



**UniMAP**

**ENHANCED MULTI-CELL COORDINATION IN  
WIRELESS COMMUNICATION SYSTEM USING  
BEAMFORMING METHODS**

by

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## LIST OF ABBREVIATIONS

APF	Adaptive Beamforming Algorithm
AJN	Adaptive Joint Network Optimization Method
AWGN	Additive white Gaussian noise
AoA	Angle of Arrival
BS	Base Station
BER	Bit Error Rate
BD	Block Diagonalizing
CA	Carrier Aggregation
C-RAN	Centralized RAN
CU	Central Unit
CQI	Channel Quality Indicator
CSI	Channel State Information
CDMA	Code Division Multiple Accesses
CCM	Constrained Constant Modulus
CMV	Constrained Minimum Variance
CoMP	Coordinated Multi-Point
CoMP-JP	Coordinated Multi-Point- Joint Process
CBF	Coordinated Scheduling / Beamforming
Cs	Coordinated Multi-Point UEs Set / CoMP UEs set
CZF	Coordinated Zero Forcing
DSP	Digital Signal Processing
DOA	Direction of Arrival
DMI	Direct Matrix inversion

DAS	Distributed Antenna System
DL	Down-Link transmission schemes
EVD	Eigen-value decomposition
eCoMP	Enhancement of Coordinated Multipoint transmission / reception
ESPRIT	Estimation of Signal Parameters via Rotational Invariance Techniques
EVDO	Evolve Data Only
EVDV	Evolution Data and Voice
eNBs	Evolve Node BS
FPGA	Field Programmable Gate Array
FIR	Finite Impulse Response Filter
1G	First Generation
FlexCoBF	Flexible Coordinated Beamforming Method
4G	Forth Generation
AF	Forward Relay
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Accesses
GPRS	General Packet Radio Service
GA	Genetic Algorithm
GPS	Global Position System
GSM	Global System for Mobile communication
DM-AIS	Dynamic Mutated Artificial Immune System
HII	High Interference Indicator
HRPD	High Rate Packet Data
IRC	Interference Rejection Combination
INR	Interference –to-Noise Ratio

IMT-2000	International Mobile Telecommunications 2000
HCDO	Hybrid Cell Downlink Optimization
ICI	Inter-Cell Interference
ICIC	Inter-Cell Interferences Coordination / Inter-Cell Interferences Coordination Cancelation
IMT-2000	International Mobile Telecommunications 2000
ITU	International Telecommunication Union
IUI	Inter-User Interference
LMS	Lest Mean Square
LCMV	Linear Constraint Minimum Variance
LTE	Long Term Evolution
LTE-A	LTE-Advanced
LTE-X2	LTE-interface
MRC	Maximum Ratio Combination
MSE	Mean- Square Error
MMSE	Minimum Mean Square Error
MV	Minimum Variance
MVDR	Minimum Variance Distortionless Response
MSs	Mobile Stations
MMVDR	Modified MVDR
MCS	Modulation and Coding Scheme
MIMO	Multiple-Input Multiple-Output
MUSIC	Multiple Signal Classification
MUI	multi-User Interference
MU-MIMO	Multi-User Multiple-Input Multiple-Output

NCs	Non-CoMP UEs set
N-CBF	Non-iterative Coordinated Beamforming
NS	Null Steering
NP-h	Non-Polynomial Hard
OFDM	Orthogonal Frequency Division Multiplexing
OI	Overload Indicator
RNTP	Relative Narrowband Transmit Power
RB	Resource Blocks
PRB	Physical Resource Block
PMI	Precode Matrix Index
QoS	Quality of Service
QBC	Quantization-Based Combination
RRM	Radio Resource Management
RI	Rank Indicator
RSSI	Received Signal Strength Indicator
RLS	Recursive Least Square
RS	Reference Signal
RBD	Regularized Block Diagonalization
SMI	Sample-Matrix Inversion
2G	Second Generation
SOI	Signal of Interest
SNR	Signal-to-Noise Ratio
SINR	Signal-to-Interference Noise Ratio
SLNR	Signal-Leakage Noise Ratio
SVD	Singular Value decomposition

SA	Smart Antenna
SAS	Smart Antenna System
SCBF	Smart CBF Beamforming Transmission
SRS	Sounding Reference Signal
SG	Stochastic Gradient
SSIC-MVDR	Sub-Space Interference Cancellation MVDR
TDMA	Time Division Multiple Accesses
3G	Third Generation
3GPP	Third Generation Project Partner
3D	Three Diminutions
2D	Two Dimensional
UA	Uniform Array
UCA	Uniform Circular array
ULA	Uniform Linear Array
URA	Uniform rectangular Array
UL	Uplink Transmission
UE	User Equipment
VC	Virtual Cell
WCDMA	wideband CDMA
ZF	Zero Forcing

