A Cognitive Implementation For High Throughput, Low Power Hybrid Adaptive And Intelligent Mimo Detectors On Reconfigurable Architectures For 5g LTE/IoT Environment

Anil Kumar Tipparti

Abstract--- ***Internet of things (IoT) is the world of technology, and it has been predicted that usage of connected devices will be around 200 billion users. As IoT in wearable health care is the major area facilitates the usage of numerous transmitters on board, which leads to the employing of MIMO system (with high performance decoders) for an effective communication. Unfortunately, employing of MIMO system suitable for IoT remains on the darker side of the research. Also, achieving the quality of performance (QoP) with low power, low energy and less computational complexity using re-configurable architectures is the real challenge.***

To meet this scenario, a novel MIMO detector called Hybrid Adaptive and Intelligent (HAI) detector has been proposed. It is a Hybrid detector (i.e. consists of different combinations of conventional MIMO detectors, such as ZF with Fuzzy K-Best & MMSE with Fuzzy K-best).One of this combination of detectors will be chosen using Cognitive Selective Permutation theory, which is Adaptive to the SM input parameters (S/N), to achieve high QoP parameters. In the proposed algorithm, Intelligence (Fuzzy based) has been incorporated to Dynamically upgrade the value of K (in Fuzzy K-Best Decoding process), to achieve very much reduced complexity as well as power. After testing this detector in the re-configurable Programmable architecture, it gives best performance parameters compared to other detectors (i.e. High BER performance, Low Complexity, High Throughput, Low power and Energy efficient).

Keywords— HAI MIMO detector, CSP, QoP, LTE/3GPP, SM, IOT,MIMO Communication Systems.

I. INTRODUCTION

Wireless communications has becoe one of the fastest growing markets worldwide. To support growing no. of users, the emergence of new applications require better quality of service (high reliability) and high data rates. Hence, in view of the demand for higher data rates and better Quality of Services (QoS) new transceiver algorithms and architectures are required, to better exploit the available spectrum and to efficiently counter the impairments of radio channel. In this regard MIMO Communication Systems are needed.

The basic idea is to employ multiple antennas both at transmitter and receiver. The important features of MIMO systems are higher spectral efficiency (SE) and high link reliability. Which results increase in data throughput and link range, without additional bandwidth and transmit power. Unfortunately, the tremendous gains associated with MIMO technology also entail a considerable increase in computational complexity particularly at the receiver, due to the complex algorithms required for the separation of these spatially multiplexed streams and this is the reason why MIMO is a current theme of international wireless research.

II. PROPOSED HAI MIMO DETECTOR

A. Overview of Operations

The HAI MIMO detector consists of following three different phases.

- Signal-to-Noise Ratio Calculator and Scheduler
- Hybrid Adaptive Permutation (HAP) Engine
- Performance Calculator-Post Processing

The block diagram of HAI detector is shown below.

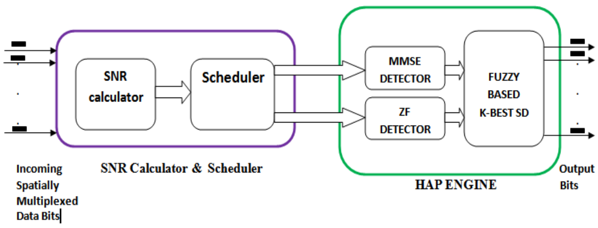

Figure 1 Block Diagram of HAI detector.

SNR Calculator block calculates the S/N of incoming SM (spatially multiplexed) data bits and sends to the Scheduler & Selector sub-block. Scheduler and Selector sub-block compares the S/N levels (supplied from the SNR calculator sub-block) to the threshold SNR level and selects the suitable detector as per following condition. If SNR level < SNR_THLD, ZF detector is selected, otherwise MMSE detector is selected. Accordingly, for each SNR preprocessed value, either one of the linear detector is selected to get the optimal solutions, which are suitable for the Fuzzy K-best Sphere decoding Stage in order to have the less dimension for the processing.

