VOL. 12, NO. 21, NOVEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ICI CANCELLATION USING NORMALISED MINIMUM MEAN SQUARE ERROR IN MIMO-OFDM SYSTEMS

R. Santhakumar and N. Amutha Prabha
School of Electrical Engineering, VIT University, Vellore, India
E-Mail: santhakumar@vit.ac.in

ABSTRACT

Today's world emerges with wireless communication technology. The network performance can be improved by using efficient signalling and receiver techniques to increases the data rate. As the data rate increases, the occurrence off channel interference is high. The channel estimator is preferred to detect and reduce the interference. Multi Input Multi Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM) is implemented to enhance the high speed data transmission and to achieve high spectral efficiency. During signal transmission, the performance degradation caused due to inter carrier interference (ICI). To overcome the ICI, Normalized Minimum Mean Square Error (NMMSE) channel estimator provides high signal receiver rate and low bit error rate with less delay. The performance achievable rate increases and reduces channel attenuation. It also proved that the channel overhead is low due to high bandwidth at receiving end compared with the conventional estimators.

Keywords: MIMO-OFDM, channel estimator, adaptive congestion filter, ICI, NMMSE.

1. INTRODUCTION

Wireless communication systems have been under major development in the upcoming wireless technology. The requirements became huge and it is shifted from the low data rate voice services to real time video transmissions. Higher data rates have become more essential and the development towards more advanced wireless systems to utilise the available limited spectrum is still on-going based on its applications. Without going for additional bandwidth the data throughput significantly increased by using MIMO technology. Multiple antennas are currently included in many of the wireless standards to achieve the required data rates. But the complexity of signal processing algorithms gets increased in the receiver side and poses challenges in developing receiver algorithms.

The objective is to develop receiver algorithms in order to meet high data rateswith low computational complexity requirements of the forthcoming wireless systems. Moreover, while evaluating the aptness of different algorithms for the wireless systems many of the system characteristics are considered. The work in the paper concentrates on signal detection, channel estimation and interference mitigation algorithms and their implementation requirements.

Orthogonality is a unique property of OFDM and it is a type of Frequency Division Multiplexing (FDM) method which can be used as a digital multi-carrier modulation technique. The orthogonality among the subcarriers is obtained by splitting the channel into intimately spaced orthogonal sub-channels or subcarriers. This reduces the carrier interference to a larger extent. MIMO-OFDM systems offer reliable data communication and find their applications in the modern wireless communication systems like IEEE 802.11n, 4G and LTE. The bottleneck to the MIMO-OFDM systems is the estimation of the Channel State Information (CSI). The channel state information can be estimated with the help of any one of the Training Based, Semi blind and Blind Channel estimation algorithms.

Literally various techniques for channel estimation has been implemented and the channel estimation can be categorised under Training based channel estimation, Blind channel estimation and semi-blind channel estimation. Training based estimation can be processed by either block type pilots or comb type pilots and this technique is suitable for slow fading channels. Blind channel estimation is carried out by estimating channels statistical information and properties of their transmitted signal. Semi-blind is the hybrid combination of training based and blind channel estimation. This utilises pilot carriers and other properties of channel.

For a highly mobile user in long-term evolution (LTE) systems, an [1] Iterative channel estimation and ICI cancellation method is proposed. By using pilot symbols, data symbols and Doppler spread information at the receiver is estimated in this iterative method. The channel estimates are attained by make use of a Least-Square (LS) method, a simplified Parallel Interference Cancellation (PIC) scheme coupled with Decision Statistical Combining (DSC) are used to cancel the ICI. The data symbol detection gets improved by using this algorithm and also the data symbols are further refined for better channel estimates.

Channel estimator for multipath multi-cell massive Multi Input Multi Output –Time Division Duplex (MIMO TDD) systems [2] with pilot contamination was proposed. Minimum mean square error (MMSE) channel estimators perform to a large extent than LS estimators as these estimators present low performance under moderate to strong pilot contamination. The minimum variance unbiased estimator is observed in the signal to estimate the users and their used channels. The proposed estimator substitutes the combined interference, i.e., the summation of the cross-cell large scale coefficients and noise power term in the ideal MMSE estimator.

