Reconfigurable design of hybrid MIMO detection scheme for spatially multiplexed MIMO system

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Abstract
In recent years, Multiple Input–Multiple Output (MIMO) has been used to expand data transfer for ensuring consistency. The transmitter and receiver use several antennas and they can achieve high spectral characteristics. The numbers of users and antennas increase rapidly questions the stability and reliability of the system. When MIMO is deployed, the complexity of the system increases and it becomes a major problem in many detection systems. When more and more number of receiver and senders pre-require an increased number of hardware components and a part it further increases the system’s complexity and design. It is important to develop sophisticated components to improve compliance with many standards without compromising the Bit Error Rate (BER) performance of the components. The proposed work introduces a New Hybrid MIMO Detector (NHMD), which provides the solution for the complicated design procedure. The core concentration of this work is to minimize the complexity (Hardware) of the system by applying simplest design approach. This Hybrid system with a minimalistic detection approach helps in improve the BER: (Bit Error Rate) of the framework without compromising the overall performance of the system. This proposed method is designed on the Modified Optimal Differential Evolution (MODE) algorithm which is used to apt the best detector by deploying the objectives of this work. In addition, this method uses parallel processing to reduce the amount of arithmetic logic. The proposed NHMD method is implemented for cylindrical devices belonging to different FPGA families with different antenna configurations (2 × 2, 4 × 4). The proposed NHMD method provides superior quality by combining multiple detectors. The simulation results confirm that the NHMD method uses low equipment as well as low power consumption and provides high efficiency without affecting BER performance.

Keywords Hybrid detection · Zero-force · Minimum mean square error · K-best · MIMO · MODIFIED-ODE algorithm

1 Introduction
MIMO (Multiple Input Multiple Output) technology shows high rates of data with improved spectral properties [1, 2]. The performance of a MIMO system is directly related to antenna interference, numerical reference coefficient, signal characteristics, and configuration obtained from multipath channels and some MIMOs' receive antennas may provide low SIR for wireless channels. They are often used together when the main direction of radiation changes. MIMO has several antennas and they can be used for broadcast and reception simultaneously. MIMO has the advantage of having many antennas and advanced signal processing technologies [3]. Using this technology, there are a lot of different data streams that can be sent or received. Independently via MIMO antennas [4] The main problem with MIMO technology is interference from neighboring antennas. Most MIMO programs are designed to achieve the advantages of using systems such as spatial multiplexing and spatial diversity [5]. With MIMO, the balance between the spectrum benefits and the diversity benefits can be trusted. However, none of them supports the practical basis for achieving the optimal compromise between spatial multiplexing and differential amplification [6]. The combined advantage of spatial multiplexing and differentiation has long been recognized as hybrid sound. As for the Bit Error Rate (BER) or the Symbol Error Index (SER), the data transfer rate can be significantly increased while maintaining a satisfactory connection [7].
Low complexity, low power consumption, high performance, high-performance hardware, and operating systems are the main problems of MIMO hybrid sound [8–11]. As of late, a few designs have been proposed to take care of the issue of presenting different exchanges among intricacy and effectiveness. Of these, Maximum Likelihood detection (ML) [12] is the most suitable detection method, and as the quantity of receiving antennas increases and intricacy increases, BER decreases in the overall search. On the other hand, nonlinear detectors do not have serious problems without the classification of Minimum Mean Square Error (MINIMUM MEAN SQUARE ERROR (MMSE)) [12–14]. When searching for advanced priority methods, the previous decoder prioritizes the nodes and node paths in the original stream [15]. A first scheme, like the K-Best Detector, on the other hand [16], suggests that a certain number of candidates should move on to the next step. The initial method of preventing node expansion uses a detection mechanism in the Q-Best cluster-based decoder to maintain maximum probabilistic performance [17]. For example, secondary amplitude modulation has been selected for 64-QAM. That is, the value of the k-star is about 4 times higher and as a result, the linear increase is less [18]. This includes significant delays in the start, antenna values, and sizes. In the proposed system, Structural placement that is distributed K best and Subsequent Interference Compression (SIC) technique have been used to reduce the computational problems and for further enhancement, Novel Hybrid MIMO detection (NHMD) has been introduced to compromise both the system complexity and hardware design challenges. The main aim of the NHMD method is to implement efficient hardware design in terms of complex-less hybrid MIMO detection with less hardware and better BER performance. Edward et al. [19] have presented a spatially multiplexed wireless MIMO system’s hardware structure and tree-search-based modified K-best algorithm. An updated method corrects the current method to determine the best queue with root size distribution problems. The addition of more antennas at all levels reduces equipment problems and improves structural performance under LTE-A standards. The revised Q-Best algorithm reduces the path metric calculations of various antenna configurations. It can be added multiple times to change the number of amplifiers to improve area and power which increases the device performance by 24%. Currently, polyamide (NP: Non-deterministic Polynomial) is a non-NP polynomial problem that can be accurately detected in MIMO systems whereas, it is difficult to detect because MIMO is not compatible with many antennas.