Hap Engine Block consists of consists of following three sub-blocks.

i) ZF Decoder
ii) MMSE Decoder
iii) Fuzzy K-Best Decoder.

It consists of following two hybrid engines

i) ZF with Fuzzy K-Best SD
ii) MMSE with Fuzzy K-Best SD.

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These engines are selected based on the adaptive inputs of pre-processed SNR calculations as per the above condition. Depending on the selected hybrid engine, incoming bits are decoded either by ZF decoder or by MMSE decoder. In the next level, these bits are given to Fuzzy K-Best SD. Fuzzy rule set is applied, to intelligently select the initial value of k and dynamically upgrade the value of K, which gives high performance with very much reduced computational complexity.

B. Steps for Detection

After SNR/BER Calculation, Cognitive Permutation theory is applied. Accordingly, the incoming bits are decoded to MMSE or Zero Forcing Algorithms. In order to maintain the K value to be optimal value for maintaining the low complexity and high performance, the Fuzzy K-Best Sphere decoding is adopted for the group of the MMSE/Zero Forcing bits which has been determined on the first level.

In the next level , decoding tree for the Sphere Decoding has been constructed based on the obtained bits which are close to the ML optimal detection .For the intensified and simplified tree search , Fuzzy rule has been incorporated.

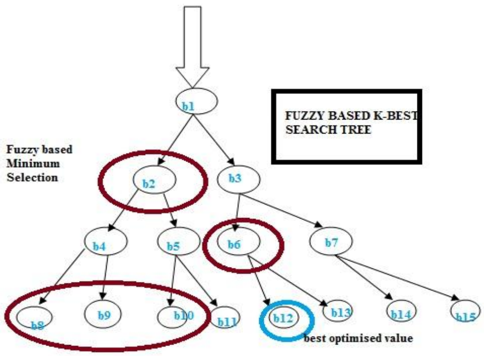

Figure 2. Fuzzy based K Best Searching Phase in HAI MIMO detector

At this point, nodes of the decoding tree are stored as the information of the partial solution in order to find the optimal solution. For each and every level of tree, partial Euclidian

Distance (PED) is calculated. Also the difference between the PED of the optimal and sub optimal(first stage bits) are calculated, to find the best one. The HAP engine incorporates the Fuzzy rule Sets and tree grows on as it reaches the optimal values.

III. SYSTEM MODEL

The MIMO system with the Number of Transmit Antennas T and no of receiving antennas R in which R>T is considered . The system Model is given

$$Y=HX+N \qquad (1)$$

where Y represents complex received Bits in terms of vectors and X represents the complex transmitted received Bits in terms of vectors that contains the infinite entries with the finite modulations S with the zero mean and variances .The H is given as the T x R channel matrix with the N as the additive Gaussian noise value with the Zero mean and variance. In this case, T=R for the channel matrix at the receiver side.

IV. ARCHITECTURE OF HAI DETECTOR

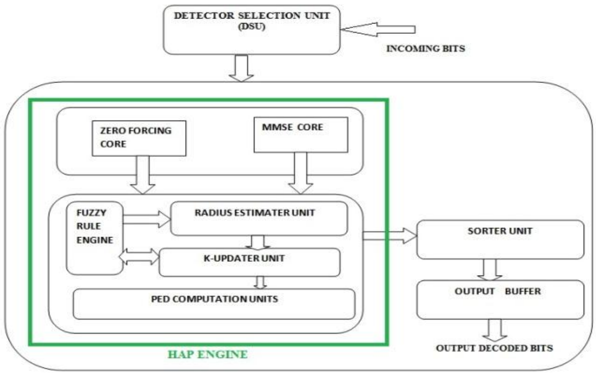

Figure 3. Architecture of Proposed HAI Detector

In the Stage 1, SNR is calculated for the SM based Input Signals. As the SNR is calculated in the pre-processing stage, two types of the linear detection are chosen in HAP engines.

