Novel Hybrid MIMO Detector for Spatial Multiplexed MIMO System

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Abstract. The need of data transmission has recently increased dramatically and the promising MIMO technology has been employed to preserve reliability. It can achieve exceptionally enhanced spectral proficiencies by adopting several antennas both at the source and the receiver. However, complexity of several detection schemes escalates because of tremendous increasing of customers and antennas. This paper proposes novel hybrid MIMO detection (NHMD) method to compromise the complexity and the hardware design challenges. The key objective is to develop a less-complex hybrid detection system to enhance hardware execution suitability without negotiating the performance of the bit error rate. The proposed NHMD method combines conventional linear detectors such as zero-force (ZF) and minimum mean square error (MMSE) with the K-best detector for quality enhancement. It introduces an optimal differential evolution (ODE) algorithm that selects detector using multiple constraints. Moreover, this method uses parallelism process to reduce the number of arithmetic logics. The proposed NHMD method has been done for different antenna configurations (2×2, 4×4) and implemented on Xilinx tool with different FPGA families. The simulation results confirm that NHMD method consumes less hardware’s, power and higher throughput without affecting BER performance.

1. Introduction

MIMO technology provides higher data rates with increased spectral efficiency [1]. By using MIMO technique, multiple numbers of data streams can be transmitted or received over the MIMO antennas independently [3]. Hybrid detection in MIMO [4] facilitates a mechanism to achieve both data rate and link reliability. In reality, HMS implements a part of data transfer as space-time coded and other part as spatially encoded.

MIMO’s key obstacle for hybrid detection is the nature of a low-complexity and high-throughput in hardware platform [6]. In the past, a number of detection schemes have been proposed to deal with the issue, contributes many exchanges between complexity and QoS.

For further enhancement, novel hybrid MIMO detection (NHMD) is introduced to compromises both the system complexity and hardware design challenges. The main aim of NHMD method is to implement
efficient hardware design in terms of complex-less hybrid MIMO detection with less hardware and better BER performance.

In this paper, related contributions given in section 2. Problem methodology discussed in section 3. System model and proposed algorithm are presented in Section 4. In section 5, reconfigurable design of proposed detector included. Simulation results presented in section 6. Finally, conclusions are given in section 7.

2. Related Contributions

A hardware-efficient architecture for 4x4 and 8x8 high-throughput MIMO detectors has been proposed by Huang et al.[8]. The successful folding scheme strikes an optimal equilibrium between complexity and high data rate. Hardware consumption is 232 kilogates.

The design of algorithm of error-resilient K-Best MIMO detector, focuses both on media noise and prompted errors were proposed by Khairy et al.[9]. This architecture gives up to 5 dB gain for 64-QAM system to yield optimal packet error rate (PER) efficiency. Compared to traditional K-Best detector with perfect memory, it can achieve robust memory and up to 34.75 percent benefits.

3. Problem methodology

Proposed algorithm addresses challenges in sorting mechanism of path metrics of standing K-best detection schemes. To reduce the complexity and thereby to enhance the data rate, all the levels in the tree, are processed in parallel. For multiple antenna configurations and constellations hardware is implemented.

Modified K-best detector implemented on Xilinx Virtex 6, targeting 2x2 antenna configuration with 64 QAM, attains a uniform throughput of 1Gbps. Here, a novel hybrid MIMO detection (NHMD) method is proposed that combines conventional detectors (ZF and MMSE) with the K-best detector for next generation services.

Main contribution of proposed NHMD method is summarized as follows:

- NHMD algorithm, process the input signal either through conventional ZF combined with novel K-best detection or through MMSE combined with the novel K-best detection, to increase the reliability.
• In NHMD method, complexity is reduced by selecting an optimal K value, based on tree traversal.

• NHMD method utilizes parallelism process to reduce the number of arithmetic logics.

4. System model

![Functional Structure of Proposed Novel Hybrid MIMO Detector (NHMD)](image)

**Figure 1.** Functional Structure of Proposed Novel Hybrid MIMO Detector (NHMD)

Algorithm : Novel K-best detection

Layer N:

1. Compute PEDs for all transmitted data symbols

2. Find optimal value of KN form eq. (1)

3. Select K symbols with lower PEDs and their corresponding symbols

Layer N-1 to 2:


1. Compute PEDs for all promising children of K parent nodes of preceding layer

2. Bring up to date value of KN-1 to 2 using eq. (2)

3. select KN-1 to 2 symbols with lower PEDs and their symbols.

