International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 4, July-Aug-2020, ISSN (Online): 2395-566X

Analysis of Channel Sensing Technique: A New Approach to Channel Estimating in Mobile OFDM System

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***Abstract*-To analyse the performance of orthogonal matching pursuit (OMP)-based compressed channel estimation (CCE) with deterministic pilot patterns, we propose a mathematical framework by defining four normalized mean-square-errors (NMSEs): the total NMSE (NMSET), the NMSE on dominant channel components (NMSED), the NMSE caused by 'lost errors' (NMSEL) and the NMSE caused by 'false alarms' (NMSE F).Then, we derive a formula with a closed form for evaluating the upper-bound of NMSED in the ideal case (NMSED;UB). Using the proposed analytical framework, the main findings include the NMSE D;UB is determined by the following four parameters: the deterministic pilot pattern, the maximum Doppler shift, the number of dominant multipath components and the SNR the NMSE D;UB can be viewed as an approximation of practical NMSE T in case that the probability of the successes of OMP exceeds a certain threshold, in which both NMSE L and NMSEF are neglect able; using linear regression models, the practical bit-error-rate performance also can be predicted well based on the proposed NMSED,UB. We believe that the proposed framework provides a useful tool for adaptively optimizing pilot parameters according to rapidly time-varying channel conditions when using OMP based CCEs in mobile OFDM systems.**

***Keywords*- SNR, NMSE D , Rapidly time-varying channel**

I.INTRODUCTION

Wireless data communications allows wireless networking between desktop computers, laptops, tablet computers, cell phones and other related devices. The various available technologies differ in local availability, coverage range and performance, and in some circumstances users employ multiple connection types and switch between them using connection manager software or a mobile VPN to handle the multiple connections as a secure, single virtual network. Supporting technologies include: Wi-Fi is a wireless local area network that enables portable computing devices to connect easily with other devices, peripheries, and the Internet. Standardized as IEEE 802.11 a, b, g, n, Wi-Fi approaches speeds of some types of wired Ethernet.

Wi-Fi has become the de facto standard for access in private homes, within offices, and at public hotspots. Some businesses charge customers a monthly fee for service, while others have begun offering it free in an effort to increase the sales of their goods. Orthogonal Frequency Division Multiplexing (OFDM) based access/multiplexing schemes are used in wireless applications such as Wireless Personal Area Network (WPAN), Wireless Local Area Network (WLAN), Wireless Metropolitan Area Network (WMAN), high quality digital radio (Digital Audio Broadcasting (DAB) and television broadcasting (Digital Video Broadcasting (DVB)) [1]. It is being considered for IEEE 802.20, IEEE 802.16 and 3GPP-LTE [2] systems.

OFDM will remain as the key enabling technology for achieving higher data rates in wireless packet based communication systems in the next few years to come [3]. Its extensions with time frequency domain spreading are under investigation for use in future wireless systems [4]. OFDM tackles the frequency selective wireless fading channel effectively by converting a wide band signal into a set of parallel narrow band signals such that each stream of narrow band signal experiences flat fading. With the use of cyclic prefix to eliminate Inter Symbol Interference (ISI), there is need for only a simple one tap equalizer at the OFDM receiver. OFDM brings in unparalleled gains in bandwidth savings, which leads to very high spectral efficiency. These properties make OFDM systems extremely attractive transmission technologies for wireless scenarios.

OFDM was initially used in military systems, such as KINEPLEX in 1958, KATHRYN in 1967, and ANDEFT in 1968 [5]. A bank of conventional transmitters/receivers with overlapping spectra was used in these systems. In 1971, Weinstein and Ebert's proposal to use the Discrete

Fourier Transform (DFT) to modulate/demodulate all the sub-carriers, with a single oscillator [6] was a pioneering effort. With its implementation via FFT finally OFDM was realizable in commercial communication system. It started with a number of wire–line standards. High bit-rate Digital Subcarrier Lines (HDSL) [7], Asynchronous Digital Subscriber Line (ADSL)[8], and Very High speed Digital Subscriber Line (VDSL)[8] were a sequence of standards which led to throughput of up to 100Mb/s. Then it was introduced into the wireless arena through DAB[9] and WLAN [10, 11]. Then came DVB[12, 13] around 2004. In the WMAN application, OFDM is considered for the Worldwide Interoperability for Microwave Access (WiMAX) implementation via the IEEE 802.16d,a,e [14, 15] standards. It is also being considered for the 3GPP Long Term Evolution, which in under development.