## LIST OF SYMBOLS

$A_d$	Desired Signal Steering Vectors Matrix
$A_i$	Interferences Steering Matrix
$A$	Steering Vectors Matrix ( $q \times M$ )
$a(\theta_m)$	Steering (singular ) Vector or Array response vector
$a(\theta_0)$	Steering Vectors of SOI
$\alpha(\theta_i)$	Interference Steering Vector
$\alpha_c(\theta)$	Modified Actual MVDR Steering Vector
$BW_{eff}$	Adjustment for Bandwidth Efficiency
$BW$	Bandwidth of System
$B$	Number of Coordinated BSs
$C_i$	Estimated Spectral Efficiency
$CBF_G$	Set of UEs Belong to Region from $X_s$ to $X_b$
$C_S$	Set of UEs Belong to Coordinated Region
$c$	Speed of Light
$C_{max}$	Upper Bound Based on the Hard Spectral Efficiency of BS
$d$	Distance between Antenna Elements of the ULA
$d_{j,k}$	Distance between Adjacent BS <sub>j</sub> and k-th UE in Kilometer
$D_{i,k}$	Distance between Serving BS <sub>i</sub> and k-th UE in Kilometer
$e$	Eigen-Value of $R_D$
$f$	Frequency of the Impinging Signal
$G$	Residual ULA's Degree of Freedom
$H$	Channel Matrix ( $N_r \times N_T$ )

$h$	Channel Vector ( $1 \times N_T$ )
$h_{i,k}$	Channel Vector from Serving BS to k-th UE
$h_{j,k}$	Channel Vector from Neighboring BS to k-th UE
$h_{j,l}$	Channel Vector from Neighboring BS to $l$ -th UE
$H_{j,k}$	Fading Channel Gain from Neighboring BS to k-th UE
$H_{i,k}$	Fading Channel Gain from Serving BS to k-th UE
$I_M$	Identity Matrix ( $M \times M$ )
$JP_G$	Set of UEs Belong to Region from $X_b$ to $R$
$k$	Number of Snapshots
$L$	Number of UEs Belong to other BSs (Neighboring BSs)
$M$	Number of Interference BSs
$M$	Number of Antenna Elements in the ULA
$N_0$	Additive White Gaussian Noise (AWGN) Power
$N_{cell}$	Neighboring Cell in Single Cell Transmission Environment
$n_k$	Noise Corrupted the k-th UE's Signal on the Antenna Elements of ULA
$n_{ci}(t)$	Noise on the i-th Element of Actual Array
$n_{vi}(t)$	Noise on the i-th Element of Virtual Array
$N$	Noise Matrix ( $M \times k$ )
$N_r$	Number of Receive Antenna
$N_T$	Number of Transmit Antenna
$NC_S$	Set of UEs Belong to Non-Coordinated Region
$NT$	Total ULA's Degrees of Freedom
$P(\theta)$	Output Power Spectrum of MVDR
$P_j$	Transmitted Power of Neighboring BS <sub>j</sub>

$P_i$	Transmitted Power of Serving BS <sub>i</sub>
$q$	Number of Impinging Signals on the ULA / Number of Signal Sources
$R_D$	Actual DOA Matrix
$R_{xc}$	Auto-Covariance Matrix for Actual Array Output Data
$R$	Cell Radius
$R_y$	Covariance Matrix
$R_d$	Covariance Matrix of the Desired Signal
$R_C$	Covariance Matrix of the Actual Data
$R_{i+n}$	Covariance Matrix of the Interference Plus Noise
$R_{vc}$	Cross-Covariance Matrix between Actual and Virtual Arrays Output Data
$R_{pv}$	Pseudo- Inverse Matrix
$R$	UE Throughput
$S_D$	Desired UEs
$S_I$	Interferences UEs Set
$S_{NT-G}$	Set of Desired UEs Serve with NT-G Freedom Degrees of ULA
$S_G$	Set of Undesired UEs Served by G Residual Degrees of Freedom of ULA
$s_q$	Signal Impinging the Actual Array
$\mathbf{S}$	Signals Matrix
$SINR_{SSIC-MVDR}$	Output SINR of the SSIC-MVDR Beamformer
$S_{n,k}$	Long-Norm Shadow Fading Random Variable
$\tau_m$	Time Delay Due to Travel the Signal from Reference to Another Element
$UE_{h_{max}}$	UE with Maximum Channel Response
$u$	Eigenvector of $R_D$