The MIMO system evolved into new Horizons like the Massive MIMO system, where the requirements of individual user experience are improved manyfold [20, 21]. The MIMO system uses various multiplexing techniques such as special multiplexing and many decoder methodologies are employed which are complex in nature [22, 23]. The spectrum need per user is increasing exponentially along with the MIMO environment of multiple Transmitting Antennas and Receiving antennas and it become a tough task to toggle between maintaining system parameters [Example BER (Bit Error Rate)] and improving performance [24]. The complete analysis and the set properties of the Zero Forcing Detractor are completely analyzed and portrayed in [25]. It is evident that the ZF is the best suited to eliminate inter-symbol interference due to the symbol present in the other channel and with this Zero Forcing property ZF detector is best suited in MIMO Environment to eliminate ISI. The conventional Zero Forcing Algorithm is very much effective in reducing or nullifying the ISI effect [20–30]. To achieve a high-performance rate without compromising BER numbers, this paper proposes an NHMD (New Hybrid MIMO Detector) detector for a multiple antenna MIMO system Environment. The proposed Hybrid MIMO Detection (NHMD) the system combines imminent communications systems, K-optimized detection for the existing ZF (Zero Forcing) technique, and MMSE: (Minimum Mean Squared Error). The MIMO system’s performance is enhanced by the proposed work. by the way of minimizing Energy consumption as well this proposed schema is not compromised on the BER rate hence the overall system performance is improved. From this analysis, the proposed method produces better numbers and improves the performance of the system. The traditional architecture (Hardware based), has high throughput due to the technical complexity of the system which in turn uses the chunk of 232 KGate/Execution hardware requirements. Most of the available design concentrates on noise on the digital media trade-off with errors and Reliability. The Traditional methods make the most of the design so complex and difficult to implement [20–32]. And most of the existing system suffers Reliability during node-to-node high data rates transfer moments because of complex hardware design which leads to increased Pocket Error Rate (P-E-R) resulting in increased memory utilization with a summative effect leading to making concessions regarding the system’s overall effectiveness. Further to manage the unplanned increase of user need for hardware to handle the situation, this reconfigurable design becomes the solution for the unplanned scenarios.

The following is how this paper is laid out. In Section II, the most recent K-best algorithm is discussed. The problem methodology and system Model of NHMD methods are discussed in Section III. In Section IV, the hardware architecture, the detailed circuit design, and the proposed NHMD detector are shown. Section V shows the simulation result and how it compares to other methods. Section 6 concludes with the conclusion.
2 Related works

The recent innovations in wireless technology open the doors for many innovations like LTE, MIMO, and Massive MIMO (5G). The MIMO uses multiple antennas at the transmission and receiving stages to improve the gain of the antenna [27]. Huang et al. [33] have provided a hardware-efficient structure for high-performance MIMO innovations. Unlike the existing K-Best algorithms and the search tree for K-Best algorithms group has high survivability and low computational complexity. It is presented both the K-Best MIMO detector algorithm and the error distribution method that integrates channel noise and errors. This method is based on a strategy of calculating internal links during a tree search which significantly reduces the search space [34]. The channel preprocessing is defined using the MMSE -SQRD QMS decomposition MMSE module, which models arrays of spatial and simulated modeling [35]. An effective Minimum Mean Squared Error—MIMO fixed point detection is done by launching interpolation software for LTE-A wireless sharing. Detection algorithms and dynamic scaling schemes improve the dynamic range of intermediate values of some Intelligent surfaces beyond the scope of the MIMO system also proposed by Ertugrual [29, 36] which still depends on shift keying techniques.

Spatial Multiplexing, Signal Noise Ratio (S/N), QoP (Quality of Performance), Power Utilization, Capacity, and Bit Error Rate (BER) are the important parameters one needs to concentrate on when dealing with a MIMO system. Depending on the target BER performance and or SNR reduction in channels, a 10% to 51% improvement in system efficiency is achieved by the system. Customizable MIMO detection and scalable MIMO detection systems are available on systems with multiple cores, and likewise, the system nodes integrated with the model of the NOC (Network-on-Chip). The tree-based MIMO detection algorithm is optimized for NOC systems and it includes processing elements for implementing the algorithm [37]. Chebyshev parallel iteration is used to study the parallelism of inverse and matrix multiplication and reduce the computational burden. Chebyshev iteration which is based on the Eigenvales method is the key process used to obtain the following (i) the initial values for the inverse matrix, (ii) Values for matrix multiplication. The high-performance K-optimal detection used in MIMO systems employs a two-dimensional (2D) parallel classification algorithm [38]. Custom algorithms classify data in parallel to improve performance and avoid delays associated with the existing algorithms. Detection of MMSE is recommended for large $128 \times 8$ 64-QAM MIMO systems with parallel full-tube configurations [39]. This design uses diagonal tuning based on diagonals and hence, there are no performance limits. It is a high-performance multimode preprocessor designed for MIMO 4 $\times$ 4 detectors with many preprocessing programs, including QRRD, SQRD, and MMSE-SQRD [40].

Susnata and Jeyanandh [28] have proposed a reconfigurable design for the 28/34 Gigha Hertz MMSE system. They have implemented the beam-forming receiver with an adaptive approach. The Hybrid Beamforming Receiver is used for the Aggregation of carrier signal used in the MIMO system. And they have adopted a multi-standard MIMO system which makes the total implementation complex.

The number of transmitting and receiving antennas, as well as the system’s overall operational complexity, significantly rise when multiple users are using the system simultaneously. The parameters like Bit Error Rate are greatly influenced by the system complexity which gets diluted when the count of sending antennas and receiving antennas and high in usage, cumulatively increases degradation in performance. As well this scenario become worsen in the LTE-A category.

The recent innovations and implementation procedures of 5G use the advantage of the MIMO system in the name of Massive MIMO. This massive MIMO system uses very large capacity transmission and receiving antennas uses to achieve higher gain for the individual user to give a better technical advantage to the End user. As per IMT-2020, the $100 \times$ in terms of data download and upload improvement over the existing network capacities and $1000 \times$ times the user accommodation expansion in comparison with the current network structure are the expected target of the 5G system which through a big battleground for the researchers to achieve such a goal. This practical implementation increases large technical advancement as well increases the complexity of the system. This leads to the use the countless antennas at any specific time interval. This complexity technically improved at a significant level by Edward et al. [19] even though the author missed to provide the solution to the best queue with root size distribution problem in the spatially multiplexed wireless MIMO system which is addressed by this proposed system.

