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UNIVERSITI PUTRA MALAYSIA

PERFORMANCE EVALUATION OF COMBINED CODE-SPACE DIVISION MULTIPLE ACCESS WITH ENHANCED PARALLEL INTERFERENCE CANCELLATION

NIDHAL A.S. ODEH

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By

NIDHAL A.S. ODEH

Thesis Submitted to the School of Graduate Studies, University Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

July 2007

DEDICATION

This thesis is dedicated to

ALL I LOVE

Specially

MY BELOVED PARENTS

and

MY COUNTRY "PALESTINE"

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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July 2007

Chairman: Associate Professor Sabira Khatun, PhD

Faculty: Engineering

To meet the ever growing need for wireless networks, several methods were adopted to increase the system capacity of wireless communication systems, such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Space Division Multiple Access (SDMA) and Orthogonal Frequency Division Multiplexing (OFDM). In this thesis, Combined Code Division Multiple Access (CDMA) and Space Division Multiple Access (SDMA) system have been investigated for capacity improvement.

The analysis considered here is to evaluate the performance of combined Code-Space Division Multiple Access (C-SDMA) system. A single cell composed with one base station (BS) and *N* classes of users is considered. In heterogeneous environment each user class is supported by one of the different media with specific data rates and minimum required quality of service. In this thesis, the synchronous uplink channel transmission is investigated in order to detect the received signal (bits) in a combined C-SDMA system with perfect power control, with and without interference

cancellation. Parallel interference cancellation (PIC) as a suboptimal multiuser detection (MUD) was employed after the matched filter (MF) receiver. The performance of the C-SDMA systems was evaluated in terms of bit error rate (BER) and user capacity, considering all the transmitted bits from other interferer users. Additionally, some asymptotic behaviour of the combined system was analyzed at high and low signal-to-noise and interference ratio (SNIR) for the desired user. Comparison between the pure CDMA and combined C-SDMA systems is done in terms of system performance with and without interference cancellation.

By using limited number of available spreading codes, a novel code assignment algorithm is proposed to maintain the maximum orthogonality among users. These codes are stored in a central pool (BS) and maintained as follows. When a new user requests for a channel, the BS first checks the available signatures in terms of codes and Angle of Arrival (AoA); it then assigns the user with an already used code (used by other users) if they are spatially orthogonal to each other, otherwise an available new code will be assigned. If all codes are already utilized then the user will be blocked. Finally, the probability of blocking was evaluated in terms of various numbers of available codes.

Matlab was used as the simulation software throughout this thesis. The results obtained showed that the combined C-SDMA system improve the performance by about 4 dB gain over the pure CDMA system at BER of 10^{-1}. On the other hand the system gains 5 dB in the combined C-SDMA system with PIC receiver over the receiver without PIC at BER of 10^{-4}. Hence, it is apparent that the combined C-SDMA system with PIC is able to accommodate more users than the other systems. Finally,

the code assignment algorithm is able to further enhance the system capacity by utilizing the same resources compared to the fixed code assignment strategy. In this case, the probability of blocking can be decreased substantially by adding few numbers of additional spreading codes in the system.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master of Sains

PENILAIAN PRESTASI TEKNIK CAPAIAN UNTUK GABUNGAN CAPAIAN BERBILANG PEMBAHAGI KOD-RUANG DENGAN PENINGKATAN PEMBATAL GANGGUAN SELARI

Oleh

NIDHAL AHMAD SALEEM ODEH

Julai 2007

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Untuk memenuhi keperluan yang meningkat kepada rangkaian wayerles, beberapa kaedah telah diambil untuk meningkatkan muatan sistem komunikas wayerles, seperti Capaian Berbilang Pembahagi Frekuensi (FDMA), Capaian Berbilang Pembahagi Masa (TDMA), Capaian Berbilang Pembahagi Kod (CDMA), Capaian Berbilang Pembahagi Ruang (SDMA), dan Pemultipleksan Pembahagi Frekuensi Orthogonal (OFDM). Dalam tesis ini, gabungan Capaian Berbilang Pembahagi Kod (CDMA) dan Capaian Berbilang Pembahagi Ruang (SDMA), telah dikaji untuk meningkatkan keupayaannya.