CSP Theory:

For each SNR preprocessed values, either one of the first stage of the linear decoder engine is selected to get the optimal solutions which are suitable for the Fuzzy K-best Sphere decoding Stage in order to have the less dimension for the processing.

Second stage of the HAP engine consists of the Low Dimension K-best Sphere Decoding Algorithm in which the K values are adaptive based on Fuzzy rule Sets.

Let us consider Nt+1 be the number of the levels in the formation of the tree and Nt anf Nr be the number of Antennas in the transmitter and the receiver respectively. Partial Euclidian distance(PED) will be calculated for each level which stores the optimal solutions.

Table1. Fuzzy Rule Sets for the Adaptive K-Best Sphere Decoding Algorithm.

Sl.No	Conditions /Fuzzy Rule Sets	Outputs
01	Let us consider the 5 thresholds like A1,A2,A3,A4,A5	
02	Calculation of PED between the optimal D(opt) and Sub optimalDistance D (Sub)	
03	IF(D(opt)-D(Sub))==D1) is LesBER than or Equal to A1	K=Kt1
04	IF(D(opt)-D(Sub))==D2) is LesBER than A2 and greater than A1	K=Kt2
05	IF(D(opt)-D(Sub))==D3) is LesBER than A3 and greater than A2	K=Kt3
06	IF(D(opt)-D(Sub))==D4) is LesBER than A4 and greater than A3	K=Kt4
07	IF(D(opt)-D(Sub))==D5) is LesBER than A5 and greater than A4	K=Kt5

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The noise of the optimal solution has less BER than the partials solutions which are obtained from the inputs, then PED values can be adjusted in accordance with the adaptive K –Values. The Fuzzy Rule Sets are implemented with the different thresholds, as the difference in PED values are large in sense the partial solutions reaches the ML solution and K value remains to be small and vice versa condition is applied for this mechanism. The mathematical description of this implementation is shown in Table I

After the finding the smallest value of K with the expanding the 'I' leaves of the nodes again the check the condition if I is not equal to the one , then implement the Fuzzy rule sets which are mentioned in above table (1) . At the final step the smallest optimal solutions are determined.

V. COMPUTATIONAL COMPLEXITY REDUCTION

A. Methodology Complexity

The hybrid combination of the different detectors are designed in order to reduce the computational complexity without sacrificing the high performance. The authors [3] have proposed the mixed detectors which consist of the combination of the Search First(SF) and Depth First(DF) detectors. These hybrid detectors works on the principle of depth and searching first which requires the higher computation. A hybrid method in the combination of the k-best and Sphere Decoding has been proposed in [4] which works on the S E algorithm which doesn't needs the initial radius estimation in which the authors has used the layered ordering of decomposition which in return increases the computations. In order to decrease the computational complexity, author [5] have proposed the combination of k-best and sphere decoding. The algorithm proves to be more vital in terms of complexity reduction but as not an intelligent method and adaptive to the inputs and doesn't suitable for all modulations schemes.

In the proposed algorithm, first L Bits are detected by the adaptive to the SNR values of the incoming datas. The values of L is large for the low SNR and it is small for the high SNR. As the first step, first L values are detected by the detectors (MMSE/ZF) and next Nt-L Bits are detected by Fuzzy K-best Sphere decoding. Besides, our proposed algorithm uses the minimum dynamic K-best values updation methodology using the Fuzzy rules sets which can adopted intelligently to reduce the complexity .The method is suitable for the different Modulation schemes.

As we seen in the previous cases, all mixed or hybrid detector uses the K-best searching algorithm as the primary layers which can reduce the complexity. But in the proposed algorithm adopts the K-best for the Nt-L Bits which reduces the complexity and also adopting the K-best which in terms of the next layer leads to the more computation, in which proposed detector uses the SD for the further computations.