The behind for presenting this paper is to develop a Hybrid MIMO Environment with less complexity. The need for fewer antennas with the MIMO benefits fits best for Internet of Things (IoT) accomplishment. This presented work is a solution to overcome the complexity issue with less Bit Error Rate and is more suitable for IoT Environment. In simple terms, the overall outcome profound by this presented work is to minimize the complexity (Hardware) with the simplest design approach as a primary outcome followed by A Hybrid system with a minimalistic detection approach and improving the system’s BER without compromising the overall performance.
3 System model and problem methodology

3.1 Problem methodology

Edward and others [19] have presented a spatially multiplexed wireless MIMO system’s hardware structure and tree-search-based modified K-best algorithm. An updated method corrects the current method to determine the best queue with root size distribution problems. The addition of wood at all levels reduces equipment problems and improves structural performance following LTE-A standards. The revised Q-Best algorithm reduces the path metric calculations of various antenna and galaxy configurations and reduces device performance by 24%. It can be added multiple times to change the number of amplifiers to improve area and power. Poor detection capabilities are displayed by the MIMO system when used with a polyamide (NP) system, since, it is a non-NP polynomial problem hence MIMO is not compatible with many antennas of the system.

This makes it a great candidate. Here, a new Hybrid MIMO Detection (NHMD), which combines K-optimized detection for existing ZF, MINIMUM MEAN SQUARE ERROR (MMSE), and future communications systems, has been proposed. The proposed NHMD system makes the following primary contributions:

- NHMD method improves BER performance by combining traditional NF and MMSE with K-best gain detection.
- The Optimal Differential Evolution (MODIFIED-ODE) algorithm is used to select the correct detector as Z-F + Q-best detector and MMSE + detector of K-best.
- This Proposed Detection system (K-Best) replaces the conventional K-Best detection algorithm by dividing it into NHMD mode.
- The NHMD method uses a parallel process to reduce the arithmetic logic.

3.2 Model of the system

A computer model of the MIMO system that NHMD has proposed is depicted in Fig. 1. On the transmitter side, the IFFT methodology is deployed for encrypting the data sets as well as the encrypted data stream can be decomposed using FFT Technique. Fourier Transform (FFT) is used to encrypt data at several carrier frequencies. When the receiver receives a signal, it is converted to an FFT. The channel transfer function is calculated to detect the H signal and some transmission characteristics are provided. MIMO systems with multiple transmission channels can use higher speeds and transmit data over a limited spectrum. The MIMO detector combines additional processing with a channel decoder before receiving each signal. Finally, the channel decoder rejects the source of the transmitted bit information.

The numbers of symbols sent by the Transmitting antennas using IFFT have been decoded using FFT by receiving antenna in the MIMO system. The received data stream is calculated as per Eq. (1)

\[ y = Hx + N \]  

(1)

where \( x \) is a complex vector of exchange symbols i.e. \( x = (x_1, x_2, \ldots, x_T)^T \) and each component is drawn independently of a complex galaxy in the M-QAM array. The complex output symbol \( H_1, y_1, \ldots, y_R \) and the main band of the potential channel of the repeater between the transmitter and the receiver define the matrix of the complex channel \( R \times T \) as well as processes the scan with zero median White Gaussian scanning (AWGN) as a vector of the scanning process.

3.2.1 Channel estimations

The channel estimation for the NHMD is founded on OFDM (Orthogonal Frequency Division Multiplexing) signal, let the OFDM is executed in the Time Domain (TD) with the count of symbols being as 'S' and where the count of Sub-Carriers which the signal contains being mentioned as 'X'. at each subcarrier the given out space will be 1/TD. As per the assumption, the sampling width of this simulation is TD/X. Data being considered in this estimation is given in Eq. (2)

\[ DAT_{I,N} \]  

(2)

In Eq. (2), \( N \) Indicates the sub-carrier counts of OFDM whereas \( I \) indicates the symbol of the OFDM to be transmitted. Mathematically described below as in Eq. (2)

\[ SYM(TD) = \sum_{TD=-\infty}^{\infty} \sum_{X=0}^{X-1} DAT_{I,N}^{TD} \]  

(3)

In Eq. (3) \( SYM \) represents the sum of all the symbols to be communicated. The value \( \theta_{I,N}(TD) \) is evaluated using Eq. (4) given below,

\[ \theta_{I,N}(TD) = e^{j2\pi X/TD} (TD - TG - ITC[U(TD - ITC)] - U(TD - (I + 1)ITC) \]  

(4)

Equation (4), \( T_G \) indicated the time interval (Guard) which is being introduced to overcome the signal interference. This is then characterized as a multipath atmosphere, which is depicted using Eq. (5)

\[ MUL(TD, \psi) = \sum_{I=0}^{MULTOT-1} \eta_I \delta(TD - \psi_I) \]  

(5)
In Eq. (5) the MULTOT indicated the summation of multiple paths in the channel. Due to the influence of the received signal’s phase difference on the receiver side, multipath fading occurs in the system. This is because the received signal moves at different distances and routes. Rail transport can reach many customers. Power relays are commonly used for speed signals. Due to the phase difference of the received signal on the receiver side, multipath fading is the probability density function of the class of the relay channel of distribution.

\[
F_{Ray} = \frac{\kappa}{\Re^2} e^{-\kappa^2/\Re^2}; \quad \kappa \geq 0
\]  

(6)

wherever \( \kappa \) is the random number and \( \Re^2 \) is the variance.

A common channel representation for all modulation methods is the AWGN channel.

