WIRELESS CHANNEL ESTIMATION FOR MIMO-OFDM SYSTEMS USING HYBRID MESSAGE

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ABSTRACT

Nowadays, as wireless communication techniques develop, there is a lot more interest in improved data rates, system capacity, as well as the QoS. For the communication system's architecture to be successful in addressing these problems, accurate channel modeling, and exact channel state information evaluation is essential. Similarly, issues like channel fading and Doppler shifts brought on by high mobility make the channel parameter estimate situation more challenging. To represent the organized sparsity with temporal dependency characteristics of Multiple Inputs and Multiple Outputs-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) channels in the angle-delay domain, a hidden Markov model is suggested. The probabilistic model displays considerable flexibility to varied realistic propagating situations. The channel estimation challenge is then solved using a unique optimization framework called Bethe free energy (BFE) minimization, which is valid for a generic statistical model. A Hierarchical Hybrid Message Passing (HHMP) technique is provided to track dynamic spectrum variables iteratively. The suggested method may learn the sparse structure and temporal correlation of multiuser channels adaptively without knowing the hidden Markov channel parameters. Numerical simulations demonstrate how the proposed HHMP algorithm could predict angle-delay domain channels effectively while reducing iteration times or pilot overhead.In comparison to existing method, the suggested channel estimator performs better, demonstrating its effectiveness.

Keyword: *Wireless Communication, Multiple Inputs and Multiple Outputs (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Hierarchical Hybrid Message Passing (HHMP).*

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1. INTRODUCTION

Due to a rapidly growing market for wireless communication systems, it must be able to transmit signals at the needed high data rate while maintaining an incredibly high Quality of Service (QoS). Since it is anticipated to satisfy demand, the 5G wireless communication system's rising popularity has imposed significant intrigue on both business and academia. However, it is difficult to accomplish such intended goals because of the negative impact of several channel impairments such as ISI, fading route loss, attenuation, and interference on the transmitting characteristics. When using various antennas and a single channel, Multiple-In, Multiple-Out (MIMO) [1]communication transmits similar data as multiple frequencies at once. At the transmission point, the information is split into various data streams that are then reassembled by a second MIMO radio set up with the same amount of antennas on the receiving side. The receiver is built to compensate for every further noise or interruption, missing transmissions, and even the little lag in timing among each signal's receipt. By utilizing spatial multiplexing, which raises spectrum efficiency, Multiple Inputs And Multiple-Output (MIMO) network might lessen these difficulties. Orthogonal Frequency-Division Multiplexing (OFDM)[2], a method of digital transmission utilized in telecommunications to encode digital data on a various of frequencies. OFDM is now often used in wideband digital communication, and it's also used in wireless networks, digital television, power line networks, as well as DSL internet access and audio transmission. In OFDM, data is delivered simultaneously using several densely packed, orthogonal subcarrier signals having overlapped spectrums.

The foundation for demodulation is a fast Fourier transform technique. Thus, MIMO-OFDMA as a pair increases the transmission system's capacity within a given bandwidth and transmits power. The fourth generation of wireless communication (4G) is based on MIMO-OFDM [3]technology that offers several benefits including lower frequency selective fading with improved spectrum efficiency. MIMO-OFDM technology could handle high-speed data transmission. Digital medical therapy and smart medical treatment have benefited from high-speed data transfer. The medical industry has adopted technologies including big data, cloud computing, virtualization radio access network, as well as the Internet of things. Digital technology enables the widespread sharing of medical resources and the efficient control and prevention of disease. Regarding space-time coding as well as other purposes in MIMO-OFDM systems, effective Channel State Information (CSI) is necessary. The stability and dependability of system transmission are dependent on obtaining frequent and precise Channel Estimation (CE). In this study, a sparse channel estimation problem for broadband massive MIMO-OFDM systems is proposed. A hidden Markov model is presented to describe the structural sparsity with temporal dependence distinctive of large MIMO-OFDM channels in the angle-delay domain, but this probabilistic model is highly adaptable to many actual propagation scenarios. The CE challenge is then solved using a unique optimization framework known as constrained Bethe free energy (BFE) reduction, which is applicable to any statistical model. A hierarchical hybrid message passing (HHMP) is proposed within this structured conceptual framework to monitor different channel parameters iteratively.