Analisis tepat adalah diambil kira di sini untuk menilai prestasi sistem gabungan Capaian Berbilang Pembahagi Kod-Ruang (C-SDMA). Satu sel mengandungi satu stesen tapak (BS) dan N kelas pengguna adalah diambilkira. Dalam persekitaran heterogen setiap pengguna adalah disokong dengan salah satu dari media yang berbeza dengan kadar data spesifik dan kualiti perkhidmatan minimum yang dikehendaki. Dalam tesis ini, penghantaran saluran ke atas segerak adalah dikaji untuk mengesan isyatat penerimaan (bit) dalam gabungan sistem C-SDMA dengan

kawalan kuasa sempurna, dengan dan tanpa pembatal gangguan. Pembatal gangguan selari (PIC) sebagai pengesanan berbilang pengguna (MUD) telah digunakan selepas penerima penuras sepadan (MF). Prestasi sistem C-SDMA telah dinilai dalam bentuk kadar ralat bit (BER) dan muatan pengguna, dengan mengambil kira kesemua bit yang telah dihantar oleh setiap pengguna pengganggu. Sebagai tambahan, beberapa perangai asimptot sistem gabungan telah dianalisis ada nisbah isyarat ke bisingan (SNIR) tinggi dan rendah untuk pengguna yang dikehendaki. Perbandingan di antara sistem CDMA tulin dan gabungan C-SDMA telah dilakukan dalam bentuk prestasi sistem dengan dan tanpa pembatal gangguan.

Dengan kod penyerakan yang kecil bilangannya, suatu algoritma penyerahan kod yang baru adalah dicadangkan untuk mengekalkan pengorthogonalan maksimum di kalangan pengguna. Kod-kod ini adalah distorkan dalam satu pool pusat (BS) dan disenggara mengikut cara berikut. Apabila satu pengguna yang baru memohon satu saloran, BS mula-mula menyemak pengenalan yang ada dalam bentuk kod dan sudut ketibaan (AoA); kemudian ia serahkan pengguna tersebut dengan suatu kod yang telah digunakan (oleh pengguna lain) sekiranya ia adalah orthogonal di antara satu sama lain, sekiranya tidak suatu kod baru yang ada akan diserahkan. Jika kesemua kod telah digunakan maka pengguna tersebut akan disekat. Akhir sekali, kebarangkalian sekatan telah dinilai dalam bentuk kod yang berbilang banyaknya.

Matlab telah digunakan sebagai perisian simulasi untuk keseluruhan tesis ini. Hasil kajian yang diperolehi menunjukkan bahawa sistem gabungan C-SDMA menambahbaikkan prestasi sihingga 4 dB ke atas sistem CDMA tulin. Sebaliknya penambahbaikan adalah lebihkurang 5 dB sahaja dalam sistem gabungan C-SDMA

dengan penerima PIC ke atas penerima tanpa PIC. Oleh itu, jelas bahawa sistem gabungan C-SDMA dengan PIC mampu menerima lebih banyak pengguna berbanding dengan sistem-sistem lain. Akhir sekali, algoritma peruntukan kod mampu untuk menambahbaikkan seterusnya muatan sistem dengan mengguna sumber yang sama berbanding dengan strategi peruntukan kod pegun. Dalam kes ini, kebarangkalian sekatan boleh diturunkan dengan banyak, dengan menambahkan sedikit kod penyerakan dalam sistem tersebut..

ACKNOWLEDGEMENTS

This work would not been accomplished without the help of so many people. In the following lines is a brief account of some but not all who deserve my thanks.

First, I would like to thank Associate Professor Dr. Sabira Khatun for taking the burden of supervising this research. She helped, reviewed and motivated this research.

My deepest gratitude and appreciation goes to Professor Dr. Borhanuddin Mohd Ali for his valuable comments and suggestions which have been indispensable in the preparation of this thesis. His professional review helped this thesis to be further improved.

Also, I would like to thank Dr. Alyani Ismail for her great efforts in reviewing this thesis and other technical papers.

My warmest gratitude goes to all of my family members especially, my father AHMAD ODEH, my mother, my brother and sisters, for their continuous support.

I also want to thank all of my second family members in Malaysia, including both the colleges' student and the staff, for providing me with great experience in my academic and social life.

Special thanks from me to MALAYSIA and to Malaysian people in general for their perfect hospitality in their green land during my study period.

