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QoS-Based Power Management Techniques for Uplink W-CDMA Cellular Systems

By

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Studyleader: Professor L.P. Linde & Professor X. Xia

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SUMMARY

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In the past, the design of PC algorithms for CDMA systems has remained at the physical layer to compensate for slow and fast channel impairments (known as fast PC and slow PC). The TDMA/FDMA manages inter-cell interference at the beginning of the radio planning process. In SS technology, real time adaptive PC and power management algorithms would need to work coherently to ensure reliable multi-media services, and the need for this real-time hybrid structure of PC and power management has only been shown recently. The emphasis in this dissertation is therefore on the design of a QoS-based PC structure in W-CDMA applications, the ultimate goal being to evaluate the new QoS-based PC structure by means of a Monte Carlo computer simulation; a multi-user, multimedia W-CDMA simulation package. Before the design of the QoS-based PC structure, this dissertation examines and proposes a new power-sensitive model that addresses factors affecting the W-CDMA system capacity. Consequently, PC problems are put into a framework for various optimization criteria. Finally the design of a QoS-based PC structure by means of Monte Carlo computer simulation is described and evaluate.

The first problem is closely related to the fact that W-CDMA is a design of a power management network architecture. The power management can co-exist in every layer of operation with different specific time scale and optimization objectives. The solution to this problem is therefore to introduce a general and mathematically tractable *power-sensitive model* to identify factors that influence the capacity of W-CDMA cellular systems and then articulate the general power sensitive model to form a PC framework aimed at finding a common systematic treatment for different schools of thought on PC algorithms. This dissertation proves the benefits of layered PC operation for guaranteed QoS transmission and also shows that this research coincides with and extend the literature on PC management by categorizing PC algorithms according to various optimization objectives and time scales.

The **second** problem is to evaluate the new QoS-based PC structure in a channel coded and RAKE combining uplink UMTS/UTRA cellular environment using the Monte Carlo simulation package. The UMTS radio channel models are described in terms of frequency-selective Rayleigh fading: *Indoor-Office*, *Outdoor and Pedestrian* and *Vehicular* environments. The package is simulated in Matlab. The influence of the number of multipath components, of Doppler Spread, the number of received antenna, the coding scheme and multi-access interference are discussed in the dissertation. The performance evaluation criteria for utility-based PC structures are Bit-Error-Rate (BER) performance (robustness), outage performance (tracking ability) and rate of convergence. The first test shows that the new proposed unbalanced step-size closed-loop FPC schemes can provide better SINR tracking ability and better BER performance than conventional balanced step-size PC schemes. The unbalanced FPCs have better PC error distribution in all scenarios. The second test shows that the proposed BER-prediction distributed OPC schemes can provide better BER *tracking ability*. This scheme converges iteratively to an optimal SINR level under current network settings with no excessive interference to other active users..

Keywords:

multi-media, W-CDMA, UMTS/IMT-2000, soft capacity, resource allocation, interference management, Signal to Interference and Noise Ratio (SINR), Quality of Service (QoS), Bit-Error-Rate (BER), power-sensitive model, intra-cell interference, inter-cell interference, Fast PC (FPC), Outer-loop PC (OPC), Network PC (NPC), Doppler spread, Multi-Access Interference (MAI), tracking ability, iterative processing.