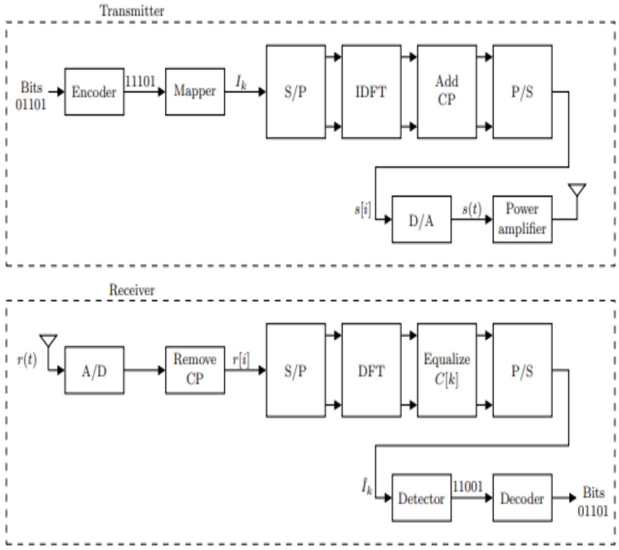

Fig. 1 OFDM system diagram.

II. RELATED WORK

Orthogonal frequency-division multiplexing (OFDM) is widely adopted for providing reliable and high-data-rate communication in high-speed train (HST) systems. In the existing system we have used Low Coherence Pilot Pattern Design algorithm. The channel estimator used is MSE- mean square error. In this paper, we consider a typical HST communication system and show that the ICI caused by large Doppler shifts can be mitigated by exploiting the train position information and the sparsity of the basis expansion model (BEM)-based channel model. The proposed optimal pilot pattern is independent of the number of receive antennas, the Doppler shifts, train position, or train speed. Simulation results confirm the effectiveness of the proposed scheme in high-mobility environments.We develop a systematic approach to wireless channel estimation, which is aimed at channels varying on the scale of a single OFDM symbol duration. From the pilot information, we compute the Fourier coefficients of the channel taps, and then the BEM coefficients of the taps. We propose a pilot-aided method for channel estimation in OFDM systems, which explicitly separates the computation of the Fourier coefficients of the channel taps, and a subsequent computation of the BEM coefficients of the channel taps. · We formulate a fast and accurate algorithm for approximate computation of the Fourier coefficients of the channel taps from the receive signal using an FDKD-type pilot placement.

Yanrong Zhao et.al (2020) Channel estimation is a well-known challenge for wireless orthogonal frequency division multiplexing (OFDM) communication systems with massive antennas on high speed rails (HSRs). This paper investigates this problem and design two practicable uplink and downlink channel estimators for orthogonal frequency division multiplexing (OFDM) communication systems with massive antenna arrays at base station on HSRs. Specifically, we first use pilots to estimate the initial angle of arrival (AoA) and channel gain information of each uplink path through discrete Fourier transform (DFT), and then refine the estimates via the angle rotation technique and suggested pilot design. Based on the uplink angel estimation, we design a new downlink channel estimator for frequency division duplexing (FDD) systems. Additionally, we derive the Cramér-Rao lower bounds (CRLBs) of the AoA and channel gain estimates. Finally, numerical results are provided to corroborate our proposed studies.