ARPN Journal of Engineering and Applied Sciences

Orthogonal Frequency Division Multiple Access (OFDMA) is a channel estimation technique proposed. Here the effects of coarse timing error and multipath propagation were considered jointly. An optimistic scenario alone considered in many conventional approaches. The timing synchronization is perfect and each of the channel delays is an integer number of system samples. But in realistic scenario, the timing offset and echoes delay are not multiples of sampling period. A novel iterative channel estimation technique [3] was proposed. The fractional timing error and non-sample spaced echo delays are considered hence CSI is not required. Orthogonality is destroyed between subcarriers and leads to ICI in OFDM. In order to provide accurate channel estimates at high Doppler spreads, ICI equalisation [4] algorithm was proposed. The ICI estimator models the channel estimation using Basis Expansion Model (BEM) and the subsequent equalization is evaluated in a Universal Mobile Telecommunications System (UMTS) long term evolution link simulator. Typical OFDM channel estimators calculate approximately the main diagonal elements of the frequency domain channel matrix.

The uplink channel estimation in massive MIMO-OFDM systems is done with frequency selective channels. An efficient Distributed Minimum Mean Square Error (DMMSE) algorithm [5] was proposed to achieve nearly optimal channel estimates at low complexity by makes use of the strong spatial correlation among antenna array elements. Through repetitive sharing of information among neighbouring array of elements the MMSE problem is reduced. A channel estimation algorithm for multi-antenna Radio Frequency (RF) energy transfer system [6] based on the received power measurements was proposed. Here energy beam-forming technique is used for resolving low energy transfer efficiency problem by estimating the channel gains between transmit and receive antennas. Receiver measures the received RF power signal and send it back to the transmitter but this leads to linear estimation problem. This problem can be solved by using least squares method and the Kalman filter-based algorithm.

In wireless systems, Direct Spread Spectrum (DSS) gives the advantage of good receiver sensitivity because of spreading gain it offers. The RF dynamic range of the receiver is defined as the range of signal strength values for which receiver works without packet loss. Because of variations in power or any other wireless channel effect received signal power varies. The received signal power can vary with a dynamic range of 70 dB to 80 dB in worst cases depending on the distance between a transmitter and a receiver. RSSI indexed Look up Table (LUT) [7] was implemented based on the approach of automatic gain control.

The improvements of spectral and energy efficiencies relies on the accuracy of the CSI in distributed MIMO. An effective pilot power adaptation method [8] was proposed to improve the accuracy of CSI and to provide optimisation in a single-cell D-MIMO system with multiple users served in orthogonal resources. Due to the mutual coupling constraints computational complexity increases and hence dual decomposition technique is established to decouple the constraints and to reduce the complexity. A novel block coding modulation scheme namely [9] Spatial Complementary Code Keying Modulation (SCCKM) was proposed. Here the input sequence is modulated using complementary code keying (CCK) modulation and spread across the transmitter antennas in MIMO system exploiting OFDM. At receiver, zero forcing equalization is applied to the OFDM modulated data to alleviate the effect of the multipath fast fading channel and then followed by maximum likelihood (ML) detection to retrieve the input sequence.

The quality of transmit pre-coding to control multiuser interference is degraded due to the coarse knowledge of CSI at the transmitter. Hence channel estimation technique employing reliable soft symbols to improve the channel estimation and subsequent detection quality of MU-MIMO [10] systems was proposed. In order to jointly estimate the channel and data symbols, the expectation maximization (EM) algorithm is employed where the channel estimation and data decoding are performed iteratively. Distributed Channel Estimation and Pilot Contamination (DCEPC) [11] analysis was proposed for finding reliable data carriers and to reduce carrier interference in the data. Data aided estimation technique is used to determine the reliable data carriers and distributed minimum mean square error algorithm is proposed to achieve optimal channel estimates using spatial correlation among antenna array elements. However this technique has large computational cost and channel overheads are high because of multi-cell massive MIMO-OFDM wireless system.

2. SYSTEM MODEL

Efficient modulation techniques are mandate in order to modulate higher rate single data stream into different lower rate data streams for providing data to multiple users. Block diagram of transmitter and receiver structure of MIMO-OFDM System is illustrated in figure.1 Input signals of OFDM System with multiple inputs $x(t_1)$, $x(t_2)$, $x(t_3)$,..., $x(t_n)$ are transmitted and $y(t_1)$, $y(t_2)$,..., $y(t_n)$ are the signal received.For efficient communication, channel encoder and decoder are included. FFT technique is used to convert the original signal to a representation of frequency domain. The mean square error is derived for all the channels in order to estimate the good channel based on the channel gain.The frequency separation makes the channel orthogonal using OFDM as they do not interfere with each other even though they are combined together. Therefore the spectrum can be shared among multiple users at the same time.