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OPSOMMING

QoS-BASED POWER MANAGEMENT TECHNIQUES FOR UPLINK W-CDMA CELLULAR SYSTEMS

deur

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In die verlede het die ontwerp van drywingsbeheeralgoritmes vir kodedivisie-multitoegang (CDMA) stelsels by die fisiese vlak gebly om te kompenseer vir stadige en vinnige kanaal tekortkomings (bekend as vinnige drywingsbeheer (DB) en stadige DB). TDMA/FDMA beheer interselsteuring in die begin van die radiobeplanningsproses. In SS tegnologie, moet intydse aanpasbare DB en DB-bestuuralgoritmes saamwerk om betroubare multimedia dienste te verseker. Die behoefte vir hierdie intydse saamgestelde struktuur van DB en drywingsbestuur is eers onlangs bewys. Die klem van hierdie verhandeling is daarom die ontwerp van 'n Kwaliteit-van-Diens (QoS)-gebaseerde DB struktuur met toepassing in W-CDMA. Die doel is om die nuwe QoS-gebaseerde DB struktuur te evalueer deur van Monte Carlo rekenaarsimulasies gebruik te maak; 'n multi-gebruiker, multimedia W-CDMA simulasiepakket. Voor die ontwerp van 'n QoS-gebaseerde DB struktuur gedoen word, word 'n nuwe drywingsensitiewe model bestudeer en voorgestel. Hierdie model addresseer faktore wat W-CDMA stelselkapasiteit affekteer. Gevolglik word die DB probleem in 'n raamwerk van verskeie optimeringskriteria geplaas. Laastens word die ontwerp van 'n QoS-gebaseerde DB struktuur, met behulp van Monte Carlo rekenaarsimulasie, beskryf en geëvalueer.

Die eerste probleem hou nou verband met die feit dat W-CDMA die ontwerp van 'n drywingsbeheerde netwerkargitektuur is. Die drywingsbeheer kan op elke vlak van operasie saamwerk, elk met verskillende tydskale en optimeringskriteria. Die oplos van die probleem behels die opstel van 'n algemene, wiskundig-aanvaarbare *drywingsensitiewe model* om die faktore wat die kapasiteit van W-CDMA sellulêre stelsels beïnvloed, te identifiseer en dan die algemene drywingsensitiewe model te artikuleer, sodanig dat 'n DB raamwerk, gemik op 'n algemene sistematiese ondersoek van verskeie DB algoritmes, gevind kan word. Hierdie verhandeling bewys die voordele van vlakgebaseerde DB operasie, sodanig dat QoS transmissie verseker word. Daar word ook getoon dat hierdie navorsing saamval met en bestaande literatuur oor DB bestuur uitbrei, deur die DB algoritmes volgens verskeie optimeringsdoelwitte en tydskale te kategoriseer.

Die **tweede** probleem is om die nuwe QoS-gebaseerde DB struktuur in 'n kanaalgekodeerde en RAKE gekombineerde opwaartse UMTS/UTRA sellulêre omgewing te evalueer, deur van die Monte Carlo simulasieprogram gebruik te maak. UMTS radiokanaalmodelle word in terme van frekwensieselektiewe Rayleigh deining (*Binnenshuis-kantoor*, *buite en voetganger* en *bewegende* omgewings beskryf. Die pakket word gesimuleer in Matlab. Die invloed van die aantal multipadkomponente, Doppler-spreiding, die getal ontvangsantennas, die koderingsskema en multi-gebruikerruis word in die verhandeling bespreek. Die werkverrigting-evalueringskriteria vir toepassingsgebaseerde DB strukture is: Bisfouttempo (BER) verrigting (robuustheid), onderbrekings-werkverrigting (volginsvermoë) en konvergeringsvermoë. Die eerste toets dui aan dat die nuwe voorgestelde, gebalanseerde stapgrootte, geslote lus FPC struktuur beter SINR volgvermoë, asook beter BER verrigting as konvensionele gebalanseerde stapgrootte DB skemas verseker. Die ongebalanseerde FPCs het beter DB foutverspreiding vir alle gevalle. Die tweede toets dui aan dat die voorgestelde BER-voorspelde verspreide OPC skemas beter BER *volgvermoë* kan verseker. Hierdie skema konvergeer iteratief na 'n optimale SINR vlak onder die huidige netwerkopstelling met geen buitensporige steuring vir ander aktiewe gebruikers nie..

Sleutelwoorde:

multi-media, W-CDMA, UMTS/IMT-2000, sagte kapasiteit, hulpbrontoekenning, steuringsbeheer, Sein tot Steuring en Ruisverhouding (SINR), Kwaliteit-van-diens (QoS), Bisfouttempo (BER), drywingsensitiewe model, intra-sel steuring, inter-sel steuring, Vinnige DB (FPC), Buitelus DB (OPC), Netwerk DB (NPC), Doppler-spreidng, Multi-toegang steuring (MAI), volgvermoë, iteratiewe verwerking.