Haihan Li et.al (2019) In this paper, the statistical properties of parameters of each path in wireless channel models are analyzed to prove that there is the static part in channel state information (CSI) which can be extracted from huge amounts of CSI data. Based on the analysis, the concept of the Tomographic Channel Model (TCM) is presented. With cluster algorithms, the static CSI database can be built in an off-line manner. The static CSI database can provide prior information to help pilot design to reduce overhead and improve accuracy in channel estimation. A new CSI prediction method and a new channel estimation method between different frequency bands are introduced based on the static CSI database. Using measurement data, the performance of the new channel prediction method is compared with that of the Auto Regression (AR) predictor. The results indicate that the prediction range of the new method is better than that of the AR method and the new method can predict with fewer pilot symbols. Using measurement data, the new channel estimation method between different frequency bands can estimate the CSI of one frequency band based on known CSI of another frequency band without any feedback.

III. PRAPOSED

1. OFDM SYSTEM MODEL: OFDM system model The baseband model for a typical OFDM wireless communication system, is shown in Fig. 1. The binary data to be transmitted is first mapped using digital modulation schemes like binary phase shift keying (BPSK), quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM). The modulated data symbols are converted from serial to parallel form. One column of data symbols forms a single OFDM symbol. Multiple OFDM symbols form the OFDM grid. Each row of data symbols is termed as subcarrier. If one OFDM symbol comprises of data symbols, the number of subcarriers are N.

The pilot insertion block is used to transmit known data, which is optional. Pilots are known data symbols, which assist in estimating the channel at the receiver. Each OFDM symbol is converted to time domain using an inverse DFT (IDFT) operation. A cyclic prefix (CP) is attached at the beginning of each time domain OFDM symbol to counteract the distortion caused by ISI in the channel. CP is the replica of last part of any given OFDM symbol. Instead of CP, a Zero Padding (ZP) can also be used. However, CP is more effective than ZP in combating ISI[10]. After the insertion of CP, the resultant OFDM symbols are converted to serial form and are transmitted through a wireless channel. The channel may be of flat fading type or frequency selective fading type. In any case, at the receiver, the presence of additive white Gaussian noise (AWGN) is inherent. In this paper, perfect synchronization is assumed between the transmitter and receiver. Imperfect timing or frequency synchronization causes reduced BER performance of any given channel estimation technique. In practice, timing synchronization can be achieved by exploiting the structure of CP[11].

IV. RESULT DISCUSSION

Channel estimation forms the heart of any orthogonal frequency division multiplexing (OFDM) based wireless communication receiver. Frequency domain pilot aided channel estimation techniques are either least squares (LS) based or minimum mean square error (MMSE) based. LS based techniques are computationally less complex. Unlike MMSE ones, they do not require a priori knowledge of channel statistics (KCS). However, the mean square error (MSE) performance of the channel estimator incorporating MMSE based techniques is better compared to that obtained with the incorporation of LS based techniques.

To enhance the MSE performance using LS based techniques, a variety of demising strategies have been developed in the literature, which are applied on the LS estimated channel impulse response (CIR). The advantage of delousing threshold based LS techniques is that, they do not require KCS but still render near optimal MMSE performance similar to MMSE based techniques. In this paper, a detailed survey on various existing demising strategy. On the other hand, given a specified mobile communication scenario, it is noteworthy that the most approximate statistical model on the wireless channel usually can be obtained via numerous experiments. As a matter of fact, the popular statistical wireless channel models, such as COST and WINNER II, have proven to be very efficient for the performance evaluations and/or comparisons for different channel estimation and equalization algorithms. Finally, in order to design the most suitable pilot patterns for OMP based DP-CCEs in mobile OFDM systems, we must answer the following two questions: 1) How many pilots should be adopted for different mobile scenarios? 2) How to position the pilots for obtaining the best channel estimation performances?

To answer these two questions, we thus need to build a bridge between the MSE performance of OMP based DP-CCEs and those determinant factors. Therefore, we address the following issue in this paper: given a specified statistical channel model, how to predict the MSE performance and evaluate the influences of the basis-mismatch problem of OMP based DP-CCEs in mobile OFDM systems? Upon the state of the art, we will develop a mathematical framework to analyze the MSE performance of OMP based DP-CCEs. The initial results of the developed analytical framework have been introduced in [19].

