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Trellis Coded Modulation For Mimo Wireless Communication System

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ABSTRACT

Signal detection algorithm providing likelihood information for coded spatial multiplexing to MIMO (Multiple Input Multiple Output) wireless communication system pose a critical design challenge due to their prohibitively high computational complexity, in this work we present a different signal detection algorithm by adopting different modulation scheme to achieve expected SNR(Signal to noise ratio). To propose the error correcting code which improves the signal strength and to improve the data rate by using different modulation, the algorithm is evaluated by computer simulation performed over Rayleigh flat fading channel and computer computational analysis.

Index Terms—*Log Likelihood Ratio (LLR), Spatial Multiplexing (SM), Wireless communication.*

1. INTRODUCTION

Wireless telecommunications refers to the transfer of information between two or more points that are not physically connected. Channel is the interface between transmitter and receiver, here free space is considered as channel.

It encompasses various types of fixed, mobile, portable applications which including cellular telephones, two-way radios, Personal Digital Assistants (PDAs) and wireless networking. In general wireless communication can be classified into lot of generation. In first Generation it supports data transfer (voice), second Generation it supports both voice and data transfer. Third Generation it supports multimedia i.e supports audio, video, data transfer.4G and 5G supports high speed and very high speed multimedia technology.

It is known that we can achieve better spectral efficiency is able to be achieved in Multiple-Input-Multiple-Output (MIMO). To exploit one of the important challenges is the very high power that is required at the MIMO receiver end.

MIMO means Multiple Input Multiple Output. MIMO is defined as multiple antennas to transmit and receive radio signals. It was developed by Io-span wireless. It can achieve high data rate, more capacity, power efficiency, and also supports Diversity. MIMO system provides high data rates and improved performance without increasing the bandwidth or transmitted power.

MIMO is a scheme, used to support technology to achieve expected outcome. In this technology constitutes the basis for upcoming wireless communication standards, such as IEEE 802.11n and IEEE 802.16e/m [3], to increasing high demand for high speed, high quality wireless services. It can provide a maximum speed of 540 Mpbs.

Depending on the resulting channel conditions, the MIMO system may not be able to properly recover the transmitted data streams (layers) if the SINR is too low at any of the receive antennas. Spatial Multiplexing means a high rate signal is split is split into multiple lower rate streams and each stream is transmitted from a different transmit antenna in the same frequency channel [1]. Spatial multiplexing can be used with or without channel knowledge.

The technical challenges we are facing in this paper are discussed below. In conventional system Energy Efficiency, Delay, Utility of the existing system has not much concentrated towards the expected outcome status. In our proposed system we are focusing on the above said parameters and the Expected outcome to be obtained. In this regard to achieve the desired outcome we have to choosen Trellis code modulation for our claimed work.

In this paper, we aim to propose the error correcting code scheme which improves the SNR (signal to noise ratio) and signal strength. A bit error rate can be reduced. High throughput can be achieved. The paper is organized as follows. Section II deals with the system model, Fixed Sphere Decoder (FSD) algorithm and MIMO signal detection. Section III describes the proposed algorithm level improvement technologies and error correcting coded modulation scheme. Section IV discusses the bit error rate (BER) performance and computational complexity. Section V draws conclusion and future enhancement.

2. MIMO SYSTEM MODEL

A. Coded MIMO System

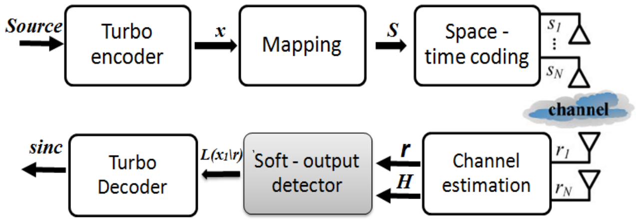

Fig.1.Block diagram of coded MIMO system

As shown in Fig. 1, we consider an SM MIMO system with N transmit and receive antennas, where the space–time coding block simply performs the serial-to-parallel conversion. The received $N \times 1$ complex signal vector is given by

$$\tilde{r} = \tilde{H}\tilde{s} + \tilde{n} \quad (1)$$

where $\tilde{s} = [\tilde{s}_1, \tilde{s}_2, \ldots, \tilde{s}_N]T$ is the $N \times 1$ transmitted vector, in which each component is taken independently from a set O of Gray mapped M-QAM constellation points, $\tilde{n}$ is the vector of independent identically distributed Gaussian noise samples with mean zero and variance $N0$ per complex entry, and $\tilde{H}$ denotes the $N \times N$ channel matrix. Each symbol vector $\tilde{s}$ is associated with a bit-level vector x, which is obtained by Error Correcting Coding (ECC) to the original binary source. In this paper, the rate $R_c = 1/3$ parallel concatenated turbo code specified in 3GPP-LTE is used as the ECC scheme. Moreover, we assume that the receiver has perfect knowledge of the channel realizations.