ARPN Journal of Engineering and Applied Sciences

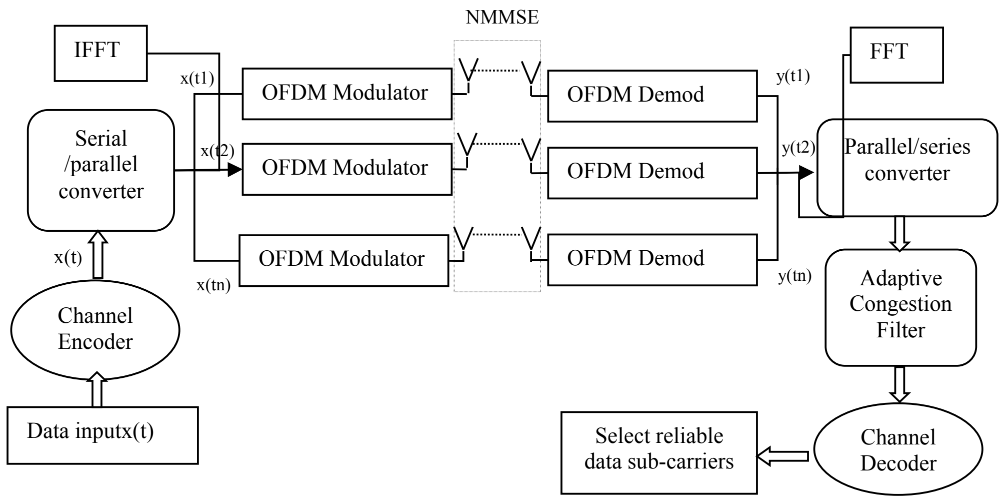

Figure-1. Block diagram for MIMO-OFDM for channel estimation.

2.1 Proposed NMMSE model

The objective is to propose the channel estimation scheme with high data delivery rates which in turn reduces ICI. The current standard of wireless communication is 3rd Generation Partnership Project (3GPP), Wi-Max, Wi-Fi, etc., It supports technologies such as different MIMO schemes, Adaptive Modulation (AM) and Hybrid Automated Repeat Request (H-ARQ) that allow to transmit data with high spectral efficiency. LTE supports bandwidth ranges 1.4MHz -20MHz, corresponding to a number of data subcarriers. The subcarrier spacing is fixed to 15 kHz. The duration of an LTE sub-frame is 1ms. The Carrier sensing range is 8.91754e-10.

a) Channel Estimation using Normalised Minimum Mean Square Error (NMMSE)

In communication network massive MIMO are placed to serve multiple users in same time-frequency resource. The channel estimator uses the normalised minimum mean square errorfor the estimation of signal. The error ratio is estimated among all the sub-channels $\chi_c$so that the successful transmission of data rate is obtained. The channel gains between sender and receiver antenna nodes should be estimatedas well. The normalised minimum mean square error for the good channel estimation is obtained through using linear system model,

$$\vec{h}\, r = R_{tap}^{-1} + (A^H R^{-1} A)^{-1} (A^H R^{-1} Yr) \quad (1)$$

$$NMMSE = recd\ Re\,(R_{tap}^{-1} + (A^H R^{-1} A)^{-1}) \quad (2)$$

The received error rate for single channel estimation using NMMSE is obtained by $\vec{h}\,r$ and the overall summation of vector error rate using NMMSE for all sub-channels can be obtained using equation (2).

