HIGH MOBILITY CHANNEL ESTIMATION BASED ON AMPLIFY-AND-FORWARD MODEL IN COOPERATIVE NETWORK

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LIST OF SYMBOLS

$E[\cdot]$	$E[\cdot]$ represents the expectation operator.
$\lvert x \rvert$	$\lvert x \rvert$ is the absolute value of a complex scalar x.
$\lfloor x \rfloor$, $\lceil x \rceil$	$\lfloor x \rfloor$ denotes the floor of a real number x while $\lceil x \rceil$ denotes the ceiling of a real number x.
$\boldsymbol{I}_N$	$\boldsymbol{I}_N$ is a $N \times N$ identity matrix.
$\boldsymbol{O}_N$	$\boldsymbol{O}_N$ is a $N \times N$ matrix with zero entries.
$\boldsymbol{X}^T$	$\boldsymbol{X}^T$ is the transpose of $\boldsymbol{X}$.
$\boldsymbol{X}^H$	$\boldsymbol{X}^H$ is the conjugate transpose of $\boldsymbol{X}$.
$\boldsymbol{X}^{-1}$	$\boldsymbol{X}^{-1}$ is the inverse of $\boldsymbol{X}$.
$\boldsymbol{X}^{\dagger}$	$\boldsymbol{X}^{\dagger}$ is the pseudo inverse of $\boldsymbol{X}$ and can be defined as $\boldsymbol{X}^{\dagger} = \left(\boldsymbol{X}^H \boldsymbol{X}\right)^{-1} \boldsymbol{X}^H$.
$\mathrm{diag}[x_1,\ldots,x_n]$	$\mathrm{diag}[x_1,\ldots,x_n]$ represents the diagonal matrix with elements $x_1,\ldots,x_n$.
$[\boldsymbol{X}]_{i,j}$	$[\boldsymbol{X}]_{i,j}$ denotes the matrix element at the ith row and jth column.
$CN(m,\sigma^2)$	$CN(m,\sigma^2)$ denotes the complex normal distribution with mean, m and variance, σ^2
FFT, IFFT	The N point FFT/DFT operation on $\boldsymbol{x} = [x(0), x(1), \ldots, x(N-1)]$ is $\boldsymbol{X} = [X(0), X(1), \ldots, X(N-1)]$, where $X(k) = 1/\sqrt{N} \sum_{n=0}^{N-1} x(n) e^{-j2\pi nk/N}$. $x(n) = 1/\sqrt{N} \sum_{k=0}^{N-1} X(k) e^{j2\pi nk/N}$. k and n are subcarrier and time indices respectively
Boldface, Non-boldface letters	Boldface italic letters denote matrices and vectors. Scalars are denoted by non-boldface italic letters.

LIST OF ABBREVIATIONS

4G	Fourth Generation
AF	Amplify-and-Forward
DF	Decode-and-Forward
AWGN	Additive White Gaussian Noise
BEM	Basis Expansion Model
BER	Bit Error Rate
BS	Base Station
CFO	Carrier Frequency Offset
CIR	Channel Impulse Response
CP	Cyclic Prefix
CRLB	Cramer-Rao Lower Bound
ICI	Inter Carrier Interference
IEEE	The Institute of Electrical and Electronics Engineers
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
LTE	Long Term Evolution
LMMSE	Linear Minimum Mean Square Error
LS	Least Square
MIMO	Multiple Input Multiple Output
MMSE	Minimum Mean Square Error
OFDM	Orthogonal Frequency-Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access

PHY	Physical Layer
RS	Relay Station
SER	Symbol Error Rate
SNR	Signal-to-Noise power Ratio
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WiMAX	Worldwide Interoperability for Microwave Access

