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Performance Analysis of Large Scale MIMO System using Noise and Relevancy Aware Low Complexity Detection Algorithm

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***Abstract:** Complexity reduction for Large Scale Multiple Input and Multiple Output (LM-MIMO) system is a most concentrated research issue to ensure the optimal and reliable signal processing. In the existing work, optimal low complexity detection procedure has been carried out by using Pruning based Maximum Likelihood Detection using Low Complexity detection Algorithm (PRUN-MLD-LCDA). The existing work might lacks in its performance with the reception signals with increased noise level and more missing information. This problem can be overcome in the proposed method namely Noise and Relevancy aware Low Complexity Detection (NRLCD). The objective of this research method is to ensure the accuracy recover of signals with reduced complexity. In this work, initially signal pruning is performed to filter out the alike signals. This is done by Normalized Cross Correlation (NCC) based pruning which is used to avoid the irrelevant signals. And then Adaptive filter is used to remove the noises present in the signals before analyzing the complexity. Then, Hybrid Genetic-Branch-and-Bound (Hybrid Genetic-BB) detection algorithm is utilized to detect the received signals with low complexity. The overall simulation of the research methods are performed using Matlab from which it is inferred that NRLCD research method significantly achieves better Bit Error Rate (BER) performance compared to the existing methods.*

***Keywords:** Signal Pruning, Normalized Cross Correlation, MIMO, Complexity, BER*

I. INTRODUCTION

The number of transmit and receive antennas in MIMO systems is scaled up to achieve higher data rates and reliability in upcoming 5G systems [1] and such large antenna systems are known as large MIMO systems [2]. To detect the received signals in such large MIMO systems is very difficult [3] due to the near ML detection methods in classical MIMO systems. Computational complexity of the tree search algorithms for large MIMO systems increases with the number of antennas are infeasible [4].

In [5], the standard BB algorithm can be used to solve the problem of Mixed Integer Quadratic Programming (MIQP). BB algorithm performs better than other existing methods [6]. The optimal solution can be provided with minimal tree exploration by BB algorithm which is based on tree search [7].

BB with Strong Branching (SB) gives the computational complexity of solving {2N + 1} QPs at every node, where 'N' represents the problem size and infeasible for small MIMO antenna systems [8]. A low complexity MIMO detection method with Lattice Reduction (LR) aided fixed complexity tree searching method was proposed which generates a small sixe fixed tree and the computational complexity is reduced noticeably [9]. An efficient data detection algorithm has been proposed to provide the Minimum Mean Square Error (MMSE) estimate and give the reduced computational complexity [10]. A factor graph based near optimal iterative receivers is proposed which introduces auxiliary variables and then a convergence problem in BP algorithm were addressed by presenting the proposed method namely hybrid Belief Propagation (BP) and Expectation Propagation (EP) receivers [11]. To solve the matrix inverse problem, Jiang et al [12] proposed a fast processing algorithm with low complexity and introduced the iterative receiver methods to decipher the linear equations. The iterative method utilized the block matrix properties to update the process independently on a small size block. Park et al [13] introduces MIMO detection with low complexity using adaptive mitigation. The quantization error based downlink multiuser MIMO uses the imperfect precoding matrix to reduce the interference and receive the desired signal at the receiver side. Zhao & Du [14] proposed a lattice reduction aided (LRA) MIMO detection to achieve low complexity.

The following sections explain the overall organization of the research work. Section 2 discusses the MIMO system and NCC based pruning technique. The detailed discussion about the proposed research method and simulation results is dealt in section 3 and section 4 respectively. Finally in section 5, the conclusion of the research work is given.

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II. NOISE AND RELEVANCY AWARE LOW COMPLEXITY DETECTION ALGORITHM

The existing work might lacks in its performance with the reception signals with increased noise level and more missing information. This problem can be overcome in the proposed research technique by introducing the Noise and Relevancy aware Low Complexity Detection (NRLCD). The objective this research method is to ensure the accuracy recover of signals with low complexity.

A. System Model

Consider a LM-MIMO antenna system with N_t number of transmitting antennas and N_r number of receiving antennas with ($N_t \leq N_r$). Then the base band system modeled as

$$y_c = H_c x_c + n_c \quad (1)$$

where $y_c \in \mathbb{C}^{N_r \times 1}$ is the received signal vector, $x_c \in \mathbb{C}^{N_r \times 1}$ denotes the transmit signal vector and each element in x_c is M-QAM symbols. $n_c \in \mathbb{C}^{N_r \times 1}$ represents the complex Additive white Guassian Noise (AWGN) with sero mean and variance is $E[n_k^2] = N_0 = \frac{N_t E_s}{\gamma}$, where n_k denotes the k^{th} receive antenna noise sample and E_s represents the transmitted symbol average energy. γ is average signal to noise ratio. H_c denotes the channel matrix with i.i.d. complex random variable. The real part and imaginary part of (1) can be written as

