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Network Placement. Description

Wireless Mobile Simulator (WiMo-SIM)

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1. Aim and scope

This document explains how to obtain a network realization related to the radio access part of both Downlink (DL) and Uplink (UL), of a two tier cellular network. The positions of Macro Access Points (MAPs), Pico Access Points (PAPs) and User Equipments (UEs) as well as some statistics that are required by Wireless Mobile SIMulator (WiMo-SIM) are obtained and stored in *.mat* files. Additionally some *.fig* files give several representations of the generated network. The network topologies that can be generated range from single tier hexagonal cellular network to two-tier cellular network with irregular deployment. Random and deterministic positions for Access Points (APs) and UEs can be considered. In the uplink, Fractional Power Control (FPC) with a maximum transmit power is considered as well as coupled and decoupled access with the downlink. Additionally it can be chosen several static frequency planning algorithms, including Fractional frequency Reuse (FFR) and Partial Frequency Reuse (PFR).

2. Features

This tool places the APs (macro and pico) and UEs according to several spatial distributions. Among the set of APs and UEs that are placed in the considered area, only a subset of those APs and UEs are actually simulated for computational reasons since in WiMo-SIM all the steps of PHY & MAC layers of LTE/LTE-A are implemented. This simulated subset of APs and UEs is chosen close to the center of the simulated area in order to avoid border effects. The average interference that generates the rest of APs and UEs to each simulated AP and UE is calculated by *networkPlacement* application. Then, this term of interference is taken into account in WiMo-SIM as Gaussian interference. However, it should be noticed that the interference caused by the simulated subset is accurately considered taking into account all the PHY & MAC layer LTE features like source model, channel aware scheduling, hybrid automatic repeat request protocol, etc.

The number of MAPs to be simulated considered for simulation is an input parameter to *networkPlacement.exe*. The PAPs that fall in the Voronoi cell of each MAP are also considered for simulation in WiMo-SIM. However, only APs that are associated with at least one UE are actually simulated in WiMo-SIM. The positions of the MAPs can follow either a Poisson Point Process (PPP) or a hexagonal grid. The positions of PAPs can be given by:

- PPP where the number of PAPs falling inside each MAP is random.
- Binomial Point Process (BPP) where the number of PAPs per MAP is deterministic.
- Deterministic a pattern where positions of the simulated PAPs are chosen.

Finally the positions of simulated UEs can be either a BPP or follow a deterministic pattern. The positions of non simulated UEs, i.e. UEs outside the Voronoi cell of simulated MAPs, follow a PPP.

The association in the DL is based on average weighted received power, i.e. received power plus a bias for Cell Range Expansion (CRE). In the UL the UE association can be either coupled with the DL, i.e. the same association as in the DL, or decoupled with the DL association. In the latter case, the association criterion is based on minimum path loss. Additionally, it is considered FPC with a maximum transmit power, hence UEs try to partially compensate their path loss as long as they do not require more power than the maximum allowed.

Regarding frequency planning, full reuse in all cells, PFR and FFR are considered. In the case of FFR the cell is spatially divided in two regions: cell interior and cell edge, based on a Signal to Interference Ratio (SIR) criterion. UEs that fall in the interior region use full frequency reuse. UEs that fall in the cell edge region use frequency reuse with a number of sub-bands given by the rombic numbers (i,j) with the following expression: $i^2+j^2+i\cdot j$. For the hexagonal case the allocation of cell edge sub-bands to each AP can follow an algorithm that maximizes the co-channel distance or either can be random. The allocation of cell edge sub-bands to PAPs can be the same as the associated MAP or a randomly chosen sub-band. Full reuse in all cells can obtained selecting PFR as frequency planning and the rombic numbers (1,0).