Determining a correlation between the array of complex integers on the left as well as the array of complex numbers on the right is known as CE[4]. Based on how it is used, the estimation's precise approach may change. For a variety of system particular characteristics, the performance of the system must be maintained. Consequently, highly accurate channel estimation is needed. Owing to the complexity in accurately estimating the channel due to the use of many antennas, modified adaptive filtering is used to estimate the channel parameters. The signal could be easily changed by the parameters impacting the communication information and can obtain the desired output when it is broadcast through the estimated channel. Typically, the pilot-CE, as well as the blind-CE algorithms, are used to categorize the CE algorithm.

2. LITERATURE REVIEW

With the aid of the variable step size, the Least Mean Square/Fourth (VSSLMS/F) method, and an appropriate control variable, non-linear adaptive channel equalization for SISO channels of communication has been developed in this study. The passband input data sequence that is delivered across the nonlinear channel is created using 4-QAM modulation. Utilizing equalized output and a decision device, the output waveform is calculated. Bit Error Rate (BER) comparative data from MATLAB simulations in the presence of additive channel noise were used to assess the effectiveness of the suggested equalizer. However, the method has limited utilization of the MIMO system[7].

To suggest a method for channel estimation, the research looks into the possibilities of combining various methodologies using BERs and the Whitening rotation matrix with an adaptive filter algorithm. Wide bandwidth and higher flexibility are required, therefore effective transmission techniques are required that can adjust to the problems of wireless channel characteristics, which are always changing. Signal power decreases when it travels from the transmitter to the receiver through several pathways, or "multipath," for short. The main causes are pathloss and fading. The study showed better results with lower BERs, however, several adaptive filters were needed for estimating the schemes[8].

Over the past ten years, wireless network users have increased exponentially. The effectiveness of a dependable system has been greatly enhanced by the usage of MIMO in conjunction with OFDM systems. In a communication system, the channel estimate is crucial. By modifying the sound or the level of radio waves, bits of information are conveyed in mobile communication systems. The estimating of transmission bits is known as channel estimation. The Recursive Least Square (RLS) methodology is proposed in this study as a channel estimate method for transmitting diversity. The RLS methodology has complex system architecture even though the method has increased system performance[9].

Inter-Carrier Interference (ICI) symbols is a result of the multipath channels' introduction of frequency resolution with time-changing features in OFDM symbols in wireless communication systems The current work provides two significant block-type pilot symbols assisted Least Square (LS) and Minimum Mean Square Error (MMSE). CE techniques for multiple fading channel models are Rayleigh and Rician. The effectiveness of these estimators for the BER characteristics is analyzed, which is slowly fading channel models using various symbol translation strategies. The results show that the MMSE estimate works well for both Rayleigh and Rician channels when compared to the LS estimator. The MMSE estimator is more sophisticated than the LS estimator, though. However, the study has minimum convergence with unfixed accuracy [10].

Based on the wireless channel model for LTE-Advanced, this study suggests a New Adaptive Matching Pursuit (NAMP) algorithm and an assessment prototype. First off, prior knowledge of the sparsity level is not necessary for NAMP. To increase the effectiveness of signal reconstruction, the fixed step size is chosen next. Third, to stop the introduction of less important atoms, single entropy order determination technique is used. The simulation results are then thoroughly analyzed, showing that the proposed strategy yields lower computational complexity and, more importantly, more reliable performance. However, the approach is expensive and has higher computational complexity [11].

The study proposes new methods that approximate an unknown sparse impulse response of an LTI system and is robust to impulsive and Gaussian disturbances. They have centered on the Least-Mean Mixed-Norm (LMMN) adaptive algorithm and use the sigmoid cost function. Simulations demonstrate that the suggested sigmoid LMMN (SLMMN) algorithms, which take advantage of penalties that enforce sparsity, outperform rival algorithms in the context of sparse system identification. The method has higher performance evaluation with faster convergence. However, the sensitivity challenges of LMS as well as LMF were sustained[12].