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ABSTRACT

Cooperative communication has been proposed for a number of next generation mobile technologies such as Worldwide Interoperability for Microwave Access (WiMAX), wireless Metropolitan Area Network (WMAN), Long Term Evolution (LTE) and LTE-Advanced. In addition to the higher data rate, the upcoming wireless technologies support higher user mobility than the previous technologies. However, due to the fast movement, the channel may experience Doppler spread which may cause the carrier frequency offset (CFO) resulting Inter Carrier Interference (ICI). Modeling and estimating this type of channel is crucial and, play a vital role to fulfil the data rate requirement of the network. In this thesis, an Amplify-and-Forward (AF) relay based cooperative network using Orthogonal Frequency Division Multiplexing (OFDM) system has been studied. The problem of high mobility OFDM channel is investigated first. To alleviate the problem, Basis Expansion Modeling (BEM) for time varying channel has been applied. BEM is used to capture the time variation of the channel with very small coherence time. Following the channel model, the OFDM based AF relaying system model is developed including transmit and receive signal model. In this study, Least Square (LS) and Linear Minimum Mean Square Error (LMMSE) estimators are formulated based on two different pilot patterns for both time and frequency domains. In addition to the estimators, Cramer-Rao lower bound is derived as a benchmark of the estimation performance of the estimation methods. Based on the theoretical analysis and simulation results it was found that the frequency domain channel estimation suffers from the estimation errors due to the ICI from the data symbols in the OFDM block. On the other hand, time domain channel estimation methods can provide interference free and more accurate estimates in high mobility channel conditions. Moreover, being a more complex and advance estimator, LMMSE was found to be more precise in compare to LS estimator in time domain channel estimation. Also, LMMSE performs more close to the CRLB and may be a better choice for channel estimation in high speed mobile environment.

ABSTRAK

Koperasi berbantu telah dicadangkan sebagai beberapa generasi teknologi mobil terkini seperti Interoperability Seluruh Dunia bagi Akses Gelombang Mikro (WiMAX), Rangkaian Kawasan Metropolitan wayarles (Vistaku), Evolusi Jangka Panjang (LTE) dan LTE-Advanced. Tambahan kepada kadar data yang tinngi, teknologi tanpa wayar yang akan datang menyokong kebebasan pengguna berbanding dengan teknologi terdahulu. Walaubagaimanapun, disebabkan oleh pergerakan pantas, saluran berkemungkinan mengalami penyebaran doppler dimana menyebabkan perubahan frenquency pembawa (CFO) membawa kepada gangguan anatara pembawa (ICI). Memodel dan mengangar saluran ini sangat penting untuk memenuhi keperluan kadar data rangkainan. Dalam thesis ini, Penguat dan kehadapan (AF) geganti berasaskan rangkaian koperasi berbantu dimana mengunakan sistem mangasing frekuensi orthogon telah dikaji (OFDM). Pertama sekali,masalah yang berhubung kait dengan OFDM disiasat terlebih dahulu. Untuk mengurangkan masalah ini, Asas Pengembangan Model (BEM) untuk masa yang berbeza-beza saluran telah digunakan. BEM telah digunakan untuk mengesan variasi masa saluran dalam julat berubahan yang kecil. Berdasarkan model saluran, OFDM berasakan geganti AF dibangunkan termasuk pemancar dan model penerima signal. Dalam kajian ini juga, penganggar Least Square (LS) dan Linear Minimun Mean Square Error (LMMSE) telah diformulasi berdasarkan dua corak iaitu masa dan kekerapan. Pada masa yang sama, Cramer-Rao rendah terikat telah di dihasilkan sebagai kayu pengukur pretasi kaedah penganggaran. Berdasarkan analisis teori dan hasil simulasi, didapati bahawa anggaran saluran domain kekerapan mengalami kesilapan anggaran disebabkan oleh ICI dari simbol-simbol data dalam blok OFDM itu. Sebaliknya, kaedah anggaran masa saluran domain adalah bebas dari gangguan dan lebih tepat dalam keadaan saluran mobiliti yang tinggi. Selain itu, sebagai penganggar yang lebih kompleks dan lebih canggih, LMMSE didapati lebih tepat di bandingkan dengan LS penganggar masa saluran domain. Prestasi LMMSE hampir dibandingkan dengan CRLB dan mungkin menjadi pilihan yang lebih baik untuk saluran anggaran dalam persekitaran mudah alih berkelajuan tinggi.

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