### 3.2.2 MIMO detector

Due to spatial variation and Inter Symbol Interference (ISI), the detection procedure needs to be shortened before the receiver can reduce the signal. The receiver uses the linear detection method the most. Through a matrix of directional changes, the amplifier converts the received signal’s amplitude linearly, and the received signal is measured to the nearest point in the open atmosphere. From here, the complex signal vectors \( \tilde{y} \) are obtained

\[
\tilde{y} = [\tilde{h}_1 \tilde{h}_2 \ldots \tilde{h}_T] \begin{bmatrix} \tilde{x}_1 \\ \vdots \\ \tilde{x}_T \end{bmatrix} + \tilde{N}
\]  

(7)

Proceed with,

\[
\tilde{y} = \tilde{h}_1 \tilde{x}_1 + \tilde{h}_2 \tilde{x}_2 + \cdots + \tilde{h}_T \tilde{x}_T + \tilde{N}
\]  

(8)

### 3.2.3 Zero forcing detectors

The main idea of Zero Forcing is to improve \( \tilde{y} \) the channel-based compatibility matrix and to reduce Inter Symbol Interference to zero. There is no sound in the calculation \( \tilde{y} \). The ZF algorithm consists of two stages [26]. The Zero forcing detector employed in a MIMO environment eliminates the symbol interferences from other symbol layers traditionally [25].

\[
\hat{Z} = \begin{bmatrix} \tilde{z}_1 \\ \vdots \\ \tilde{z}_T \end{bmatrix} = \hat{C}_ZF \hat{y} = \begin{bmatrix} \tilde{g}_1 \\ \vdots \\ \tilde{g}_T \end{bmatrix} \hat{y}
\]  

(9)
where \( \tilde{y} \) is used to indicate the complex signal vector and \( \tilde{C} \) is the channel noise in the Multi transmit and receive antenna, all in the MIMO environment. MMSE Detector: The main strategy of the MMSE detector is Zero Forcing. The difference is that a new inverse matrix \( \tilde{C}_{MMSE} \) is calculated to reduce signal distortion, due to channel and expected noise.

\[
\tilde{C}_{MMSE} = \left( \tilde{H}^H \tilde{H} + \frac{1}{\rho} I_R \right)^{-1} \tilde{H}^H
\]

(10)

Here, \( \tilde{C}_{MMSE} \) is the representation for channel noises due to symbol interference in multiple transmit antenna and multiple receiving antenna environments where inter-symbol interference is quite high? Where the Zero Forcing applied to the MMSE yield better elimination of ISI in the received signal.

SSNR is the \( n \times n \) identity matrix. MMSE ZF for AWGN is canceled. This is because the average effect of Gaussian noise is calculated when the ISI effect is reduced.

3.2.4 K-best detector

As the number of MIMO antennas increases and the modulation method is adjusted, even the most suitable algorithm is difficult to evaluate and it cannot be implemented at the hardware level. Equation (11) I represents the Unity Parent Matrix of \( 2Nr \times 2Nr \) in the J is the indication of the upper triangle of the parent matrix of the original K-Best Channel tree Matrix. the Decomposition of the channel matrix in the K-Best Detection scheme is disclosed using Eqs. (11) to (15).

The modified channel matrix is defined as follows:

\[
y = Jx + N
\]

(11)

Therefore,

\[
I^{-1} y = Jx + I^{-1} N
\]

(12)

Simplified as \( Z = I^{-1} y \) and \( w = I^{-1} N \)

\[
Z = Jx + w
\]

(13)

The proposed system with k-best modifications is now finalized and obtained through Eq. (14) as follows:

\[
\tilde{C}_{K\text{best}} = \text{arg min}_{x \in \mathcal{X}} \| Z - Jx \|^2
\]

(14)

where the \( Z \) is the Zero Forcing which is augmented with Channel ISI to get the best rates (No inference or minimal inference). ‘J’ ‘J’ is the matrix of parent triangles and hence, searching through the \( Jx \) tree is complicated. Partial Euclidean Distance (PED) is the distance between a received and a given signal. The PED of each column is calculated as follows.

\[
P_l(x_i) = P_l(x_{i+1}) + |R_l(x_i)|^2
\]

(15)

\[
P_l(x_i) = Z_i - \sum_{j=1}^{4} J_{ij} x_j
\]

(16)

Each K-best detector Tree stack focuses on choosing the best K game and choosing the best hint. The choice of the optimal value for the cable depends on the current location of the tree, such as the antenna, modulation system, and system parameters, Where the received signal is notified as K-Best, then its values are obtained through Eq. (17)

The value of ‘K’ may be deduced with the following bounds:

\[
K = \sqrt{M} \times \frac{B}{4}; \ L = B
\]

(17)

\[
K_L = \text{ceil}[K_{L+1}/P_L]; \ L < B, \text{ where } P_L = B - (C_L - 1)
\]

(18)

where ‘L’ is the summation of all the branches in the tree, ‘M’ indicates the total count of branches present in the tree. The order of the Matrix set in the above equation is indicated through ‘B’. And the capacity of the channel is indicated through ‘C’. The P indicates the point Set of the total constellation. The calculated data vector is used to determine the best mobile node. The inverse calculation of the channel matrix is made easier by having the same number of transmitter and receiver antennas. The expected data depends on the size of the vector channel and it can be specified.

\[
\tilde{C}_{K\text{best}_{est}} = H^{-1} y
\]

(19)

The processing steps for determining the K-best detection are summarized in Algorithm 1.