The value of L can be taken from 0 to Nt or Nt to 0 in which the detectors are selected based on the adaptive Environment of SNR. Hence the proposed detectors will have enhanced performance with the lower complexity.

B. Implementation complexity

As the previous section clearly illustrates that the no of computations has been reduced to one half of the any hybrid detectors. Also no of additions and multiplications will also be reduced which leads to the occupation of the less BER and also low power consumption during the operation.

VI. PERFORMANCE EVALUATION

The performance of the proposed HAI detectors has been evaluated based on the test bench designed with 2x2 MIMO with the different modulation techniques and with the AWGN channel. The proposed detectors has also evaluated based on the Simulation when the transmitting antenna and receiving antenna increases to 4.

The SNR and Eb/N0 has been calculated based on the SNR iterations which is given as follows as For each iterations, the BER is calculated with the different Modulations like 4-QAM,16-QAM,64-QAM the results are shown as follows.

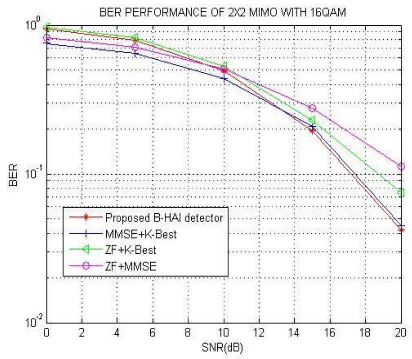

Figure 4. BER performance of Proposed HAI detector for 2×2 MIMO System with 16 QAM Modulation under AWGN Channel

For comparative Analysis, the performance of the proposed HAI detector has been compared with the hybrid detector like MMSE+Zero forcing hard detectors has proposed by [2]. The test bench also supports with the MMSE+ZF hybrid detectors apart with the proposed detectors.

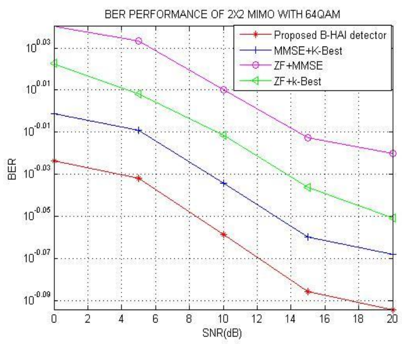

Figure 5. BER performance of Proposed B-HAI detector for 2×2 MIMO System with 64 QAM Modulation under AWGN Channel

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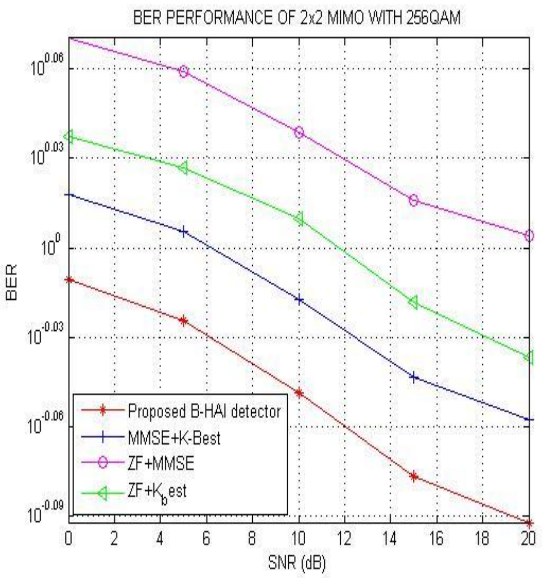

Figurre 6. BER performance of Proposed B-HAI detector for 2×2 MIMO System with 256 QAM Modulation under AWGN Channel

VII. CONCLUSIONS

The proposed detectors outperforms other combinations of the hybrid detectors in terms of Power, Area and Throughput. The designed detectors with the high throughput can be implemented in the Internet of things when it finds the applications of wearable implantable devices for monitoring the different body parameters of the users. These detectors with the Intelligence will lead to the Cognitive MIMO detectors which can be used as the pervasive and ubiquitous transceivers.

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