The main contributions lie in the following two folds: 1) Propose an evaluable framework integrating the MSEs caused by the basis-mismatch problem of OMP. It can be used for not only analyzing the MSE performance of CCEs under different Doppler shifts, but also evaluating the impacts of both ‘lost errors’ and ‘false alarms’. 2) Derive a closed form upper-bound on evaluating the MSE performance of OMP based CCEs in the ideal case. It will reveal the connection between the MSE of OMP and those determinant parameters such as deterministic pilot patterns (including the numbers and the locations of pilots), SNR, and the maximum Doppler shift etc

1. Proposed block diagram

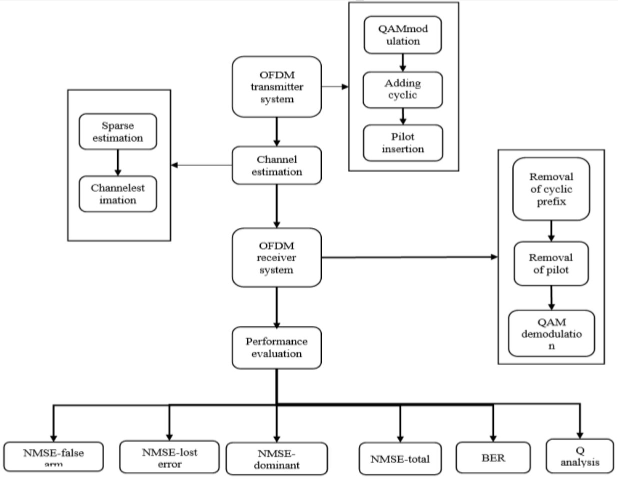

Fig. 1 Block Diagram.

2. Modules

- OFDM system
- Orthogonal Matching Pursuit (OMP) algorithm
- Channel estimation-Normalized mean square error
- Performance evaluation

4.Ofdm Systems: Orthogonal Frequency Division Multiplexing (OFDM) is a digital multi-carrier modulation scheme that extends the concept of single subcarrier modulation by using multiple subcarriers within the same single channel. Rather than transmit a high-rate stream of data with a single subcarrier. Orthogonal Frequency Division Multiplexing or OFDM is a modulation format that is being used for many of the latest wireless and telecommunications standards.OFDM is a form of multicarrier modulation. In this system the data is generated and given for baseband modulation where, adding of cyclic prefix and conversions are performed. After the cyclic prefix adding the pilot insertions are added to the signal and the modulation used is 4 QAM modulation.We focus on OFDM as a digital multicarrier technique using TS-based channel estimation.

5. Orthogonal Matching Pursuit (Omp) Algorithm : In this paper, we only consider a general OMP algorithm to analyze its MSE performance in case of given the second-order statistical information of a statistical wireless channel model. To analyze the influences of ‘lost errors’ and ‘false alarms’ by OMP, we will divide the NMSET into three parts: one is from the components recovered successfully, one is due to the ‘lost errors’, one is due to the ‘false alarms’.OMP is an iterative greedy algorithm that selects at each step the column, which is most correlated with the current residuals. One of the oldest and simplest greedy pursuit algorithm is the orthogonal matching pursuit. Unfortunately, it is quite difficult to answer. At present, there are two major approaches, orthogonal matching pursuit (OMP) and basis pursuit (BP). OMP is an iterative greedy algorithm that selects at each step the dictionary element best correlated with the residual part of the signal. Then it produces a new approximant by projecting the signal onto the dictionary elements that have already been selected. This technique extends the trivial greedy algorithm that succeeds for an orthonormal system. BP is a more sophisticated approach that replaces the original sparse approximation problem by a linear programming problem. Empirical evidence suggests that BP is more powerful than OMP. The major advantage of OMP is that it admits simple, fast implementations