$v$	Eigenvector
$w$	Beamforming Complex Weighting Vector
$w_{NS}$	Beamforming Wight of Null Steering Algorithm
$w_{i,k}$	Beamforming Weight Vector from Serving BS to k-th UE
$w_{j,k}$	Beamforming Weight Vector from Neighboring BS to k-th UE
$w_{j,l}$	Beamforming Weight Vector from Neighboring BS to l-th UE
$w_{opt}$	MVDR Optimum Weight
$w_{mmvdr}$	MMVDR Optimum Weight
$w_{SSIC-MVDR}$	SSIC-MVDR Optimal Beamforming Weight
$x(t)$	Observation Complex Signal Vector
$x_{ci}(t)$	Observation Complex Signal Vector of i-th Element in the Actual Array
$x_{vi}(t)$	Observation Complex Signal Vector of i-th Element in the Virtual Array
$X_b$	Distance of 0,6R and/or Equal to 1500 in the Proposed HCDO Technique
$X_s$	Saturation Distance (0-380) m
$X$	Transmitted Signal which Consists of the Modulated Data $s$ and the Transmit Antenna weight $w$
$X_{j,k}$	Transmitted Signal to k-th UE from Neighboring BS <sub>j</sub>
$X_{i,k}$	Transmitted Signal to k-th UE from Serving BS <sub>i</sub>
$Y_{i,k}$	Received Signal of k-th UE at Serving Cell (i)
$y(t)$	MVDR Beamforming Output
$Z_{n,k}$	Rayleigh Fading and is a Zero-Mean Unit Variance Complex Gaussian Random Variable
$\Gamma_{eff}$	Adjustment for SINR Efficiency

$\Gamma_{MVDR}$	Output SINR of the MVDR Beamformer
$\Gamma_{k\_CBF}$	SINR for k-th UE at CBF Region
$\Gamma_{k\_AJN}$	SINR for k-th UE at AJN Region
$\Gamma_i$	SINR for UE
$\Gamma_{i,k}$	Ratio of the Signal Power that UE Received from Serving BS to the Interference Signals Received from Adjacent BSs (SINR)
$\theta$	Angle of the Received Signal
$\mathcal{C}$	Channel Capacity
$\Delta d$	Change Amount in the Distance ( $d$ )
$\mu$	Eigen-Value
$\varphi$	Electric Phase Between the Array Elements
$\emptyset$	Empty Set
$\cdot^H$	Hermitian Operators
$\sigma_i$	Interference Power
$\lambda$	Lagrange multiplier
$\sigma$	Noise Power
$\bar{d}$	Path Loss Exponents
$\sigma_0$	SOI Power
$\cdot^T$	Transpose operators

## Meningkatkan Koordinasi Multisel Dalam Sistem Komunikasi Wayarles Menggunakan Kaedah Pembentukan Alur.

### ABSTRAK

Satu reka bentuk seni bina CoMP baru dicadangkan melalui bahagian inovatif sel LTE kepada tiga ruang. Teknik yang dicadangkan dikenali sebagai HCDO (Hybrid Cell Downlink Optimization). Teknik ini memberi tumpuan terhadap peningkatan kawasan litupan berdasarkan kuasa pemancaran di samping mengurangkan isyarat overhed *backhaul*. menggunakan algoritma pembentukan alur. Pembentuk alur MVDR (Minimum Variance Distortionless Response) merupakan algoritma pembentukan alur terbaik. Malangnya, MVDR sangat peka terhadap ralat vektor steering, dan dalam kes tertentu, isyarat yang diperlukan boleh dimampat. Justeru, dua kaedah pembentukan alur dicadangkan dalam tesis ini bagi mengubah suai dan meningkatkan prestasi algoritma pembentukan alur MVDR semasa. Dua kaedah yang dicadangkan, iaitu, *Modified MVDR (MMVDR)* dan *Sub-Space Interference Cancellation MVDR (SSIC-MVDR)*, menekankan tentang peningkatan keanjalan MVDR terhadap ralat vektor steering yang disebabkan ralat daripada kalibrasi / tentukur atau pembuatan. Prestasi penilaian, perbandingan dan analisis menunjukkan bahawa algoritma MMVDR dan SSIC-MVDR adalah kaedah yang tidak begitu kompleks, yang dapat mengurangkan kos (bilangan antena) lebih daripada 61.5 % di samping mengurangkan masa pemrosesan melalui pengurangan bilangan tangkapan gambar sehingga 99%. Keputusan juga menunjukkan bahawa penggabungan SSIC-MVDR ke dalam teknik HCDO dapat meningkatkan kualiti isyarat pemancaran, dan sel litupan isyarat pengguna yang dimodulasi dengan skema QAM, dan meningkatkan sektor sel thruptut sebanyak 136.99%. Selanjutnya, isyarat overhed dan kependaman respons dapat dikurangkan kerana stesen pangkalan CoMP berupaya menjana pembentukan alur tanpa bantuan CU.