$$y_c = y_I + j y_Q,$$

$$x_c = x_I + j x_Q$$

$$n_c = n_I + j n_Q,$$

$$H_c = H_1 + j H_Q$$

Then the equation (1) is modeled as

$$y = Hx + n \quad (2)$$

In (2), $H \in \mathbb{R}^{2N_r x 2N_t}, y \in \mathbb{R}^{2N_r x1}, x \in \mathbb{R}^{2N_t x1}$ and $n \in \mathbb{R}^{2N_r x1}$ can be defined as

$$y = \left[y_1^T \; y_Q^T\right]^T, \qquad x = \left[x_1^T \; x_Q^T\right]^T$$

$$n = \left[n_1^T \quad n_Q^T\right]^T, \quad H = \begin{pmatrix} H_1 & -H_Q \\ H_Q & H_1 \end{pmatrix}$$

B. Signal Pruning using Normalized Cross Correlation Technique

To keep the signal correlation between antennas is difficult to maintain the good receive diversity and for high data rate in MIMO techniques. In low complexity detection algorithm it is required to find the highly correlated transmission channels to reduce the bit error rate considerably. In this work normalized cross correlation technique is applied to find the signals with more correlation that are received from the same transmission to predict the original signal more accurately with low complexity. Cross correlation strategy is utilized for feature detection as a component of increasingly complex procedures. The correlation depicts the convolution theorem and probability of proficiently computing correlation in frequency domain utilizing Fast Fourier Transform (FFT). The target of NRCLD research technique is to guarantee the precision signal recovery with decreased complexity level. In this work, signal pruning is performed to filter the signal of same type. To eliminate the irrelevant signals, NCC based pruning method is used which is defined as

$$R_{NCC}(u, T) = \frac{\sum_{n=u}^{u+W-1} f(n) g(n+T)}{\sqrt{\sum_{n=u}^{u+W-1} f^2(n) . \sum_{n=u}^{u+W-1} g^2(n+T)}}, T_1 \leq T \leq T_2 \quad (3)$$

Where, g(n) and f(n) are the comparison and reference signals, W represents the size of the window and τ denotes the shift between the reference and comparison windows. Search range is denoted by [τ1, τ2]. This calculation is repeated for entire signal length. Then the noises in the signals are removed by the adaptive filter before analyzing for complexity.

III. LOW COMPLEXITY DETECTION USING HYBRID GENETIC-BB ALGORITHM

There are various precoding techniques are available already which attempts to transmit signal with low energy consumption. However, existing precoding techniques tends to have discrete optimization problem which would increase the complexity. This is resolved in this work by introducing the Hybrid Genetic-BB algorithm which can solve the discrete optimization problem and can ensure the accurate low complexity detection. In the branch and bound phase the algorithm maintains satisfiability (constraint satisfaction) with integrality being relaxed. Information from hanging nodes is used to suggest chromosomes (set of symbols) to be added to the GA gene pool, which initially is filled with random chromosomes. Potential solutions are generated by the GA from the gene pool, and after a sequence of GA operations the fittest is passed back to be added to the branch and bound tree, and control returns to the branch and bound engine. Thus in the GA phase, the algorithm promotes integrality with satisfiability relaxed (constraint satisfaction). When the algorithm returns to branch and bound, each new potential solution is examined in turn and grafted onto the existing tree. Although control has been returned to the branch and bound engine, all decisions concerning branching node, branching variable and branching direction are made using information extracted from the potential solutions generated during the GA phase. Once these potential solutions have been grafted onto the branch and bound search tree, branch and bound is forced to explore all immediate descendants of these newly created nodes. Finally full control of branching is handed back to branch and bound. Subsequently the hybrid Genetic-BB algorithm incorporates a meta-heuristic approach and this algorithm guaranteed to find the optimal solution.

Hybrid Genetic-BB Algorithm:

GA (R, L, u)
////initialize the generation=0;
i:=0;
P_i := 'R' set of individuals;
//// P_i - set of symbols received
//// evaluate P_i: s
Compute fitness (j) for each j ∈ P_i;
//// Error rate is considered as fitness. Fitness function is the error rate of the actual and predicted signal.
do
{
//// creates i+1 generation then copy.
Choose (1-L) × R members of P_i and insert into (P_{i+1})
//// crossover
Choose (L × R) members of P_i; Pair them up; Procedure off-spring then inserts them into (P_{i+1})
//// mutate:
Choose (u × R) members of (P_{i+1}); then select the bits randomly and the bits are inverted;
////Create new population:
Apply BB operator to select the new population

