estimation (MAP) that assumes a uniform prior distribution of the parameters, or as a variant of the MAP that ignores the prior and which therefore is un-regularized. The method of maximum likelihood corresponds to many well-known estimation methods in statistics. One may be interested in the heights of adult female penguins, but it unable to measure the height of every single penguin in a population due to cost or time constraints.

Step 1: Compute the pseudo-inverse of \( H^H \)

Step 2: Find the minimum squared length row of \( H^H \). This weight vector is modified to be the last row and permute the columns of \( H \) accordingly.

The scheme is presented in terms of the bit error rate (BER) performance of the ML detector that the data is QAM modulated. The performance of the ML decoder operating on quantized channel measurements (ML) and its approximation terms of bit error rate (BER) averaged over fading channel realizations the conventional ML detector. Then the exact ML detector and its naive version outperform the conventional ML detector when operating on quantized data especially at high SNR.

**Table 1. Parameter Analysis**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel model</td>
<td>Rayleigh Fading Model, RicianFading, AWGN</td>
</tr>
<tr>
<td>Detector</td>
<td>ML, ZF, LLR, MMSE, N-ML, detector</td>
</tr>
<tr>
<td>Modulation</td>
<td>64-QAM</td>
</tr>
<tr>
<td>FFT</td>
<td>128</td>
</tr>
<tr>
<td>Antenna transmitting power</td>
<td>Equal</td>
</tr>
</tbody>
</table>

**V. CONCLUSION**

In this paper, the recently proposed MIMO scheme has been investigated for next generation networks. The MIMO scheme, new detector maximum likelihood (ML) detectors, log-likelihood ratio (LLR) detectors, near-maximum likelihood detector (N-ML) detector, minimum mean square error (MMSE) detector have been proposed and their ABEP have been theoretically examined. It provides an interesting trade-off between complexity, spectral efficiency and error performance compared to classical MIMO-OFDM scheme and it can be considered as a possible candidate for 5G networks. The main features of MIMO can be summarized as follows better BER performance, flexible system design.
with variable number of active OFDM subcarriers and better compatibility to higher MIMO setups. IM is an up and coming concept for spectral and energy-efficient next generation wireless communications systems to be employed in 5G wireless networks. IM techniques can offer low-complexity as well as spectral and energy-efficient solutions towards the massive MIMO, and cooperative communications systems to be employed in 5G networks.

REFERENCES

[1] Comparison of various detection algorithms in a MIMO wireless communication receiver.
[4] Fifty Years of MIMO Detection: The Road to Large-Scale MIMOs.