3. EXISTING METHOD

Sparse SLMMN Algorithm

In the existing method, an efficient channel estimator for a MIMO-OFDM system based on sparse modeling for estimation of wireless channel parameters are introduces. It uses a sigmoid-based least-mean mixed norm approach to estimate Jake’s outdoor channel model. The proposed channel estimator performs better as compared to other algorithms that prove its efficacy. The performance of the system is evaluated by the Mean Square Error (MSE) and Bit Error Rate (BER) level. The weight update equation for the ZA-SLMMN method is given by: The Least-Mean Mixed-Norm (LMMN) is a linear combination of LMF and LMS, however, its effectiveness degrades in real-world settings because of impulsive interferences. However, channel estimation under impulsive noise could perform better when utilizing Sigmoid LMMN (SLMMN). Due to the sparseness of the channel, SLMMN is unable to enhance system performance since it cannot make use of the system's preexisting sparse structure. However in the existing method the number of iterations is large and it takes more time. As well as the method has several missing data.

4. PROPOSED METHOD

The study proposes an effective wireless channel parameter estimate for a MIMO OFDM system with sparse modeling. . A Hierarchical Hybrid Message Passing (HHMP) technique is provided to track dynamic spectrum variables iteratively. The suggested method may learn the sparse structure and temporal correlation of multiuser channels adaptively without knowing the hidden Markov channel parameters. Numerical simulations demonstrate how the proposed HHMP algorithm could predict angle-delay domain channels effectively while reducing iteration times or pilot overhead. In comparison to existing methods, the suggested channel estimator performs better, demonstrating its effectiveness.

4.1. Hierarchical Hybrid Message Passing

A hierarchical hybrid message passing (HHMP) methodology is devised in the angle-delay domain for evaluating time-varying sparse networks with minimal pilot latency as well as significant approximated reliability. The approach calculates the channel utilizing the first difference operator of the Lagrange function.

The suggested technique can detect the sparse structure as well as temporal correlation of multiple user channels despite understanding the hidden Markov channel parameters.

4.1.1. Lagrange Function

The HHMP approach is obtained by defining the Lagrange function with Lagrange multipliers weighting the constraints to solve the BFE minimization issue. The Lagrange function's channel transfer portion is calculated by Eq.1:

$$l_c = \sum_{dv} 2r_e\{(t_{dv}^{z,fb1}) * (e_a[av|vb1] - e_a[av|fb1])\} + \sum_{dv} 2r_e\{(t_{dv}^{z,fb2}) * (e_a[av|vb1] - e_a[av|fb2])\} + \sum_{dv} 2r_e\{(t_{dv}^{z,fb2}) * (e_a[v|vb2] - e_a[v|fb1])\} + \sum_{dv} 2r_e\{(t_{dv}^{z,fb3}) * (e_a[v|vb2] - e_a[v|fb3])\} + \sum_{dv} n_{dv}^{z,fb1}(vr[av|vb1] - vr[v|fb1]) + \sum_{dv} n_{dv}^{z,fb2}(vr[av|vb1] - vr[v|fb2]) \quad (1)$$

Here, dv is the dimensional vector, fb is the factor belief, vb is the variable belief of the corresponding parameters respectively.

The Lagrange function's state indication is given in Eq.2:

$$l_s = \sum_{dv} u_{dv}^{s,fb3}(idv)(vb3) - (fb3) + \sum_{dv} u_{dv}^{s,fb4}(idv)(vb3) - (fb4) + \sum_{dv} u_{dv}^{s,fb5}(idv)(vb3) - (fb5) \quad (2)$$

Eq.3 contains the Lagrange function's hidden value component:

$$l_h = \sum_{dv}\{2r_e\{(t_{dv}^{\theta,fb3}) * (e_a[hv|vb4 - e_a[hv|fb3])\} + 2r_e\{(t_{dv}^{\theta,fb4}) * (e_a[hv|vb4 - e_a[hv|fb4])\} + (n_{dv}^{\theta,fb3})(v[hvr|vb4] - vr[hv|fb3]) + (n_{dv}^{\theta,fb4})(vr[hv|vb4] - v[hv|fb4])\} \quad (3)$$

As a result, the entire expression of the Lagrange function is Eq.4:

$$l_b = l_c + l_s + l_h \quad (4)$$

The suggested method can detect the sparse structure as well as temporal correlation of multiple user channels without understanding the hidden Markov channel parameters. Hierarchical hybrid message forwarding is plagued by network interruptions, channel capacity loss, as well as computational complexity.