6.Channel Estimation-Normalized Mean Square Error : We propose a mathematical frame-work for analyzing the NMSE ofOMP based CCE.In this NMSE total, NMSE false arm, NMSE lost error and NMSE dominant channel components.In statistics, the mean squared error (MSE) or mean squared deviation (MSD) of an estimator measures the average of the squares of the errors that is, the average squared difference between the estimated values and what is estimated.The mean error is an informal term that usually refers to the average of all the errors in a set.In statistics and signal processing, a minimum mean square error (MMSE) estimator is an estimation method which minimizes the mean square error (MSE), which is a common measure of estimator quality, of the fitted values of a dependent variable.

V. PERFORMANCE EVALUATION

In this system the performance evaluation of all the NMSE channel with some of the NMSE false arm, lost error and dominant upper bound. Then the performance evaluation of BER and the probability of lost error, success an false arm is calculated.The performance evaluation is thus plotted with different speed of channels and calculated.Systems for which bit error rate, BER is applicable include radio data links as well as fibre optic data systems, Ethernet, or any system that transmits data over a network of some form where noise, interference, and phase jitter may cause degradation of the digital signal. In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The bit error rate (BER) is the number of bit errors per unit time. The minimum cyclic prefix for satisfying a predefined target BER requirement for given scenarios with different speeds. In this subsection, we still choose the mobile OFDM systems as presented before for the illustrations. First, we build a regression model between the NMSET and the BER through simulations.

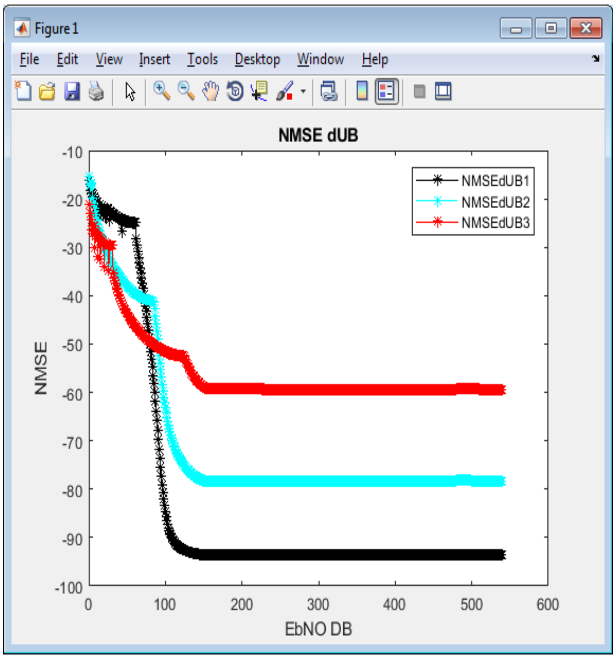

Fig. 2 Comparisons on NMSED with dUB.

For validating the framework in mobile OFDM systems, we consider the scenarios with unneglectable Doppler shift by setting different mobile speeds.

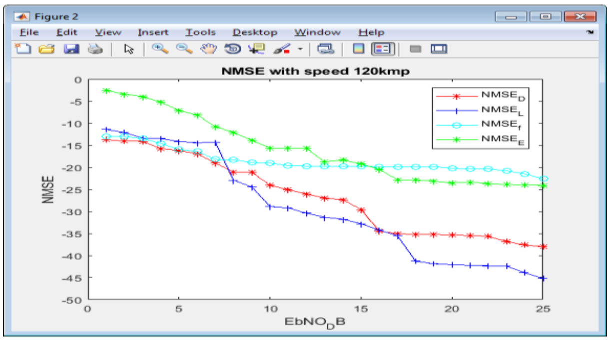

Fig. 3 Comparisons on NMSED with Np=32.

