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

**by**

**OMAR KHALDOON ABDULRAHMAN**
**(1340811034)**

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Author's full name: OMAR KHALDOON ABDULRAHMAN

Date of birth : 09 - 04 - 1973

Title: Enhanced Multi-Cell Coordination in Wireless Communication System Using Beamforming Methods

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| | |
|---|---|
| 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$\times M$) |
| $\mathrm{a}(\theta_m)$ | 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 $BS_j$ and k-th UE in Kilometer |
| $D_{i,k}$ | Distance between Serving $BS_i$ 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 $BS_j$ |

| | |
|---|---|
| $P_i$ | Transmitted Power of Serving $BS_i$ |
| $q$ | 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 |
| $\mathsf{R}_{\mathrm{y}}$ | Covariance Matrix |
| $\mathsf{R}_{\mathrm{d}}$ | Covariance Matrix of the Desired Signal |
| $R_C$ | Covariance Matrix of the Actual Data |
| $\mathsf{R}_{\mathrm{i+n}}$ | 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 |
| S | Signals Matrix |
| $SINR_{SSIC-MVD}$ | Output SINR of the SSIC-MVDR Beamformer |
| $\mathcal{S}_{n,k}$ | 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 |
| $\mathrm{w_{opt}}$ | MVDR Optimum Weight |
| $\mathrm{w_{mmvdr}}$ | 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 Vertual 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 $\mathrm{BS_j}$ |
| $X_{i,k}$ | Transmitted Signal to k-th UE from Serving $\mathrm{BS_i}$ |
| $Y_{i,k}$ | Received Signal of k-th UE at Serving Cell (i) |
| y(t) | MVDR Beamforming Output |
| $\mathcal{Z}_{n,k}$ | Rayleigh Fading and is a Zero-Mean Unit Variance Complex Gaussian Random Variable |
| $\Gamma_{eff}$ | Adjustment for SINR Efficiency |

| | |
|---|---|
| $\Gamma_{\text{MVDR}}$ | 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) |
| θ | Angle of the Received Signal |
| $\mathcal{C}$ | Channel Capacity |
| $\Delta d$ | Change Amount in the Distance ($d$) |
| $\mu$ | Eigen-Value |
| φ | Electric Phase Between the Array Elements |
| ∅ | Empty Set |
| $)^{H}$ | Hermitian Operators |
| $\sigma_{i}$ | Interference Power |
| $\lambda$ | Lagrange multiplier |
| σ | Noise Power |
| $\partial$ | Path Loss Exponents |
| $\sigma_0$ | SOI Power |
| $)^{T}$ | Transpose operators |