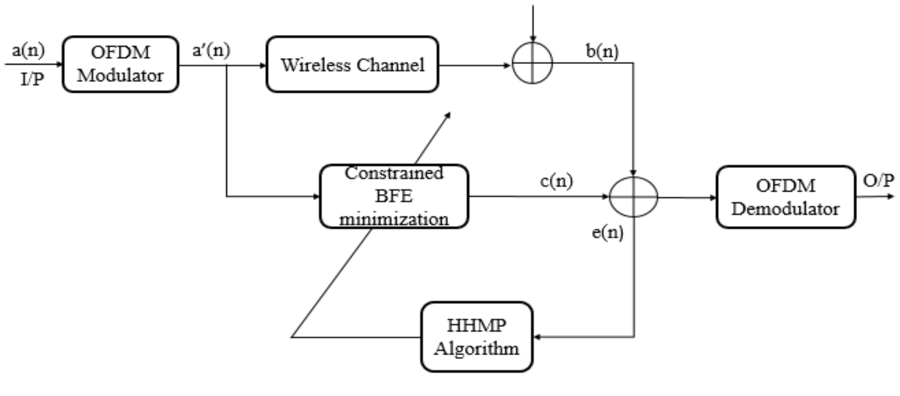

Fig -4.1: Block diagram of the proposed method

The network model's block diagram is displayed in Fig. 1. Here, hidden Markov model-based channel is employed to transmit the modulated data stream, and the MIMO-OFDM system has been selected with the $N_{\mathrm{ta}} * N_{\mathrm{ra}}$ antenna configuration. Here, N_{ta} stands for the total number of transmitting antennas, while Nr stands for the total number of receiving antennas. To retrieve the original data at the communication system's receiver end, constrained BFE minimization are utilized for channel estimation. Here, the system's input, a_{n}, is a signal with 16-QAM modulation. $n = 1,2,3 \ldots N_{\mathrm{ra}}$. The Fast Fourier Transform (FFT) operation is carried out after feeding the input of the OFDM modulator block with the transmitted signal. The following block, a channel, receives the output of the modulator block, b_n. T, a channel matrix with dimension $N_{ta} * N_{ra}$, stands in for the characteristic. For a particular Doppler spectrum, channel gain and Rayleigh's distribution can be used to characterize any fading channel. This is a signposted as given n Eq.9:

$$T_{ta,ra} = T_{ta,ra}^{x} + y * T_{ta,ra}^{y} \tag{9}$$

Here $T_{ta,ra}^{x}$is the imaginary portion of the channel impulse response with the ta^{th} transmitting antenna and $T_{ta,ra}^{y}$which is the real portionra^{th} receiving antenna.

5. RESULT AND DISCUSSION

This section presents simulations to evaluate the performance of the proposed HHMP algorithm in MIMO-OFDM systems. The time averaged normalized mean-squared error (TNMSE), which is formulated as

$$\mathrm{TNMSE} = \frac{1}{T} \sum_{t=1}^{T} \frac{\left\| \bar{\mathbf{w}}^{t} - \mathbf{w}^{t} \right\|^{2}}{\left\| \mathbf{w}^{t} \right\|^{2}}$$

is taken as the primary performance metric in all of our simulations.

- **LMMSE:** This algorithm performs the linear minimum mean square error estimation on angle-delay domain channels with knowing accurate statistical information.
- **HHMP without temporal correlation:** This algorithm is the HHMP under the assumption that channels at different time slots are mutually independent.