This vector error rate is identified to determine the best channel among the sub-channels in order to achieve higher spectral efficiency. The received error rate is compared with the certain receiver sensitivity threshold levelΥ_T.

$$NMMSE(\forall h_r) = X \sum_{r=1}^{R} NMMSE = RL / \zeta K \quad (3)$$

Algorithm for NMMSE

Step 1: Split the channel in to several sub-channels χ_c
Step 2: Estimate for good channel among the sub-channels with minimum error rate $\vec{h}_r$.
Step 3: Received error rate NMMSE with Υ_T
Step 4: Maximum error rate is subjected to ACF
Step 5: Filtering repetitive information which leads channel overhead $\Theta_c$using EPCF.
Step 6: Repeat step 2
Step 7: Compute RSSI
Step 8: Find a set of most reliable data carriers
Step 9: Transmit Data with high speed for multi-user at same time-frequency

b) Adaptive congestion filtering

Traffic jam inside the network leads to packet latency and low throughput. Traffic in the network is caused due to high congestion, repetitive information and low cache size. End point congestion filtering technique is used to filter the repetitive data at the receiver end. High congestion rates are mostly occurred on the receiver side of the antenna and this reduces the speed of data transmission rate. To avoid this low speed and high congested scenario, EPCF algorithm is added at the end. This algorithm is computed for high speed data transmission in fast routers. ICI can be avoided by using congestion filter thus it prevents the congested packets spreading over the network.

ARPN Journal of Engineering and Applied Sciences

Data exceeds the channel capacity causes congestion in the data path and it can be filtered by clearing the cache size of data storage and reducing the redundancies. The repetitive information is identified by the node sequence id and the transmit and receive filters are employed in each transmitter and receiver antenna. The filtered channel response can be identified using the equation

$$h_{n_t n_r},k[t] = g_t[t] * h_{n_t n_r},k[t] * g_r[t] \quad (4)$$

where

$g_t[t]$ → baseband transmit filter
$g_r[t]$ → baseband receive filter

The overall filtered channel can be represented as

$$h_{n_t n_r},k(m) = [h_{n_t n_r},k(1),\ h_{n_t n_r},k(2),...,\ h_{n_t n_r},k(M)]^T \quad (5)$$

where T → Baud rate and M → Number of channels.

The data derived from the sub-carriers after processing the filtering mechanism is then estimated for its signal quality. The instantaneous CSI is obtained through the baseband transmit and receive filter.

c) Received Signal Strength Indicator (RSSI)

The Received signals from the estimated channels are measured for the data accuracy and efficiency. RSSI indicates the achieved signal level of all the channels. The achieved data rate for every channel is evaluated through the simulation. Data is splitte into multiple sub-channels across different paths in order to serve multi-node communication.

3. PERFORMANCE MEASURES

The simulation analysis of channel estimation for different channel conditions is conducted using the Network simulator (NS2) tool and the performance is measured. The parameters used for the simulation of the channel estimation are tabulated in Table-1.

The traffic is handled using the traffic model constant bit rate (CBR). The radio waves are propagated by using the propagation model two ray ground. The nodes in the network receives signal from all direction by using the Omni directional antenna. The performance of the NMMSE for high speed data transmission is evaluated by the parameters signal receives, bit error rate, average delay and throughput.

A. Signal received

The signal received ratio is the rate of successfully received data to the total time. It can be calculated through the equation (5),

$$Signal\ rate = \frac{\sum_0^n signal\ Received}{No\ of\ channels} \quad (6)$$

B. Bit Error Rate (BER)

Bit error rate is determined for the quality of digital transmission. BER is the percentage of bits that have errors relative to the total number of bits sent over a communication channel. Bit error rate is usually calculated using the equation (7)

$$BER = \frac{No.of\ errors}{Total\ no\ of\ bits\ sent}\ \forall\ channels \quad (7)$$

C. Delay

The delay is defined as the time difference between the received signal and the sent signal. It is shown in the equation

$$Average\ Delay = \frac{1}{n}\left(\sum_0^n Pkt\ Recvd\ Time - Pkt\ Sent\ Time\right) \quad (8)$$

D. Signal to noise ratio vs achievable rate

Signal to noise ratio is defined as the ratio of signal power i.e. desired data signal to amplitude of noise power in a transmission channel. It is a measure of achievable signal strength relative to the background White Gaussian noise added to the original signal.

E. Overhead

Data overhead is nothing but creation of congestion in the receiver side of the network due to continuous data flow by the transmitter side and reduces the overall transmission speed. Channel overheads are caused due to low processing power or minimum bandwidth on the receiver side.

4. RESULT AND SIMULATION

The parameters used for simulation are indicated in the Table-1. The Figure-2 shows that the signal received rate for the existing methods DCEPC and DMMSE and the proposed scheme NMMSE. NMMSE has high signal received rate comparatively and this proved for high speed data transmission. Channel 3 has high signal received rate.

Table-1. Simulation parameters.