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Also, to my creator and heavenly Father, my saviour Jesus Christ and my companion the Holy Spirit.

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ABBREVIATIONS

3GPP	3^{rd} Generation Partnership Project (produces W-CDMA standard)
ACTS	Advanced Communication Technologies and Systems EU Research Projects Framework
APC	Adaptive Power Control
PSTN	Fixed Public Telephone Network
ARIB	Association of Radio Industries and Businesses (Japan)
AWGN	Asymmetric Digital Subscriber Loop
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
BSA	Base Station Assignment
cdf	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CIR	Carrier to Interference Ratio
CRC	Cyclic Redundancy Check
DCH	Dedicated Channel
DM	Delta Modulation
DS	Digital Signal
DPA	Diversity Power Assignment
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
ETSI	European Telecommunications Standards Institute
FA	Fixed Assignment
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FER	Frame Error Rate
FPC	Fast Power Control

iid	Independent, Identically Distributed
IPC	Inner-loop Power Control
IMT-2000	International Mobile Telecommunications by the year 2000
ITU	International Telecommunications Union
LOS	Line of Sight
MA	Multi-Access
MAC	Medium Access Control
MAI	Multi-Access Interference
MIP	Multipath Intensity Profile
MPA	Minimal Power Assignment
MRC	Maximum Ratio Combining
MROPA	Multi-rate Outer Power Assignment
MS	Mobile Station
MT-PC	Multi-Target Adaptive Power Control
MUD	Multiuser Detection
MUPC	Multi-target Utility-based Power Control
N-CDMA	Narrowband Code Division Multiple Access
NPC	Network Power Control
OPC	Outer-loop Power Control
OVSF	Orthogonal Variable Spreading Factor
PC	Power Control
PCM	Pulse Coded Modulation
PDA	Power Distributed Algorithm
pdf	Probability Density Function
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RE	Resource Estimator
RNC	Radio Network Controller
RRM	Radio Resource Management
Rx	Received Signal
SIR	Signal to Interference Ratio
SINR	Signal to Interference and Noise Ratio
SNR	Signal to Noise Ratio
SS	Spread Spectrum

STOPA	Space-Time Processing and Outer Power Assignment
TDMA	Time Division Multiple Access
TPC	Transmitted Power Control
Tx	Transmission Signal
ULA	Uniform Linear Array
UMTS	Universal Mobile Telecommunications Service
UTRA	UMTS Terrestrial Radio Access (ETSI)
W-CDMA	Wideband Code Division Multiple Access

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LIST OF SYMBOLS

K	Number of base stations
k	Assigned base station
N	Number of active users within base station k
i	Reference user
W	total bandwidth
$\mathbf{P} = [P_1, P_2, ...P_N]$	transmitted power vector for user i
$P_i \leq P_i^{\max}$	maximum power level
$\mathbf{R} = [R_1, R_2, ...R_N]$	Vector of rates
E_b/N_o	SINR
γ	BER/FER requirement
$\mathbf{R}$	The vector of rates
$b_i(l)$	Information symbol stream
$d_i(\tau)$	The sequence output at encoder and interleaver.
l	Number of user data
k/n	A rate k/n coding scheme
L	Symbol Interval
$1/T_b$	Data rate at symbols per seconds (sps) .
$1/T_d = n/kT_b$	Coded data rate at symbols per seconds (sps).
$1/T_c = C/T_d = nC/kT_b$	Chips per second (cps)
τ	Symbol interval index.
C	Spreading Gain.
$G = \frac{1/T_c}{1/T_b} = \frac{nCT_b}{kT_b} = \frac{nC}{k}$	Processing Gain.
$s_i(\tau)$	Spreading sequence.
$x_i(\tau) = d_i(\tau) * (\mathrm{u}_1 \otimes \mathrm{s}_i(\tau)) * \mathrm{p}$	Transmitted signal for user i.
$\mathrm{r} = \sum_{\tau=0}^{L-1} \sum_{i=1}^{N} \mathrm{x}_i(\tau) + \mathrm{n}$	The received signal after A/D conversion.
n	A iid complex Gaussian random variables of