4 Reconfigurable design of novel hybrid MIMO detector (NHMD)

The proposed NHMD’s operational structure is first discussed in this section. The reconstructed design of the K-Best special method and the optimal differential evolution method are focused on. The functional structure of this presented NHMD technique is explained through Fig. 2. The purpose of the NHMD system is to open the receiver to obtain a transmission cModified-ODE with minimal error by using other methods. This is due to the number of bit representations that the MIMO should focus on reducing hardware
4.1 Isolated K-best detector

There are two main functions for measuring and placing PEDs in FPGAs to activate the Q-Ideal Insulation detector. These two functions require more complex functions, such as complex multiplication, complex addition, and regular operations. Hence, these functions require a large amount of memory in the FPGA. To calculate the PED, the condition has to be evaluated. To evaluate the criteria of rule 2 or L2, a square root function with two main functions is needed to calculate the PED in the FPGA to initialize the detector using K-Best isolation.

\[
\| P \| = \sqrt{p_1^2 + p_2^2 + \ldots + p_m^2} \quad (20)
\]

Both of these functions require significant resources and hence, the L2 standard and the L2 algorithm have changed a lot. L1 reduces the absolute difference. The linear characteristics that a device can detect without using an amplifier significantly reduce the existing design problems and the PED are mentioned through 'P'.

\[
\| P \| = \sum_{i=1}^{n} P_i \quad (21)
\]

Testing performance for errors according to the L1 standard, the difference in performance between the two types of words is checked following the L1 standard. The input variable depends on the layer that calculates the PED. PED calculations are performed as follows:

\[
\text{Sym}_1 = |a_1 - r_{11}b_1 - r_{12}b_2 - r_{13}b_3 - r_{14}b_4| \quad (22)
\]

\[
\text{Sym}_2 = |a_2 - r_{22}b_3 - r_{23}a_3 - r_{24}b_4| \quad (23)
\]

\[
\text{Sym}_3 = |a_3 - r_{33}b_3 - r_{34}b_4| \quad (24)
\]

\[
\text{Sym}_4 = |a_4 - r_{44}b_4| \quad (25)
\]

where, \(\text{Sym}_1, \text{Sym}_2, \text{Sym}_3,\) and \(\text{Sym}_4\) indicate the symbols in the calculation of PEDs for the proposed NHMD system. 'a' and 'b' are the independent variable and symbols are represented using \(Z_i\).

---

**Algorithm: 1 Isolated K-Best finding**

**Stage X**
1. Calculate P's Pi for all \(Z_i\)
2. Select the value of \(K_N\) from Eq (32)
3. Shortlist the value of \(K\) symbols with minimum PEDs \(P_i\) and their corresponding \(Z_i\)

**Stage (End at 2 & Starting from X-1)**
1. Determine the P's for each beneficial child of the \(K\) parents in the previous layer
2. Eq. (33) can be used to bring \(K_{N-1}\)’s value up to 2
3. Select \(K_{N-1}\) to 2 symbols that have the bare minimum of PEDs \(P_i\) and \(Z_i\).

**Stage 1**
1. Determine the P's for all \(K_{N-1}\) offspring and their two parents from the preceding layer.
2. Consider the symbol’s hierarchy as a potential solution and choose one with the lowest P.

For each PED calculation module, three types of function blocks are added, multiplied, and completed. Actual results can only be used to evaluate the verdict after the entire decision. Memory requirements are reduced during classification according to the asynchronous array created by the inventor and the continuous linear array method is recommended. Two types of modifications are made during sorting. If the queue is halfway, it moves left and right. T lists all candidates for TT [41–43].
4.2 Optimal differential evolution (MODIFIED-ODE) algorithm for detector selection

A subset of hardware modules includes ODM (optimal differential evolution) algorithm. The general configuration of the control module is shown in Fig. 3. The addresses of the PM and FM modules, 3 registers for storing the code, 3 64-bit registers for storing attributes, and log files are displayed. The 64-bit version is written down and each subsequent character is saved.

The step-by-step procedure of the presented MODIFIED-ODE algorithm for symbol detection and estimation is illustrated in Algorithm 2.

Algorithm: 2 MODIFIED-ODE algorithm
(For Symbol Detection)

Step 1 Initialize \( I=1, J=1 \)
- Estimate Current Population Value \( r_1, r_2, r_3 \)
- Estimate Current Fitness Value as \( X=1 \) to Infinity

Step 2 Get Value for
- \( X \) - Sub Carrier Value
- Start With \( X=1 \)

Step 3 Get All Sub Carrier Frequency of FFT using K best Detector
- Go To Results of Algorithm 1

Step 4 Estimate Step 3 Values
- Do TD conversion of Step 3 Values

Step 5 Do
- MULTOT using \( MUL(TD, \psi) = \sum_{i=0}^{MULTOT-1} \eta_i \partial(TD - \psi_i) \)

Step 6 Adopt \( \theta_{I,N}(TD) = e^{j2\pi X/TD(TD - T_D - IT_C)(U(TD - IT_C) - U(TD - (I+1)TC))} \)

Step 7 Repeat Step 5

Step 8 Do FFT
- For Symbols X from Step 7

Step 9 End

4.2.1 PM module

The primary module consists of the memory unit and the protection part of the memory unit. The memory size of the proposed MODIFIED-MODIFIED-ODE algorithm is maintained by the PM module and the memory size is defined as follows:

\[
PM = NP \times Dwords
\]  (26)
The PM size, expressed in bytes, is as follows if each word is specified by 8 bytes (64 bits):

\[ PM = NP \times D \times 8\text{bytes} \]  
(27)

4.2.2 Module of frequency MOD

Similar to PM, this module is implemented. Since only one value is stored, the fill parameter determines the FM size in this case. FM exposure is defined as:

\[ FM = NP \times \text{words} \]  
(28)

Each word is determined by 8 bytes (64 pieces), then the FM size communicated in bytes is determined as follows:

\[ FM = NP \times 8\text{bytes} \]  
(29)

4.2.3 Module for mutation and crossover

Mathematically generated mutation and crossover functions are depicted in Eqs (7) and (8). The in-depth hardware architecture is explained in this section. The configuration has three floating-point values, and the odd set is produced by the binary floating-point function.

\[ temp_1 = x_{i,r1}^0 - x_{i,r2}^0 \]  
(30)

\[ temp_2 = F \times temp_1 \]  
(31)

\[ MV_{i,\text{best}}^1 = x_{i,\text{best}}^0 - x_{i,r2}^0 \]  
(32)

Figure 4 shows the vector of complete and genetic mutation tests for the next project.