In this paper, we apply the orthogonal version of real-value decomposition (ORVD), which has been introduced to MIMO detector design in [16]. After ORVD, the complex system model in (1) is rewritten as

$$r = Hs + n \quad (2)$$

The real-value decomposition also transforms the complex constellation O of M points to its equivalent real constellation P of $\sqrt{M}$ points, e.g., 64-QAM modulation is transformed to 8-Pulse-Amplitude Modulation (PAM) in the equivalent real valued system. The use of space-time coding along with MIMO is very useful to maximize spatial diversity and introduce high capacity gains. In the literature survey we learned soft-output and hard-output detectors. In soft-output to generate soft information based on the received vector r and channel matrix H [2]. The need of soft output mostly wireless communication use error correcting codes. That is turbo codes, convolutional codes, low density parity check and Trellis codes. Turbo codes give high efficiency, it preserve the codes efficiently. So this demanding soft input for decoding. So soft output MIMO signal detection is highly desirable. In the existing work hard output Maximum Likelihood (ML) was studied. The complexity is less but not perfectly matched.

B. Fixed Sphere Decoder

Hard output is detected then only it provides the hard estimation of each bit. In a hard output we take exponential values are difficult [4]. If it is soft output then it provides posteriori probability information about each bit. Soft outputs are used to perfect matching, and then it takes exponential also.

The hard-output FSD was first introduced in [12] and has been demonstrated in to be capable of providing almost- ML performance. Uniquely characterized by a parameter P, an FSD instance searches over a fixed number of nodes in a tree by performing a full search in the first P layers, exhaustively expanding all the $\sqrt{M}$ branches per node, while a single search in the remaining $(2N - P)$ layers expands only one branch per node.

The FSD tree can also be[12] represented by a node extension vector $m = [m1, m2, \ldots, m2N]$, where $m_i = [1, \sqrt{M}]$ means that FSD spans each node at layer $i + 1$ to m_i child nodes at layer i. FSD can be combined with detection ordering for further performance enhancement.

It is suggested in that signal with the largest post processing noise amplification is detected first in the full-search layer. In single-search layers, signals with the smallest post detection noise amplification are selected first to reduce the error propagation.

It has been shown in [13] that the FSD achieves an almost-ML performance in a complex-value system if $(P + 1)2 \geq N$. For example, $P = 1$ allows the FSD to present an asymptotical ML performance for 4×4 MIMO detection.

The essential meaning of such parameter setting is that all the possible nodes (i.e., all the M nodes in the M-QAM modulation) of the first symbol should be expanded to avoid its decision error being propagated to the remaining layers.

Given that one complex symbol has been decomposed into two layers of real symbols in the real-valued system, the full-search scheme should be adopted at the first two layers of the equivalent 8×8 real-valued system to maintain the performance, i.e., m is equal to $[1, 1, 1, 1, 1, 1, \sqrt{M}, \sqrt{M}]$.

The completely constant and regular tree traversal order makes FSD a very attractive candidate for highly efficient implementation. Unfortunately, the FSD is more interested in finding the ML result in the hard-output scenario.

In a soft output system, its performance can be degraded significantly due to its inefficiency in finding T^{ML}.

To verify this conjecture, we simulated the detection performance of FSD in terms of un-coded BER, coded BER with hard output, and coded BER with soft output and compared with the K-Best detection [5]. As expected, in un-coded and hard-output coded systems, FSD owns a BER performance that is almost the same as the K-Best algorithm.

In case of a coded BER with soft output, FSD demonstrates a large performance loss. The BER performance of the soft-output system depends on the quality of the LLR values provided by the signal detector.

3. PROPOSED IMPROVEMENT TECHNIQUES

In this paper introduces four algorithm-level improvements to the FSD. This technologies include the following: (1) a reliability dependent extension scheme with a novel polygon-shaped constrain to reduce unnecessary node extensions; (2) an on-demand list-size reduction method for keeping the candidate list as small as possible; (3) an early bit-flipping technique that first flips the bit value of the binary ML vector and the list LLR to attain more reliable soft information; (4) finally, the l^1-norm Euclidean distance but reduces the LLR error magnitude as well. The result shows that the proposed algorithm provides better detection performance.