Parameter	Value
Channel Type	Wireless Channel
Simulation Time	50 s
Number of nodes	20
Traffic model	CBR
Antenna Model	Omni Antenna
Network size	600×600
Transmission range	200m
Mobility Model	Random way point

ARPN Journal of Engineering and Applied Sciences

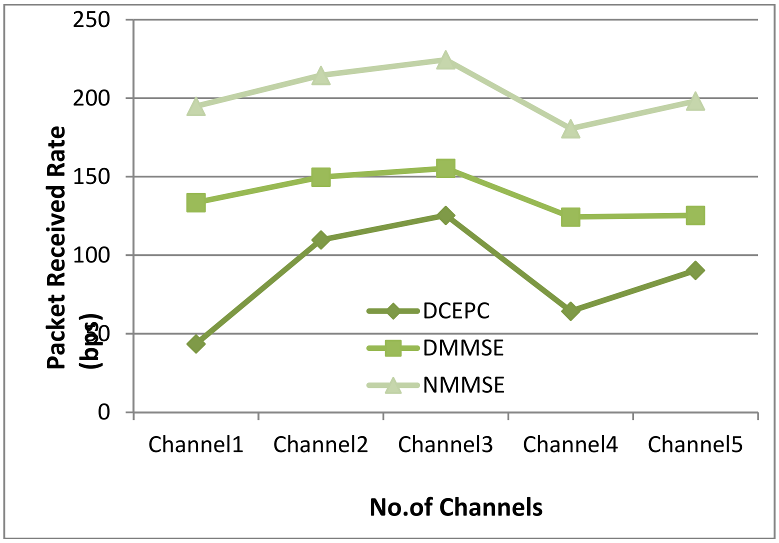

Figure-2. Signal received rate.

BER for both the proposed and existing schemes are shown in the Figure-3. NMMSE have lower bit error rate compared to the existing methods. BER is calculated to quantify the channel by counting the error rate in the data string.

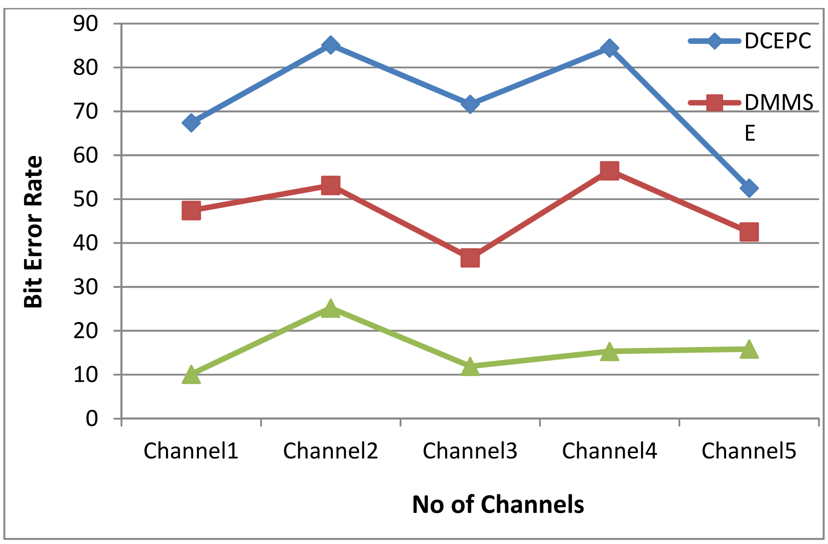

Figure-3. Bit error rate.

The Figure-4 shows the average delay for NMMSE is better compared to DMMSE and DCEPC. The obtained delay (period of time taken for processing) values for all communication channel is lower.