Random numbers for all reduced process sizes (for example, find the values and locations of several sizes and go to the next multiplexing tool) are recorded.

Depending on the value and size of CR shown in Fig. 5, the best (target) or experimental multiplexer vector follows. A cell automation program is used to generate random numbers for each 3D value.

4.2.4 Fitness function module

The actual calculation depends on the use of the module and so, this module only switches between applications. A set of six reference mathematical functions is used to evaluate the applicability of the MODIFIED-MODIFIED-ODE algorithm. The performance of the existing systems is:

\[ f(x) = \sum_{i=1}^{D} x_i^2 \]  
(33)

5 Simulation setup and discussion of results

The Hardware prototypes are efficiently designed with the help of the Xilinx platform and to attain the possible results those proto models are run through Simulink and MATLAB tools. The result of the analysis matches with the real-world working environment outcomes. This proposed system is designed with the help of the Xilinx platform which eliminates the programming of Hardware coding since the job is done by MATLAB and Simulink tools. The proposed new NHMT system is implemented using the above-said methodology that is Xilinx system Modelis used to develop the Hardware prototype then the MATLAB and Simulink tool is used to generate the necessary outcomes and testing.
Fig. 6  a BER comparison using a two-by-two antenna configuration (16 QAM). b BER comparison using a two-by-two antenna configuration (64 QAM). (c) BER comparison using a two-by-two antenna configuration (256 QAM)

Fig. 7  a BER comparison using a four-by-four antenna configuration (16 QAM). b BER comparison using a four-by-four antenna configuration (64 QAM). c BER comparison using a four-by-four antenna configuration (256 QAM)

The following hardware structures are involved in the proposed simulation process. The proposed simulation work is performed using various FPGAs from the Xilinx series Vertex-4 (XC4 VFX12), Vertex-5 (XC5 VSX 240D), and Vertex-6 (XC6 VCX 75D). The simulation outcomes are analyzed for effectiveness on the hardware and complexity involved in the proposed NHMT method. These outcomes of the simulation were then compared with the results of drilling mechanisms namely the QRTM-Z hybrid, MMSE -K best, along with the K-best hybrid [18, 20, 26].

5.1 BER analysis

MIMO BER 2 × 2 and 4 × 4 are used to analyze all the detectors and to transmit 100,000 antennas and 96 bits in a single volume configuration. Antenna configuration is compared with 2 × 2 and different QAMs as depicted in Fig. 6. The proposed MIMO cross breed indicator gives 4 dB higher effectiveness than K-viable items with BER = 10−1. This suggests that the proposed BR NHMD method has a low NAB SNR. Similarly, Fig. 7 shows the comparison of 4 × 4 antenna configurations with different QAM sizes, respectively. The shown hybrid detector of MIMO is larger than the K-Best, and the proposed 10 dB SNR is much smaller than the NHMD.

5.2 Complexity analysis

Using two-by-two and four-by-four antenna configurations, a comprehensive analysis of each detector is carried out based on the number of observed nodes and floating point calculations. The configuration of antennas 2 and 2 is depicted in Fig. 8, and the number of review nodes is compared to various QAMs, respectively. The NHMD method and the hybrid MMSE -K are superior [20] and K-Best [18]. K-Best is inferior to the proposed MIMO hybrid detector at all SNR values. This shows that the number of observed nodes can be neglected in comparison with the current detector. Similarly, Fig. 9 shows antenna configurations 4 × 4 and the count (nodes) observed compared to different QAMs, respectively. The NHMD method and the hybrid MINIMUM MEAN SQUARED ERROR (MMSE) -K are superior [20] and K-Best [18]. The proposed detector redefines K-Best and demonstrates that the proposed NHMD method visits very few nodes at any SNR value. The NHMD method compares hybrid MMSE -K best [20] and Q-best [18] with Fig. 10 2 × 2 antenna configurations and different QAMs floating point numbers, respectively. The proposed MIMO hybrid detector is superior to the K-Best for all SNR values. This demonstrates that the current invention outperforms the observed performance of floating point. Similarly, Fig. 11 shows A and C floating-point operating systems with 4 × 4, different
QAMs antenna configurations (NHMD mode, hybrid MINIMUM MEAN SQUARED ERROR (MMSE) - K best [20] and K-best [18]), respectively. The proposed update overrides the K-Best and shows that the floating point All SNR values have negligible effects on the proposed NHMT method’s performance.

5.3 Hardware utilization analysis

The proposed NHMT FPGA system’s performance section is examined, including several product families, Wireless 4 (XC4VLX200D), Vertex 5 (XC5VLX20D), and Xilinx version 14.5. Extension Silicon is a tool that integrates design and graphics into target devices. The design process
Fig. 11  a Comparison of the number of operations performed in floating point with a Four-by-Four antenna configuration (16 QAM). b Comparison of the number of operations performed in floating point with a Four-by-Four antenna configuration (64 QAM). c Comparison of the number of operations performed in floating point with a Four-by-Four antenna configuration (256 QAM)

Table 1 New hybrid MIMO detector hardware consumption (usage) snapshot

| Metrics                          | Two crosses Two & QAM of 64 | Four crosses Four & QAM of 64 |
|----------------------------------|-------------------------------|-------------------------------|
|                                  | Virtex4 | Virtex5 | Virtex6 | Virtex4 | Virtex5 | Virtex6 |
| Count of Slice- Registers utilized | 1563    | 1113    | 1116    | 1629    | 1119    | 1125    |
| Count of Flip-Flop (Slice) used  | 1119    | –       | –       | 1119    | –       | –       |
| Count of LUT: Look-up-Table used | 2952    | 1239    | 707     | 3071    | 1239    | 707     |
| Count of Flip-Flop-LUT: Look-up-Table used | – | 1798 | 1447 | – | 1799 | 1459 |

is checked with the built-in ISIM Simulator. External and detailed images of RTL NHMD (2 × 2 antenna configuration) are shown in Fig. 10, respectively.