A. Reliability-Dependent Tree Search

Although the use of single-node expansion in the lower $(2N - P)$ layers reduces computations to a certain extent, the exhaustive expansion at upper layers of the FSD tree introduces a large amount of wasted calculations by including vectors with large Euclidean distances in the candidate list. This motivates us to propose the reliability-dependent extension method to conveniently find the list of vectors closer to the ML result [11].

Its basic idea is derived from the well-known sphere constraint technology, which has been widely applied in tree search algorithms to reduce the unnecessary visits to some nodes i.e., given a radius constraint r^2, we only consider those nodes that could possibly lead to a PED of less than r^2.

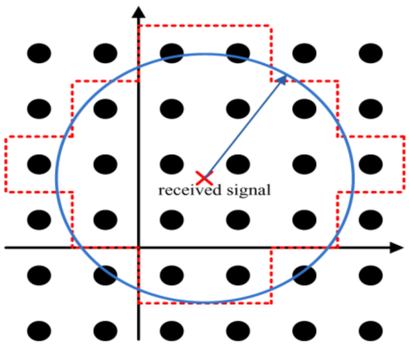

Fig.2. Example of polygon shaped constraint

To exploit the merit of the sphere constraint while preventing its complexity overhead, we propose to approximate this traditional circular-shaped admissible region with a polygon shaped admissible region.

Practically, this polygon constraint is realized by introducing an extension number limitation L_i^{m}, with which only the L_i^{m} best nodes are extended from the m^{th} father node at the i^{th} ($i <= P$) layer. If L_i^{m} is equal to 0, it means that no new path is expanded, and the whole branch is trimmed [16]. The reliability-dependent extension with the number constraint L_i^{m} is conducted by expanding more/fewer branches from those relatively more/less reliable nodes. The corresponding equations are referred to [12].

Since in a tree-search detection the reliability of a candidate node is related to its PED, and a larger PED means a smaller possibility that the node is indeed transmitted, we set a smaller L_i^{m} for the node with larger PED. Furthermore, taking into account that the FSD performs full extension at the first two layers for a 4 × 4 system, the constraint L_i^{m} is applied only at the $(2N - 1)^{th}$ layer (the constraint to the top layer is accomplished by setting the corresponding L^{m}_{2N-1} to 0).

Finally, we are interested in finding the appropriate value of L^{m}_{2N-1} with an additional constraint that the size of the generated list would be the same to that of the K-Best detection [12].

B. On-Demand List-Size Reduction

It can eliminate a certain number of vectors with larger Euclidean distances [22]. To get the appropriate list-size efficiently, we introduce this algorithm by adding a simple yet effective step after the tree search. Given the set of candidate vectors, we first sort them in ascending order of the Euclidean distances; then, we generate the final list by selecting the minimum number (D_{final}) of best vectors with a constrained. The bit is correct if its LLR is the same as that generated by the MAP detection.

$$D_{final} = \arg_{D<=D_{original}} \min \left[D \mid N^{CB}(D) = N^{CB}(D_{original})\right] \quad (3)$$

C. Early bit flipping

The bit flipping can be used [25] for low complexity in soft output detection. When computing LLR for the l^{th} bit of x, i.e., L (x_l/r) the bit flipping is to flip the corresponding bit value of the ML vector is to check 0 or 1[10]. In this method to increase the probability based on list-size. The corresponding equation of x^{ML} is referred as [1].

D. L^1-norm LLR calculation

To calculate Euclidean distance for each bit of the $N\log_2(M)$ length transmitted vector, which in occurs high extra computational complexity [25]. By replacing the Euclidean distance (l^2-norm) with the Manhattan distance (l^1-norm). From this detection performance received all the signal vectors then high signal can be denoted as '1' and low signal can be denoted as '0'.

E. Error correcting codes scheme (Trellis Coded Modulation)

In this paper we propose Trellis coded modulation scheme, is as automatic error correcting scheme. In general MIMO technique [10], theoretically we can achieve 10^{-7} bit error rate. By using this Trellis code we can achieve maximum bit error rate of 10^{-8}. It is an effective error correcting code.

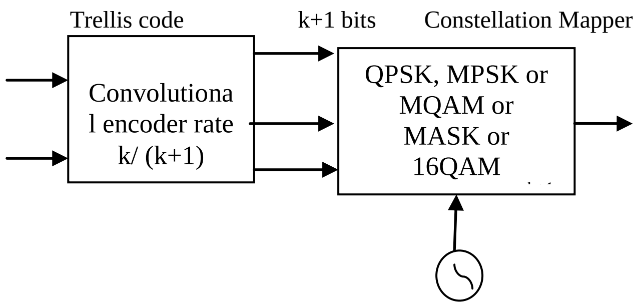

Fig.3. A general Trellis coded modulation

Trellis Coded Modulation (TCM) is a bandwidth efficient transmission scheme that can achieve high coding gain by integrating coding and modulation. Trellis coded modulation is best to design in long sequences of messages [18]. The allowed sequence should be very different from each other. The receiver can then make a decision between sequences using their statistics rather than on symbol-by-symbol basis.