//// evaluate P_i+1:
Find fitness (j) for each j ∈ P_i ;
//// increment: i:=i+1;
}
while P_i fittest individuals are not high enough in the fitness.
return the fittest individual from P_i;

IV. RESULTS AND DISCUSSION

To assess the performance of the LM-MIMO system, the proposed NRLCD detection method and existing methods are evaluated in the MATLAB Communication tool box version 13a and analysis is done under AWGN channel with 32x32 transmit and receive antennas. In this research work, comparison results is carried out by using the metric called BER where the goal of this research work is to reconstruct the signals accurately. The analysis of the proposed method and existing methods are done using 16-QAM, 32-QAM and 64-QAM modulations. Figure 1 depicts the BER performance comparison of the NRLCD detection and existing methods using 16-QAM. Figure 2 depicts the BER performance comparison of the NRLCD detection and existing methods using 32-QAM. Figure 3 depicts the BER performance comparison of the NRLCD detection and existing methods using 64-QAM. From the figures [1-3], the proposed NRLCD tends to provide significantly better performance in terms of lesser BER rate than the other methods.

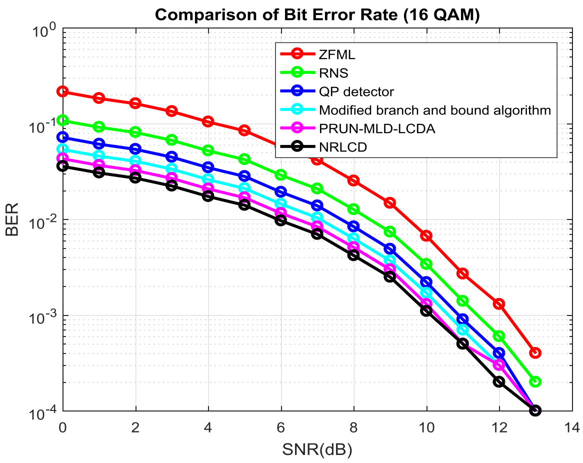

Figure.1 BER performance comparison using 16-QAM

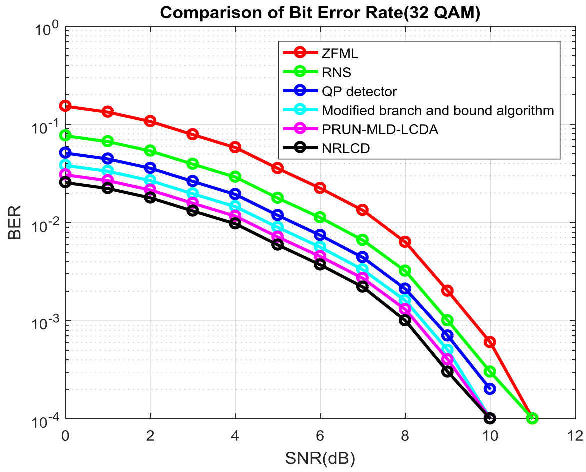

Figure.2 BER performance comparison using 32-QAM

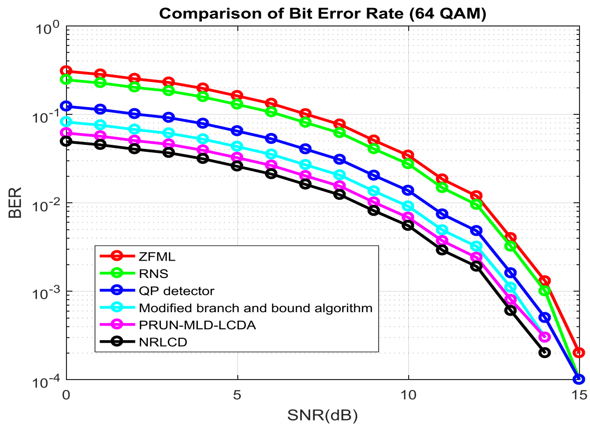

Figure.3 BER performance comparison using 64-QAM

The time complexity is referred as the time consumed by an algorithm to perform for a length of a sequence. Figure 4 shows the time complexity performance comparison between NRLCD method and existing methods using 64-QAM for varying the message sizes from 100 to 500. From this figure 4, it is inferred that NRLCD detection method provides significantly improved performance than the existing methods.