I will never forget to extend my thanks to Dr. Nasser Hamad for supporting me in my academic life starting from my bachelor degree until finalizing this thesis.

Finally, big thanks to all of my friends especially, Wael, Asem, Wahbi, Thamer, Omar and all of the others with our nice memory.

APPROVAL

I certify that an Examination Committee has met on 17 July, 2007 to conduct the final examination of Nidhal A. S. Odeh on his Master of Science thesis "Performance Evaluation of Combined Code-Space Division Multiple Access with Enhancement Parallel Interference Cancellation" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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Date: 13 September 2007

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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NIDHAL A.S. ODEH

Date: 1st October 2007

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LIST OF ABBREVIATIONS/ SYMBOLS

1st G	First Generation
2nd G	Second Generation
3rd G	Third Generation
4th G	Fourth Generation
AF	Antenna Factor
AG	Antenna Gain
AMPS	Advance Mobile Phone Service
AoA	Angle of Arrival
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
CDMA	Code Division Multiple Access
CSMA	Carrier Sense Multiple Access
D-DF	Decorrelating Decision Feedback
DS/SS	Direct Sequence Spread Spectrum
DS-CDMA	Direct Sequence Code Division Multiple Access
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access

FH/SS	Frequency Hoping Spread Spectrum
GSM	Global System for Mobile communication
i.i.d	independent and identical distribution
IC	Interference Cancellation s
ISI	Inter Symbol Interference
MA	Multiple Access
MAI	Multiple Access Interference
MC	Multi Code
MCH	Multi Channel
MCR	Multi Chip Rate
MF	Matched Filter
MLSE	Maximum Likelihood Sequence Estimation
MM	Multi Modulation
MMSE	Minimum Mean Square Error
MPG	Multi Processing Gain
MSE	Mean Square Error
MUD	Multiuser Detection
NAK	Negative Acknowledgement
PE	Polynomial Expansion
PIC	Parallel Interference Cancellation

PN	Pseudo Noise
PSD	Power Spectral Density
QOS	Quality of Service
SDMA	Space Division Multiple Access
SIC	Successive Interference Cancellation
SMS	Short Message Service
SS	Spread Spectrum
SSS	Spread Spectrum System
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TH/SS	Time Hoping Spread Spectrum
VSG	Variable Spreading Gain
VSL	Variable Spreading Length
W-CDMA	Wideband- Code Division Multiple Access
ZF-DF	Zero Forcing Decision Feedback

LIST OF SYMBOLS

ρ_{ij}	Cross-correlation
$(.)^{-1}$	Inverse
α	Phase Shift
θ	Angle of Arrival
σ^2	Noise Power Spectral Density
var$[\cdot]$	Variance
η	Noise correlator output
χ	Threshold value
A	Signal Amplitude
AF	Antenna Factor
$AF(\theta)$	Antenna Factor at Angle θ
b_P	Blocking probability
$b(t)$	Information Sequence
$\hat{b}$	Estimated information Bit
$b^{'}$	Estimated Information Bit after PIC receiver
$c(t)$	Spreading Code
d	Distance
E_b/N_0	Bit Energy over Noise Power Spectral Density Ratio

$\mathbf{F}$	Lower Triangular Matrix
G	Total number of users using the same code
$\hat{I}$	Estimated Multiple Access Interference
I	Multiple Access Interference
L_{PE}	Linear Mapping of Polynomial Expansion Receiver
L	Total Number of Available Codes
N	Sequence Period
N_u	System capacity
N_e	Number of Antenna Elements
$n(t)$	Additive White Gaussian Noise
$P_T(t)$	Rectangular Pulse
P_b	Probability of Bit Error
$Q(x)$	Q Function
$r(t,\theta)$	Received Signal
$\mathbf{R}$	Correlation Matrix
R_b	Data Rate
$S(t)$	Modulated Signal (Transmitted Signal)
$\text{sgn}(\cdot)$	Decision statistic
$SINR$	Signal to noise and interference ratio
PG	Processing Gain

T_c	Chip Duration
T_b	Bit Duration
τ	Time Delay
u_i	Number of users belong to *i*-th class
$w(t)$	Weight vector
$y(t,\theta)$	Correlator output
γ_i	Difference of the transmitted and detected information *i*-th bit
$Z^{'}(t,\theta)$	Output of the PIC cancellation Receiver