3. Description of input network parameters

Name	Data type	Values	Description
GENERAL PARAMETERS			
p_wirelessLink	string	DL, UL	It indicates whether the DL or UL is considered for simulation
p_resultFolder	string		Name of the result folder
p_wimoResultFile	string		Beginning of the name assigned to the *.mat* file with simulation results
p_loadSpatReal	bool	true, false	It indicates whether the positions of APs and UEs are loaded from a *.mat* file or generated in this run
p_loadFolder	string		Name of the file that contains the positions of APs and UEs in case *p_loadSpatReal ='true'*
p_nSpatReal	scalar	> 0	Number of network realization to be generated
p_sideLength	scalar		Length of the simulated area in meters

p_statistCalc	string	empirical, semiAnalytical	It indicates whether the statistics are obtained empirically through pure Monte Carlo simulations or if they are obtained using analytical results
p_nStatistReal	scalar	> 0	Number of realizations in order to compute statistics through Monte Carlo simulation
p_nValues	scalar	> 0	Number of elements of vector parameters
p_saveFig_spatReal	scalar	0 , 1	It indicates whether informative figures are stored for each spatial realization (1) or not (0)
p_saveFig_values	scalar	0 , 1	It indicates whether informative figures are stored additionally for each value of the vector parameters (1) or not (0)
		ASSOCIATION	
p_ul_decoupled	bool	true, false	It indicates whether the access in the UL is coupled with the DL association or not
p_credB(*)	scalar	≥ 0	Cell Range Expansion bias for association related to PAPs. Bias for MAPs is considered to be 0 dB.
p_map_pMaxdBm(*)	vect		Maximum transmit power (dBms) per Resource Element (RE) for MAPs
p_pap_pMaxdBm(*)	vect		Maximum transmit power (dBms) per RE for PAPs
		UL FRACTIONAL POWER CONTROL (FPC)	
p_ue_epsilon(*)	vect	[0 – 1]	Power control factor for the UL
p_ue_pMaxdBm(*)	vect		Maximum transmitted power per RE for UEs
p_ue_p0dBm(*)	vect		Target received power for FPC
		POINT PROCESSES (PPs)	
p_map_type	string	grid, ppp	It determines whether the positions of the MAP follows the hexagonal grid (*grid*) or a PPP (*ppp*)
p_map_density	vect		It specifies the density of MAPs in terms of points/m^2
p_map_nSim	scalar		Number of MAPs to be simulated in WiMo-SIM

p_pap_type	string	ppp, bpp, det	It determines whether the positions of the PAPs follows a PPP (*ppp*), a BPP (*bpp*), or are deterministic (*det*)
p_pap_density	vect		It specifies the density of PAPs in terms of points/m^2
p_pap_n	scalar		It specifies the number of PAPs to be simulated in WiMo-SIM in case of *p_pap_type* = *'bpp'* or *'det'*
p_pap_posPol	matrix		It specifies the positions of the PAPs to be simulated in WiMo-SIM in case of *p_pap_type* = *‘det’*. Positions are represented as row vectors
p_ue_type	string	bpp, det	It determines whether the positions of the UEs to be simulated in WiMo-SIM follow a BPP (*bpp*) or they are deterministic (*det*)
p_ue_density	vect		It specifies the density of UEs that are not simulated in WiMo-SIM in terms of points/m^2. These UEs are considered in order to be taken into account for the interference from non simulated cells.
p_ue_n	scalar		Number of UEs to be simulated in WiMo-SIM
p_ue_posPol	matrix		It specifies the positions of the UEs to be simulated in WiMo-SIM in case *p_ue_type* = *‘det’*
FREQUENCY PLANNING			
p_frPlan_spatReuse	string	PFR, FFR	It indicates whether PFR or FFR is considered
p_ffr_sirThreshdB	vect		It is a vector of two elements that indicates the SIR threshold in order to consider that a UE is a cell-edge UE or a cell-interior UE. This vector is used in case of the FFR algorithm (*p_frPlan_spatReuse* = *‘FFR’*)
p_frPlan_TypeMap	string	rombic, rand	It specifies the algorithm for MAP frequency planning. The case *rombic* is only possible for hexagonal grid (*p_map_type* = *‘grid’*) and assigns frequency obtaining maximum co-channel distance. The case *rand* is valid for both hexagonal and irregular