The use of tools and materials is analyzed in the design process. Table 1 shows the hardware usage of some NHMD systems: Vertex 4 (XC4 VLX 200D), Vertex 5 (XC5 VLX 20D), and Vertex 7 (XC7VLX30T). Antenna configurations 64 2 × 2 and 4 × 4 QAM are implemented in two configurations. The recommended NHMMT method in this list uses at least 6 FPGAs based on FF and LUT. The existing hardware designs are contrasted with the proposed NHMD method’s performance [19, 33–45].

Table 2 compares the hardware usage of specific inventors with the existing inventors. This indicates that the number of updated slice records for FF, LUD, and FF-LUD pairs is less than the hardware application of the proposed NHMD method (Fig. 12 and 13).

5.4 Throughput analysis

Typically, after a detector is implemented in FPGA, the performance is measured using the maximum clock frequency (Fmax), sprocket size (M), number of antennas (N), and clock rotation required for design. The proposed NHMD method’s throughput is compared to that of the existing hardware designs [19, 33–45]. The performance comparisons of the existing innovators and current innovators are described in Table 3. The proposed NHMD method’s efficacy is clearly shown by this.

5.5 Power analysis

K-Best, an isolator detector, provides the NMMD method. The proposed NHMD method’s power consumption is compared to that of existing hardware designs [19, 33–45]. The comparison of the proposed inventor’s and the current inventor’s energy costs is shown in Table 4. It demonstrates that the proposed NHMT system’s energy consumption is insignificant in comparison to the actual outcomes.
| Refs.  | Detector         | Target device | Antennas | QAM | K | Hardware utilization |
|--------|------------------|---------------|----------|-----|---|----------------------|
|        |                  |               |          |     |   | Registers | LUTs | FFs | FF-LUT pairs     |
| [33]   | K-Best           | 90.00 nm      | 4 × 4    | 64  | 8 | 321 KG gates        |
| [34]   | K-Best           | 65.00 nm      | Not Applicable | 64 | 10| 177 KG gates        |
| [35]   | K-Best           | 65.00 nm      | 4 × 4    | 64  | 10| 586 KG gates        |
| [36]   | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | Not Applicable | 64 | Not Applicable | 9145 | 136 | Not Applicable | Not Applicable |
| [44]   | K-Best           | 22.00 nm      | 4 × 4    | 16  | 5 | 425 KG gates        |
| [47]   | K-Best           | Virtex        | 4 × 4    | 64  | Not Applicable | 303,372 | 847,459 | 2768 | Not Applicable |
| [45]   | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | 128 × 16 | 64 | Not Applicable | 70,288 | 70,452 | Not Applicable | Not Applicable |
| [38]   | K-Best           | 90.00 nm      | 4 × 4    | 64  | 16| 182 KG gates        |
| [39]   | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | 128 × 8  | 64 | Not Applicable | 20,454 | 25,103 | Not Applicable |
| [40]   | MINIMUM MEAN SQUARED ERROR (MMSE) –SQRD | 90.00 nm | 4 × 4 | 64 | Not Applicable | Not Applicable |
| [19]   | K-Best           | Virtex5       | 4 × 4    | 16  | Not Applicable | 3458 | 6587 | Not Applicable | Not Applicable |
|        | NHMD             | Virtex4       | 2 × 2    | 64  | 10| 1561 | 1116 | 2949 | Not Applicable | Not Applicable |
|        |                  |               | 4 × 4    | 64  | 10| 1626 | 1116 | 3068 | Not Applicable | Not Applicable |
|        |                  | Virtex5       | 2 × 2    | 64  | 10| 1116 | 1236 | Not Applicable | 1795 |
|        |                  |               | 4 × 4    | 64  | 10| 1117 | 1236 | 1796 | Not Applicable |
|        |                  | Virtex6       | 2 × 2    | 64  | 10| 1113 | 704  | Not Applicable | 1444 |
|        |                  |               | 4 × 4    | 64  | 10| 1122 | 704  | Not Applicable | 1456 |

NA—not applicable, *this paper
Table 3 Comparison of maximum clock frequency and throughput

| Refs. | Detector                  | Target device | Antennas | QAM | K  | Metrics                     | Max. clock frequency (MHz) | Throughput (Mbps) |
|-------|---------------------------|---------------|----------|-----|----|-----------------------------|----------------------------|------------------|
| [33]  | K-Best                    | 90.00 nm      | 4 × 4    | 64  | 8  |                             | 170                        | 4080             |
| [34]  | K-Best                    | 65.00 nm      | Not Applicable | 64  | 10 |                             | 499                        | 1198             |
| [35]  | K-Best                    | 65.00 nm      | 4 × 4    | 64  | 10 |                             | 550                        | 2640             |
| [36]  | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | Not Applicable | 64  | Not Applicable |                              | 422                        | 1146             |
| [44]  | K-Best                    | 22.00 nm      | 4 × 4    | 16  | 5  | Not Applicable              | Not Applicable             | 3200             |
| [37]  | K-Best                    | Virtex        | 4 × 4    | 64  | Not Applicable              | 148.7                      | 281.3            |
| [45]  | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | 128 × 16 | 64  | Not Applicable              | 205                        | 1230             |
| [38]  | K-Best                    | 90.00 nm      | 4 × 4    | 64  | 16 | Not Applicable              | 200                        | 1200             |
| [39]  | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | 128 × 8  | 64  | Not Applicable              | 205                        | 308              |