Table -5.1: Simulation parameters of MIMO-OFDM system

BS antenna number M	2
Subcarrier number N	7
Subcarrier spacing	15kHz
Symbol length	71.4 μs
Path number N_i	6

5.1 Effect of SNR

Fig.5.1 shows the TNMSE performance comparisons between different algorithms versus SNR under three typical propagation scenarios. We can find out that, in all the considered scenarios, both two kinds of HHMP achieve remarkable performance gain over the LMMSE and LS over known arrival delay. Moreover, it can be observed that the HHMP with temporal correlation obtains much better performance than the HHMP without temporal correlation, which shows that considering the temporal correlation can further improve the channel estimation performance of HHMP. In particular, the performance of the HHMP with temporal correlation approaches that of the LMMSE with knowing accurate statistical information in the low SNR regime. This demonstrates that, by exploiting the structured sparsity and temporal correlation, the proposed HHMP can effectively improve channel estimation accuracy

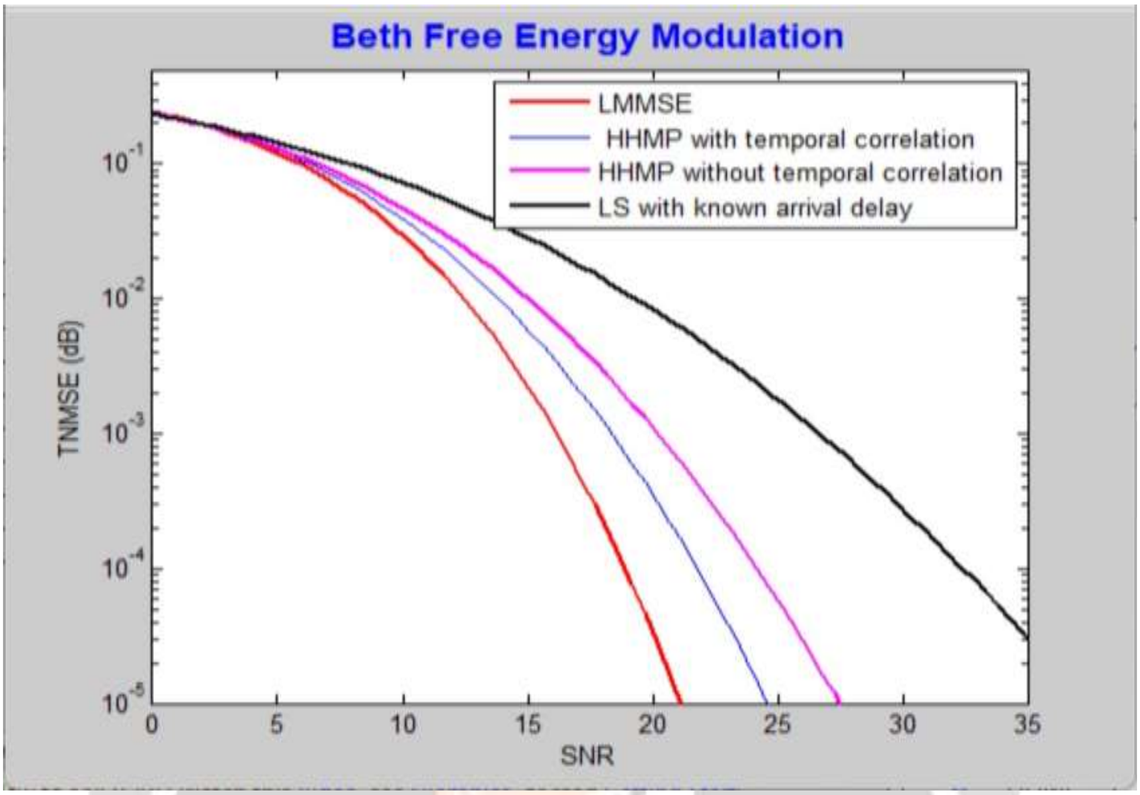

Fig -5.1: TNMSE vs SNR for the algorithms

5.2 Comparison for HHMP and SLMMN

Fig 5.2 shows the energy comparison chart between the existing system and the proposed system i.e. HHMP and SLMMN. From this it can be known that the proposed HHMP algorithm performs better than existing SLMMN algorithm.