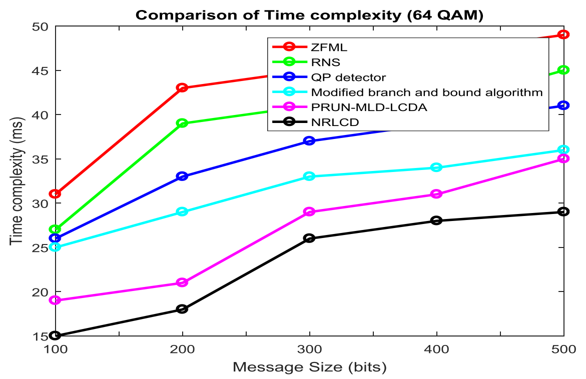

Figure.4 Comparison between time complexity and message size

V. CONCLUSION

The proposed NRLCD detection method is proposed for large MIMO receiver to ensure the accuracy recover of signals with reduced complexity and to reduce the noise. The signal pruning is performed to filter out the alike signals. This is done using the NCC based pruning method which avoids the irrelevant signal. And then Adaptive filter is used to remove the noises present in the signals. Finally, Hybrid Genetic-BB detection algorithm is used to detect the signals with low complexity. The overall evaluation and analysis of the NRLCD proposed method and existing methods is done using MATLAB simulation for higher order QAM modulation from which it is inferred that NRLCD detection method for large MIMO system achieves significantly better performance in terms of lesser BER and complexity than the other methods.

REFERENCES

1. Agiwal, M, Roy, A, & Saxena, N (2016), 'Next Generation 5G Wireless Networks: A Comprehensive Survey', IEEE Communications Surveys & Tutorials, vol. 18, no. 3, pp.1617-1655.
2. Larsson, E. G, Edfors, O, Tufvesson, F, & Marzetta, T. L (2014), 'Massive MIMO for Next Generation Wireless Systems', IEEE Communications Magazine, vol. 52, no. 2, pp. 186-195.
3. Lu, L, Li, G. Y, Swindlehurst, A. L, Ashikhmin, A, & Zhang, R (2014), 'An Overview of Massive MIMO: Benefits and Challenges', IEEE Journal of Selected Topics in Signal Processing, vol. 8, no. 5, pp. 742-758.
4. Mirfarshbafan, S. H, Shabany, M, Amini, A, & Nezamalhosseini, S. A (2018), 'Near ML Detection in Massive MIMO Systems with One Bit ADCs: Algorithm and VLSI Design', Circuits and Systems (ISCAS), 2018 IEEE International Symposium, pp. 1-5.
5. Bonami, P, Lodi, A, & Zarpellon, G (2018), 'Learning a Classification of Mixed Integer Quadratic Programming Problems', International Conference on the Integration of Constraint Programming, Artificial Intelligence and Operations Research, pp. 595-604.
6. Mullin, T. J, & Belotti, P (2016), 'Using Branch-and-Bound Algorithms to Optimize Selection of a Fixed-Size Breeding Population under a Relatedness Constraint', Tree Genetics & Genomes, vol.12, no.1, pp.1-4.
7. Agarwal, S, Sah, A. K, & Chaturvedi, A. K (2017), 'Likelihood Based Tree Search for Low Complexity Detection in Large MIMO Systems', IEEE Wireless Communications Letters, vol. 6, no. 4, pp. 450-453.
8. Burrage, K, Burrage, P, Leier, A, & Marquez-Lago, T (2017), 'A Review of Stochastic and Delay Simulation Approaches in Both Time and Space in Computational Cell Biology', Stochastic Processes, Multiscale Modeling, and Numerical Methods for Computational Cellular Biology, pp. 241-261.
9. Kim, H., Park, J, Lee, H, & Kim, J (2014),' Near-ML MIMO Detection Algorithm with LR-Aided Fixed-Complexity Tree Searching', IEEE Communications Letters, vol. 18, no. 12, pp. 2221-2224.
10. He, H, Wen, C. K, & Jin, S (2018),' Bayesian Optimal Data Detector for Hybrid mmWave MIMO-OFDM Systems with Low-Resolution ADCs', IEEE Journal of Selected Topics in Signal Processing, vol. 12, no. 3, pp. 469-483.
11. Yuan, W, Wu, N, Guo, Q, Li, Y, Xing, C, & Kuang, J (2018), 'Iterative Receivers for Downlink MIMO-SCMA: Message Passing and Distributed Cooperative Detection', IEEE Transactions on Wireless Communications, vol. 17, no. 5, pp.3444-3458.
12. Jiang, F, Li, C, & Gong, Z (2018), 'Low Complexity and Fast Processing Algorithms for V2I Massive MIMO Uplink Detection', IEEE Transactions on Vehicular Technology, vol 67, no. 6, pp. 5054-5068.
13. Park, J, Kim, M, Kim, H, Jung, Y, & Kim, J (2016), 'Low Complexity MIMO Detection Algorithm with Adaptive Interference Mitigation in DL MU-MIMO Systems with Quantization Error', Journal of Communications and Networks, vol. 18, no. 2, pp. 210-217.
14. Zhao, K, & Du, S (2014), 'Full Diversity Approximated Lattice Reduction Algorithm for Low Complexity MIMO Detection', IEEE Communications Letters, vol. 18, no. 6, pp.1079-1082.