We now take an example for the illustrations using a scenario with a speed of 120km/h and Np=32. Fig. 4 shows different NMSE measured in the simulations. Fig. 5 shows three kinds of probabilities counted in the same simulations. They are the probability of the successes, the probability of 'lost errors' and the probability of 'false alarms', respectively Then, note that Fig. 4 shows that the NMSET can almost reach the NMSED,UB at Eb/No=16dB. Correspondingly, Fig. 5 shows that the probability of successes is about 0.5 at Eb/No=16dB. Furthermore, Fig. 4 also shows that the NMSET is nearly same to the NMSED,UB at Eb/No=24dB. Correspondingly,

Fig. 5 shows that the probability of successes is about 0.6 at Eb/No=24dB. These results indicate that the NMSET can achieve at the NMSED,UB when the probability of successes of OMP is more than a certain threshold. It hints that the influences of both the 'lost errors' and the 'false alarms' can be neglected when the SNR is high enough. Therefore, the analytical framework on the NMSED,UB is a useful tool for predicting the MSE performances of OMP based CCEs

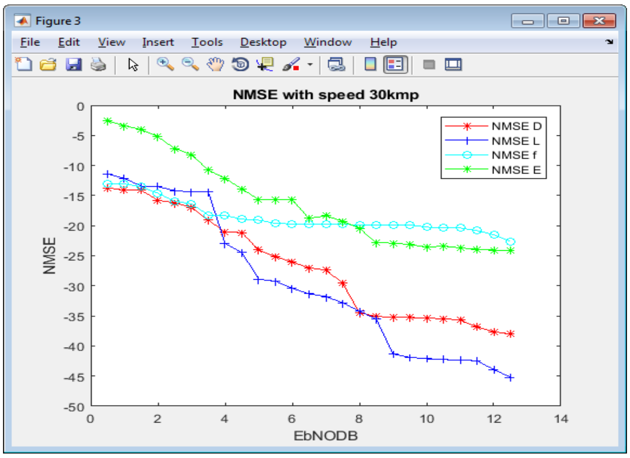

Fig. 4 The NMSE with Np=32 and 120km/h.

However, according to the observations in Fig. 4, there is always a gap between the NMSET and the NMSED in the simulations due to the errors of OMP. As mentioned above, both the NMSEL and the NMSEF can be neglected so that the NMSET can reach the NMSED when the probability of successes of OMP is more than a certain threshold. To validate this hypothesis, we carried out similar simulations for a scenario with a speed of 30km/h and Np=32. These results are shown in the following Fig. 4.3 and Fig. 4.

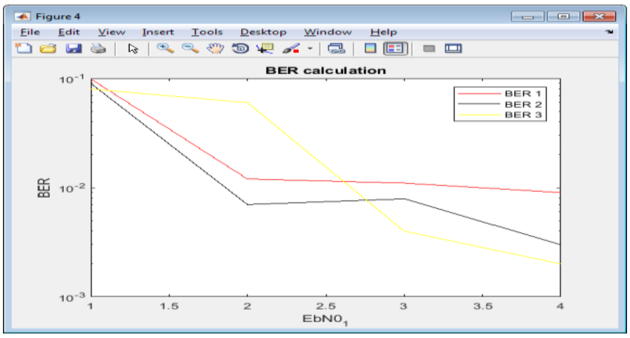

Fig. 5 The Corresponding BER performances.

We choose different mobile speeds to make the maximum normalized Doppler shift varying 0.09 to 0.15. Using Corollary 1 by setting Np=32 and Q=3, we then can predict the NMSED,UB for this case with different ϑmax. Afterwards, both simulation and analysis results are shown in Fig. 2, and the corresponding BER performances by simulations are shown in Fig. 4.5 .

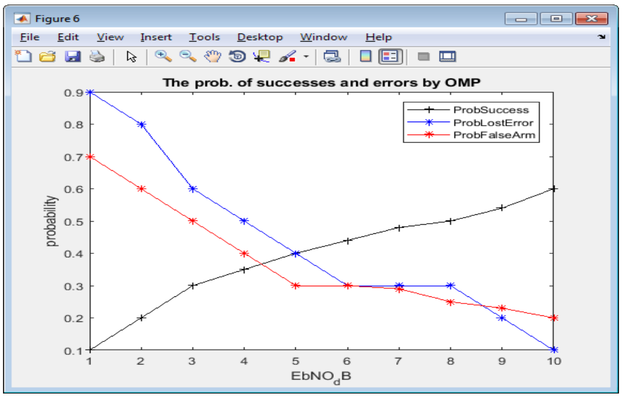

Fig. 6 The prob. of successes and errors by OMP.