In this Fig.3 shows TCM combines the functions of a convolutional coder of rate R=k/k+1 and M-ary signal mapper that maps $M=2^k$ input points into a larger constellation of M=2k+1 constellation points. By using Trellis coded modulation with MIMO we can achieve energy efficiency throughput and spectral efficiency. We have to implement the TCM with MIMO technique to achieve normalized utility power, normalized packet delay, normalized power for coded and uncoded MIMO system. We discussed more about the TCM in section IV.

4. SIMULATION AND ANALYSIS

We conclude the resulting soft-output MIMO detection algorithm after adopting the four technologies described in Section III, which we will refer as enhanced-FSD hereafter. In this section, the proposed enhanced-FSD is verified and compared with other fixed complexity algorithms in terms of BER performance and computational complexity.

When the FSD is equipped with different improvement techniques described in Section III. Such simulation results clearly demonstrate how the proposed technologies affect the BER step by step. This is because it not only promises the occurrence of T_l^{ML} for all the N log2 (M) bits in x but also improves the reliability of soft information by calculating the final LLR with the minima of T_l^{ML}, FSD. The application of l^1-norm approximation is helpful for performance enhancement. This comes from the fact that although bit flipping is capable of guaranteeing the existence of T_l^{ML}, is minimized. In such circumstance, l^1-norm approximation relaxes the LLR enlargement effect, leading to a relatively better performance.

A. Comparison to Other Algorithms:

The BER performance of the enhanced-FSD (with all the four improvements) is compared with that of the K-Best detection, and the LFSD algorithm. The simulation results shows that the enhanced-FSD gives better performance than the other fixed-complexity soft-output detections within the entire SNR region, and a larger performance gain is obtained for a higher order modulated system.

B. Number of Arithmetical Operations

In this section, the computational complexity is analyzed in terms of arithmetical operations. For this complexity analysis, we divide the algorithm into two components: 1) the list generation (or tree search) that outputs a set of candidate vectors and their corresponding distance metrics via tree-search process and 2) the LLR computation that calculates the soft information using the candidate list and/or bit-flipping scheme.

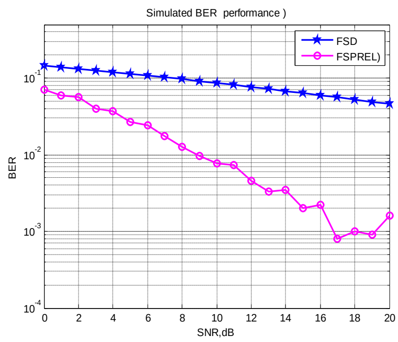

Fig.4. Simulated BER Performance with Fixed sphere decoder Reliability Extension.

In this Fig.4 shows that if the SNR value = 9, fixed sphere decoder Bit error rate is 10^{-1} suppose we have to send 10 bits means one bit error will occur. We also explain that SNR value =9, Fixed sphere decoder reliability extension Bit error rate 10^{-2} suppose we have to send 100 bits means one bit error will occur..Here we conclude FSPREL provides better performance.

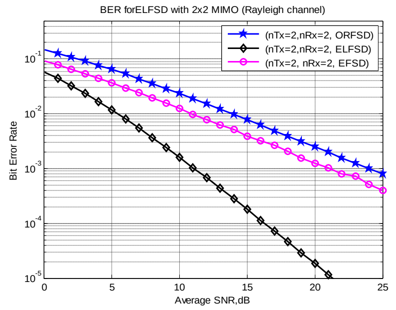

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Fig.5. BER Performance of the Original / Enhanced K-Best, LFSD and FSD

In this simulation result Fig.5.shows that three parameters we are consider. Original fixed sphere decoder, Enhanced fixed sphere decoder, Enhanced list fixed sphere decoder...For ORFSD if the SNR value =20 it provides 10^{-1} bit error rate. For EFSD if the SNR value=20 it provides 10^{-2} bit error rate. For ELFSD if the SNR value=20, provides 10^{-5} bit error rate. Compare this all ELFSD is best. Because it can achieve expected bit error rate

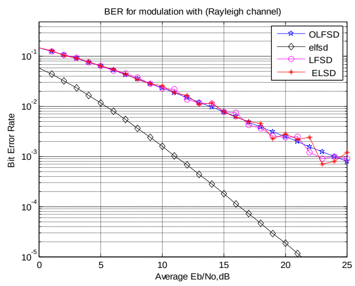

Fig. 6.Simulated Bit Error Rate Performance for QAM MIMO Systems

In this Fig.6 shows that Enhanced list fixed sphere decoder provides better bit error rate performance. If the SNR value=20 it achieves expected 10^{-5} bit error rate.