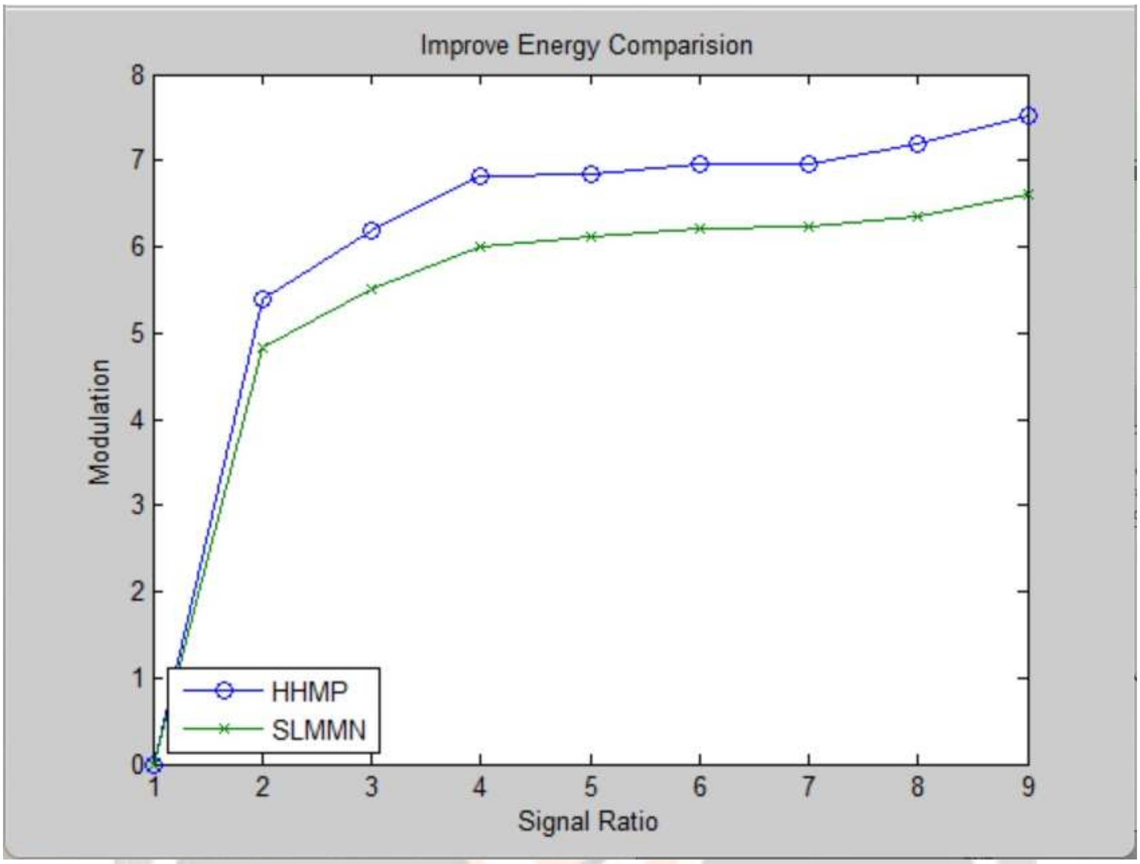

Fig -5.2: Energy comparison for HHMP and SLMMN

The suggested method can detect the sparse structure as well as temporal correlation of multiple user channels without understanding the hidden Markov channel parameters. The proposed HHMP can reduce iteration time compared to any other algorithms. It also Increases its growing popularity with 5G wireless communication systems. The HHMP can Obtains high channel estimation accuracy. Also it has fast convergence speed with low pilot overhead

6. CONCLUSION

To monitor the impulse response of the MIMO wireless channel, which has numerous antennas and is subject to issues like noise effects, effective adaptive modeling is required. A Hierarchical Hybrid Message Passing (HHMP) technique is provided to track dynamic spectrum variables iteratively. The suggested method may learn the sparse structure and temporal correlation of multiuser channels adaptively without knowing the hidden Markov channel parameters. Numerical simulations demonstrate how the proposed HHMP algorithm could predict angle-delay domain channels effectively while reducing iteration times or pilot overhead. Furthermore, its straightforward design and low computing complexity make it the perfect real-world channel estimator for the next wireless systems. It is demonstrated that the suggested algorithms obtain a reduced steady-state mis-adjustment compared to other techniques and are capable of overcoming impulsive noise as well as efficiently estimating the network with varying levels of sparsity.

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