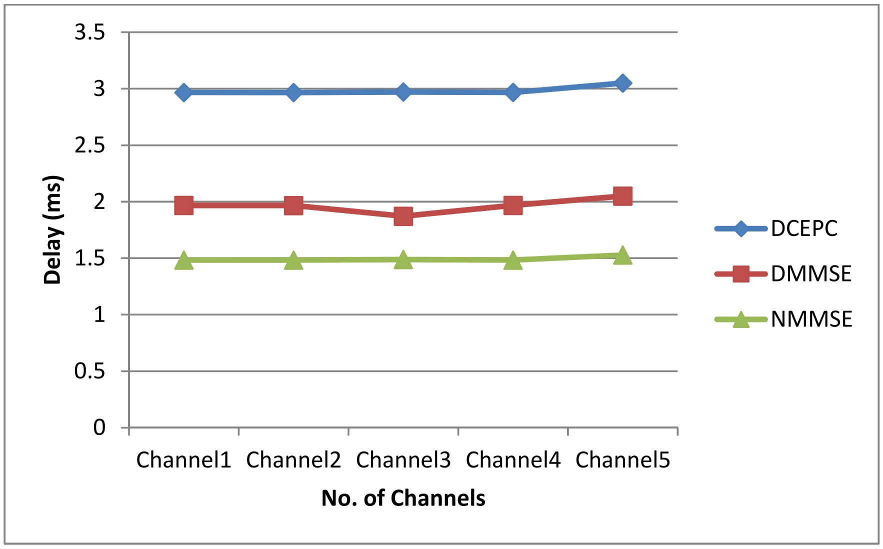

Figure-4. Delay.

The Figure-5 shows the signal to noise ratio for both the proposed and existing distributed channel estimation scheme. The performance of achievable rate gets increased when the noise contamination is lower in the received signal and this is achieved by implementing adaptive congestion filtering process with normalised function in order to reduce the channel attenuation and noise ratio.

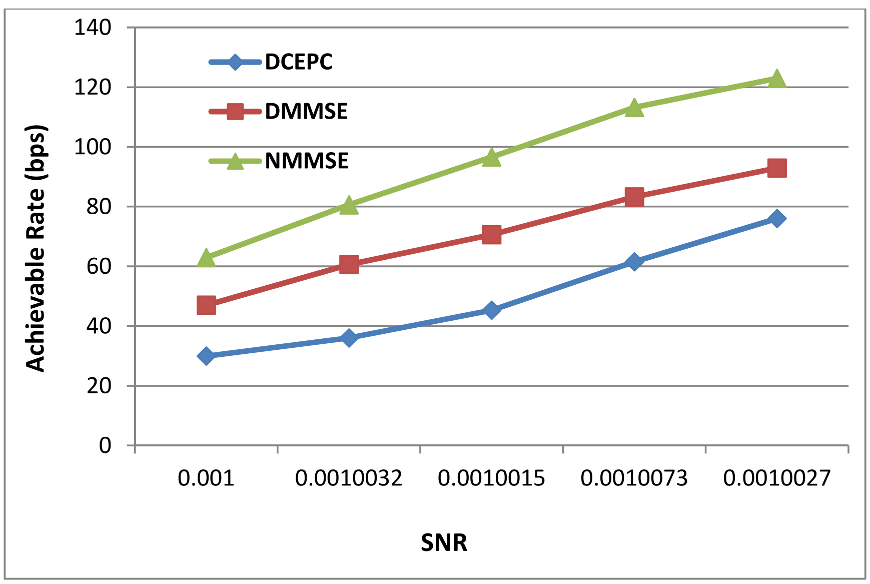

Figure-5. Signal to noise ratio vs achievable rate

The channel overhead in NMMSE is low due to high bandwidth on receiver side. The RSSI is evaluated for all the channels to obtain lower channel overhead as in Figure-6.

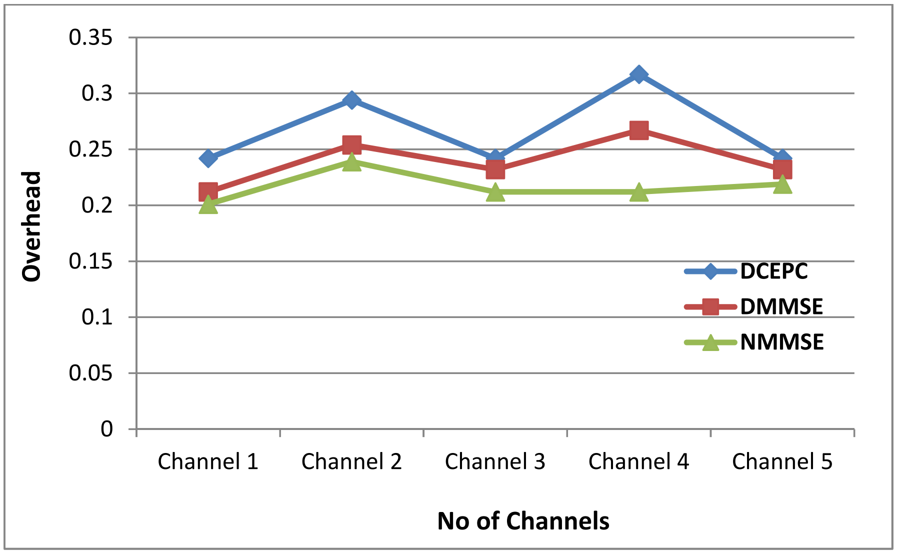

Figure-6. Channel overheads.