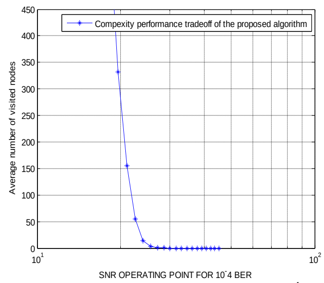

Fig.7: SNR Operating Point for 10^{-4} BER.

In this Fig.7 where the computational complexity is measured by the number of visited nodes per vector detection, the SNR operating point means the minimum SNR required to achieve a given BER.

C. Trellis coded modulation

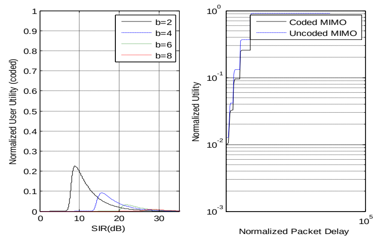

Fig.8.Normalised user utility for coded and un-coded MIMO

In this Fig.8 shows the lower modulation have maximum utility and higher modulation had minimum utility. For lower modulation we can use longer distances, (eg: BPSK). For higher modulation we can use shorter distances (eg: QAM, QPSK). In this Fig.8 shows before applying the Trellis code uncoded MIMO have maximum utility power and coded MIMO have minimum utility power. That is the reason we go for particular Trellis codes designing for further section.

Trellis-coded modulation means for achieving a coding gain on bandwidth-constrained channels, where we wish to transmit a bit rate to bandwidth ratio R/W>1.For such channels, the digital communication system is designed to use bandwidth efficient multilevel or multi phase modulation (PAM, PSK, DPSK or QAM), which allows us to achieve an R/W>1.When coding is applied in signal design for a bandwidth constrained channel, a coding gain is desired without expanding the signal bandwidth.

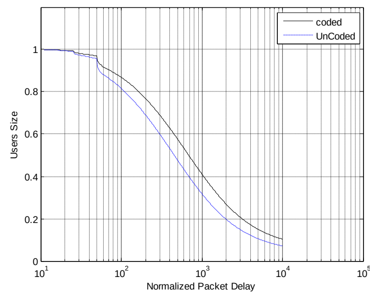

Fig.9. Normalized packet delay for MIMO system

In this Fig.9 packet delay increases means user size reduced. The coded system increases the number of signal points in the constellation to achieve the required goal over the corresponding uncoded system to compensate for the redundancy introduced by the code, and designing the trellis code so that the Euclidean distance in a sequence of transmitted symbols corresponding to paths that merge at any node in the trellis is larger than the Euclidean distance per symbol in an un coded system.

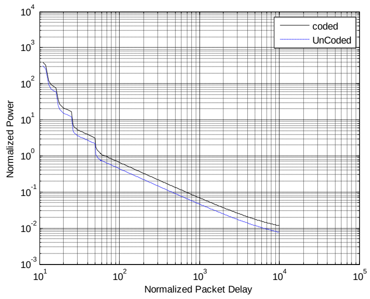

Fig.10.Normalized packet delay Vs normalized power

In this Fig.10 the normalized packet delay is 10^3 for coded system we can achieve 10^{-1} and un-coded system we can achieve $10^{-1.5}$, coded system have low power and un-coded system have high power.

In the design of trellis code, our objective is to achieve a large a free distance as possible, since this parameter is equivalent to the amount of diversity in the received signal.

5. CONCLUSION AND FUTURE SCOPE

This work has described the cost reduction and performance improvement technology for soft-output MIMO signal detector design. A substainle complexity reduction has achieved for developing on demand list size reduction method. Likelihood Generation can be aggressively optimized by performance simulation and complexity Analysis. Our system model is capable of covering a large complexity performance trade off region by adjusting a single parameter which has obtained from simulation results. By using Trellis coded modulation we can achieve better power efficiency, energy efficiency and spectral efficiency.

This system can be incorporated with any 4G and 5G system. This system can be best suitable for WLAN applications. A suitable detector can be implemented in receiver side which will give expected SNR. We can incorporate with the advantages of all Generations. It provide high data rate, Power efficiency, Energy efficiency and achieve more capacity.

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