According to Fig. 4.6 we can understand how the probabilities of successes and failures influence the NMSE performances. With the increase of SNR, Fig. 4.5 shows that the probability of successes increase rapidly, while the probabilities of both the 'lost errors' and the 'false alarms' decrease rapidly. It thus can explain the trends of those different NMSEs variation shown in Fig. 4.6

IV. CONCLUSION

In this paper, we propose a framework for analyzing the MSE performance of the OMP based DP-CCEs in mobile OFDM systems by defining four kinds of normalized MSEs: the total NMSE, the NMSE on those re-covered dominant channel components the NMSE caused by 'Lost Errors' and the NMSE caused by 'False Alarms'. Then, we derive a formula with closed forms for evaluating the upper-bound performance of NMSED in ideal cases. The simulation results show that the proposed NMSED;UBis tight when the probability of successes of OMP exceeds a certain threshold Additionally, given a mobile OFDM system, we also take an example to illustrate how to minimize the number of pilots for meeting a predefined target BER requirement using the proposed NMSED;UBthe number of pilots for guaranteeing the target BER requirement under different mobile speeds in high SNR regime. It indicates that the NMSED;UB provides a good way for the tradeoff between the transmission efficiency and the transmission reliability.Therefore, the proposed framework is a good candidate tool for predicting the total MSE performance of OMP based CCE in mobile OFDM systems.

Following are the areas of future study which should be considered for further research work.

- Implementation of other interpolation techniques for channel estimation: In this work we have considered only two type interpolation techniques. We can extend this work for other interpolation techniques such as second order, low-pass etc.
- Feasibility study of Multiple Input Multiple Output (MIMO) OFDM systems: In this study we have discussed about Single Input Single Output (SISO) OFDM systems. MIMO OFDM can be implemented using multiple transmitting and receiving antennas which is an interesting work of future. According the findings and the analysis, we believe the proposed analysis framework in this paper could be a useful tool for guiding the design and the optimization of the OMP based CCEs in mobile OFDM systems. Here we list some potential applications and future works:
- Optimizing the pilot patterns: from the proposed framework, we know that the NMSED,UB is only determined by the pilot patterns except for those variable physical parameters such as Doppler shift, delay taps etc. Therefore, the framework is a good candidate tool for optimizing the pilot parameters for OMP based CCEs. For example, using this framework, we can study how to minimize the NMSED,UB by adjusting pilot locations and/or symbols.
- Aided design adaptive modulation and coding (AMC) schemes: given a statistical wireless channel model, we also can build a mapping relationship between the NMSED,UB and BER performances under a certain AMC scheme (e.g. QAM and Turbo coding employed). Then, we can obtain thresholds for a target BER requirement under different scenarios immediately so that an AMC scheme could be designed for practical mobile OFDM systems.
- Improving the proposed framework: note that the framework can be adopted for analyzing the MSE caused by "false alarms" and "lost errors" of OMP quantitatively. However, the accurate analysis of both NMSEL and NMSEF depend on the prior knowledge of the probabilities of those failures. Due to the difficulties in obtaining those probabilities, it is still a challenge on how to analyze NMSEL and NMSEF in a tractable way. Furthermore, for the proposed framework, it is also a challenge on how to analyze the influence of the parameter Q in a tractable way. We leave these two issues to our future work.
- Evaluating novel ideas: the framework provides a fast way for evaluating the performances of many novel ideas of new related emerging techniques. For example, the NMSED,UB can be used for fast evaluating the performance of the detection techniques employing OMP based imperfect CCEs

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