5. CONCLUSIONS

A novel normalised MMSE algorithm for MIMO-OFDM channel estimation is proposed that relies on synchronization among mobile nodes. To overcome the channel overheads adaptive congestion filtering technique is used so that the repetitive data that uses the limited spectral frequency can be avoided. The channels are splitter and the sub-channels are estimated using normalised minimum mean square and the higher achievable data rate is taken for high speed data transmission in wireless communication. This technique can be efficiently used for the LTE applications and upcoming 5G wireless networks. Finally simulation results are evaluated for the achievable rates in the presence of channel estimation error.

REFERENCES

[1] Aboutorab Neda, Wibowo Hardjawana and Branka Vucetic. 2012. A new iterative Doppler-assisted channel estimation joint with parallel ICI cancellation for high-mobility MIMO-OFDM systems. IEEE Transactions on Vehicular Technology. 61(4): 1577-1589.

[2] de Figueiredo, Felipe AP, Fabiano S. Mathilde, Fabricio P. Santos, Fabbryccio ACM Cardoso and Gustavo Fraidenraich. 2016. On channel estimation for massive MIMO with pilot contamination and multipath fading channels. In Communications (LATINCOM), 2016 8th IEEE Latin-American Conference on, pp. 1-4. IEEE.

[3] Nguyen Tung T., Brian Berscheid, Ha H. Nguyen and J. Eric Salt. 2017. A Novel Iterative OFDMA Channel Estimation Technique for DOCSIS 3.1 Uplink Channels. IEEE Transactions on Broadcasting.

[4] Simko Michal, Christian Mehlfuhrer, Thomas Zemen and Markus Rupp. 2011. Inter-carrier interference estimation in MIMO OFDM systems with arbitrary pilot structure. In Vehicular Technology Conference (VTC Spring), 2011 IEEE 73rd, pp. 1-5. IEEE.

[5] Zaib Alam, Mudassir Masood, Anum Ali, Weiyu Xu and Tareq Y. Al-Naffouri. 2016. Distributed Channel Estimation and Pilot Contamination Analysis for Massive MIMO-OFDM Systems. IEEE Transactions on Communications. 64(11): 4607-4621.

[6] Choi Kae Won, Dong in Kim and Min Young Chung. 2016. Received Power-Based Channel Estimation for Energy Beamforming in Multiple-Antenna RF Energy Transfer System. IEEE Transactions on Signal Processing.

[7] Boyapati Hari Krishna, Rajeev Kumar Elubudi, Sailaja Ungati and Manoj Jain. 2016. Implementation of RSSI indexed look up table based AGC for improved dynamic range of DSSS based wireless rf transceivers. In Next Generation Computing Technologies (NGCT), 2016 2nd International Conference on, pp. 373-377. IEEE.

[8] Zhang Yingjie, Wei Feng and Ning Ge. 2017. Pilot power adaptation for tomographic channel estimation in distributed MIMO systems. IET Communications 11, no. 1 (2017): 112-118.

[9] Jafari Amir H. and Timothy O'Farrell. 2015. Performance Evaluation of Spatial Complementary Code Keying Modulation in MIMO Systems. In Vehicular Technology Conference (VTC Spring), 2015 IEEE 81st, pp. 1-5. IEEE.

[10] Sun Yong, Zixiang Xiong and Xiaodong Wang. 2016. EM-based iterative receiver design with carrier-frequency offset estimation for MIMO OFDM systems. IEEE Transactions on Communications. 53(4): 581-586.

[11] Zaib Alam, Mudassir Masood, Anum Ali, Weiyu Xu and Tareq Y. Al-Naffouri. 2016. Distributed Channel Estimation and Pilot Contamination Analysis for Massive MIMO-OFDM Systems. IEEE Transactions on Communications. 64(11): 4607-4621.