Layer 1:

1. Compute PEDs for all promising children of the KN-1 to 2 parents of preceding layer.

2. Choose symbol with lowest PED, gives the original transmitted symbol

Optimal K value is estimated using following equations:

\[ K = \sqrt{m \times \frac{b}{4}}; \quad L = b \]  

\[ K_i = \text{ceil}\left[K_{i,l+1}/p_i\right]; \quad l < b, \text{ where } p_i = b - (c_i - 1) \]  

Where cl is presently traversed layer, Kl is value of K in present layer, and Kl+1 is value of K in the (cL+1)th layer. Depends upon assessment of data vector, no. of traversed nodes are reduced further.

The assessed data vector is based on channel condition represented as,

\[ \tilde{C}_{K_{best}} = H^{-1}y \]  

5. Reconfigurable design of novel hybrid MIMO detector (NHMD)

The reconfigure design of novel K-best algorithm is proposed. The aim of NHMD method is to recuperate original transmitted information with highest reliability by employing smallest level of precision in the detector by making use of various decomposition schemes. The multiple constraints are considered for selecting detectors among ZF and MMSE are: SNR, BER and modulation index. This method has been encouraged to lower the no. of bits required in the detection process, so that both hardware requirements and power consumption are reduced.

Novel K-best detector:
PED computation and two-dimensional sorting are the key functionalities in the FPGA development of novel K-best detector. Both the functionalities require several complex operations such as multiplications, additions and norm operations and demands large memory.

Computation of PEDs involve norm operations such as norm \(-2\), requires complex square root and square operations as follows.

$$\|P\| = \sqrt{p_1^2 + p_2^2 + \ldots + p_n^2}$$  \hspace{1cm} (4)

$$\|P\| = \sum_{i=1}^{n} p_i$$  \hspace{1cm} (5)

For PED computation, input data variables are based on tree layer as follows.

$$s_1 = |x_1 - a_{11} y_1 - a_{12} y_2 - a_{13} y_3 - a_{14} y_4|$$  \hspace{1cm} (6)

$$s_2 = |x_2 - a_{22} y_3 - a_{23} y_3 - a_{24} y_4|$$  \hspace{1cm} (7)

$$s_3 = |x_3 - a_{33} y_3 - a_{34} y_4|$$  \hspace{1cm} (8)

$$s_4 = |x_4 - a_{44} y_4|$$  \hspace{1cm} (9)

### 6. Simulation Results

The proposed novel hybrid MIMO detection (NHMD) method is tested in Xilinx system generator and executed using MATLAB, consider the 2x2 antenna configuration for different QAM modulations (16, 64 and 256).

#### 6.1. BER performance

BER performance is analyzed for all combinations of detectors such as proposed NHMD detector, MMSE + K-Best, ZF + K-Best and ZF + MMSE with the 2x2 antenna configuration for different QAM modulations (16, 64 and 256) with dynamically changed K as shown below figure 2 (a, b and c). Rayleigh fading environment with AWGN, B.W of 90 MHz and data packets of 1,000 each contains 256 bits is considered in implementation process. From the simulation results, it is obvious that performance of proposed NHMD detector (i.e. B-HAI) is much better compared to other detectors (i.e. BER is very low particularly after SNR of 9 dB).
6.2. Computational Complexity analysis

Computational complexity is analyzed by calculating number of nodes visited for all combination of detectors such as proposed NHMD detector, MMSE + K-Best and K-Best detector used with the 2x2 antenna configuration for different QAM modulations (16, 64 and 256) as shown below figure 3 (a, b and c). From the simulation results, it is clear that proposed method visited very small number of nodes compared to other detectors.

Figure 2: Comparison of BER with 2 × 2 antenna configuration and (a) 16 (b) 64 (c) 256 QAM

Figure 3. Comparison of number of nodes visited (a) 16- QAM (b) 64-QAM (c) 256 QAM
7. Conclusion

A novel hybrid MIMO detector (NHMD) is proposed for spatial multiplexing operation. Performance analysis is simulated using Xilinx system generator and executed in MATLAB for 2x2 antenna configuration with different QAM modulations (16, 64 and 256). Proposed detector supports higher data rates with greater link reliability due to its reconfigurable architecture and dynamically chosen K-value. Also, design of algorithm is complexity-less and hence requires less hardware as well as power consumption. All these features are possible due to hybrid nature of detection algorithm using novel K-best detector with conventional detectors (ZF and MMSE).

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