Fig. 13  b RTL screenshot of NHMD method with 2 × 2 antenna configuration—Deep architecture
### Table 3 (continued)

| Refs. | Detector | Target device | Antennas | QAM | K | Metrics |
|-------|----------|---------------|----------|-----|---|---------|
|       |          |               |          |     |   | Max. clock frequency (MHz) | Throughput (Mbps) |
| [40]  | MINIMUM MEAN SQUARED ERROR (MMSE) –SQRD | 90.00 nm | 4 × 4 | 64 | Not Applicable | 220 | 44 |
| [19]  | K-Best | Virtex5 | 4 × 4 | 16 | Not Applicable | 52 | 27.7 |
| *NHMD |         | Virtex4 | 2 × 2 | 64 | 10 | 165.079 | 495.237 |
|       | K-Best | Virtex5 | 4 × 4 | 64 | 10 | 217.794 | 1306.764 |
|       | K-Best | Virtex6 | 2 × 2 | 64 | 10 | 518.483 | 1555.449 |
|       |        |          | 4 × 4 | 64 | 10 | 454.143 | 2724.858 |

NA—not applicable, *this paper

### Table 4 Comparison of Power Consumption

| Ref | Detector | Target device | Antennas | QAM | K | Power consumption (mW) |
|-----|----------|---------------|----------|-----|---|-----------------------|
| [33] | K-Best | 90.00 nm | 4 × 4 | 64 | 8 | 234 |
| [34] | K-Best | 65.00 nm | Not Applicable | 64 | 10 | 20.77 |
| [35] | K-Best | 65.00 nm | 4 × 4 | 64 | 10 | 245 |
| [36] | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | Not Applicable | 64 | Not Applicable | Not Applicable |
| [44] | K-Best | 22.00 nm | 4 × 4 | 16 | 5 | Not Applicable |
| [37] | K-Best | Virtex | 4 × 4 | 64 | Not Applicable | Not Applicable |
| [45] | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | 128 × 16 | 64 | Not Applicable | 1660 |
| [38] | K-Best | 90.00 nm | 4 × 4 | 64 | 16 | Not Applicable |
| [39] | MINIMUM MEAN SQUARED ERROR (MMSE) | Virtex7 | 128 × 8 | 64 | Not Applicable | Not Applicable |
| [40] | MINIMUM MEAN SQUARED ERROR (MMSE) –SQRD | 90.00 nm | 4 × 4 | 64 | Not Applicable | 167 |
| [19] | K-Best | Virtex5 | 4 × 4 | 16 | Not Applicable | Not Applicable |
| *NHMD | Virtex4 | 2 × 2 | 64 | 10 | 197 |
|       |        | 4 × 4 | 64 | 10 | 198 |
|       |        | Virtex5 | 2 × 2 | 64 | 10 | 209 |
|       |        | 4 × 4 | 64 | 10 | 333 |
|       |        | Virtex6 | 2 × 2 | 64 | 10 | 575 |
|       |        | 4 × 4 | 64 | 10 | 1293 |

NA—not applicable, *this paper
6 Conclusion

The MIMO system’s performance is heavily influenced by the BER. The MIMO system’s NHMT Detector was successfully implemented in this paper. The MIMO system’s performance was enhanced by the presented system. The NHMT method combines ZF and MMSE to extract maximum gain for the MIMO system’s antenna, directly improving the MIMO’s performance. This proposed system was suitable for designing and developing devices used for future communications like 5G and 6G. The values are estimated using the Optimum Differential Evolution (MODIFIED-ODE) algorithm in the proposed system, which employs optimal detection schema from optimal antenna locations. The proposed equipment configuration is utilized to decrease plan rationale and energy utilization. The proposed NHMD is superior to the conventional hybrid detectors in terms of effectiveness, as demonstrated by BER and complex analysis. The progression of the proposed NHMD design in comparison to the technologies that are currently in use is shown by the analyses of hardware usage, efficiency, and profitability. In short, the presented design optimizes to use of the perfect memory needed for the process, increases the cumulative data transfer rate by reducing the complexity involved in the hardware process, and makes sure that the processes all happened in execution in a parallel manner.

7 Future direction

1. The MIMO system moved from Multi MIMO into Massive MIMO system, this presented work possibly implemented in the 5G Environment (Massive MIMO)
2. 6G adaptability may be tested in the sophisticated laboratory environment
3. Integration of IoT with 5G and IOT-6G possibilities opens the door for many research possibilities

8 Limitation

1. The analysis is made up of 256QAM sampling and the higher rates are not tested.
2. The uniform throughput is justified at one billion bits per second higher level not tested.
3. The results produced only 35% and below the level of improvement over the existing methodologies. Higher levels are not recorded in this work.
4. Only $2 \times 2$ and $4 \times 4$ antenna configurations alone evaluated in the presented work.
5. The MIMO is structured for complex high-end application antennas where the cost is justifiable but in the IoT Environments, the proposed system is on the higher side of the cost.
6. The environment in which the developed and tested system operates has fewer antennas, so whether or not a large number of antennas would be practical is a concern.
7. The overall system cost and size may increase if it is placed on a tiny device based application.

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Declarations

Conflict of interest According to the authors of this paper, there is absolutely no conflict of interest with anyone. Thanking You Corresponding Author. The Authors of this work state that there is no conflict of Interest with any thing and anyone in any form.

Ethical approval This paper is single-authored work and not require anybody’s approval to submit to this journal the authors state that any part of this work is not copied or parenthesized from already published or under-consideration research work. And the author (Dr. A. Raja Basha) declares that there is no other journal processing this paper at this point.

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