			grid for MAPs and assigns frequency sub-bands to each MAP randomly
p_frPlan_TypePap	string	sameAsMap, rand	The case *sameAsMap* considers that the frequency of each PAP is the same as the nearest MAP. The case *rand* assigns frequency sub-bands to each PAP randomly
p_frPlan_rhombicNbrs	vect	≥ 0	Rombic numbers that specifies the number of sub-bands for frequency planning. The number of sub-bands follows the next expression: $i^2 + j^2 + i \cdot j$
		PROPAGATION	
p_pL_model	string	standard, hata	It determines whether the propagation model is the standard, where the path loss is r^{-alpha} or it follows the Hata COST 231 model
p_pL_standard_alpha	vect		Vector of two elements that specifies the path loss exponent for the standard model of MAPs and PAPs, respectively
p_pL_hata_hm	vect		Vector of two elements that specifies the height of the antennas of MAPs and PAPs, respectively, for the case of Hata path loss model (*p_pL_model = 'hata'*)
p_pL_hata_fMHz	scalar		Carrier frequency for Hata model in MHz
p_pL_hata_env	int	1, 2, 3	It indicates the environment related to Hata model: 1 → urban 2 → sub-urban 3 → rural
		NOISE	
p_noise_thermaldBmHz	vect		Power Spectral Density (PSD) of thermal noise expressed in terms of dBm/Hz
p_noise_BHz	scalar		Bandwidth for each subcarrier. It is 15 kHz for the case of LTE
p_noise_NFdB	vect		Noise figure for the receivers in dBs

BANDWIDTH		
p_nPRBs	scalar	Number of Physical Resource Blocks (PRBs) per Component Carrier (CC)
p_nCC	scalar	Number of CCs
p_ccSpec	Vect	Vector with dimensions 1 x p.nCC where position *i* indicates the number of PRBs associated to the *i*th CC
p_subBandSpec	matrix	Matrix with dimensions 2 x nSubBands, where nSubBands is the number of sub-bandas that depends on the rombic numbers. The first row indicates the first PRB index of each sub-band whereas the second row indicates the last PRB index

Table 1. Description of Input parameters

The parameters marked with (*) are vector parameters. All the vector parameters have *p_nValues* elements and it allows running *p_nValues* simulations in WiMo-SIM where the *i*th simulation in WiMo-SIM is associated to the *i*th element of each vector parameter. If we aim to obtain simulations results in WiMo-SIM where only one vector parameter varies we can leave the rest of vector parameters as scalar values.

The result generated for the *x*th element of the vector parameters is identified with the string: '_iV'+ *x*. Hence, *x* ranges from 1 to *p_nValues*.

Moreover, according with the value of the parameter *p_nSpatReal,* it will be generated as many spatial realization as *p_nSpatReal*. Each spatial realization generated is stored in a concrete *.mat* file which is identified with the string: '_iR'+*j*, where *j* represents the number of the spatial realization and ranges from 1 to *p_nSpatReal*.

Therefore, there will be generated as many *.mat* files as *p_nValues·p_nSpatReal* identified by the name: *p_wimoResultFile* + '_iR' + *j* + '_iV' + *x* + '.mat'. The number of spatial realizations and values considered should be taken into account in the *Params.xml* file in order to configure the simulation run in a correct way [1].

4. Description of output variables

In each result file with the name *p_wimoResultFile* + '_iR' + *j* + '_iV' + *x* + '.mat', we have the following variables that are used in WiMo-SIM.

Name	Dimensions	Value	Description
dl	*N/A*	0, 1	It indicates the considered link: 1 → DL 0 → UL

ueSystem	*N/A*		Number of UEs to be simulated in WiMo-SIM
cellNbr	*N/A*		Number of APs to be simulated in WiMo-SIM
nUEperCell	*cellNbr x 1*		Position 'i' contains the number of UEs associated to the *i*th AP to be simulated
nSubBands	*N/A*		Number of sub-bands
userAllocSubBand	*ueSystem x nSubBands*	0 , 1	In position 'i''j', 1 →UE *i* can be scheduled in sub-band *j* 0 → UE *i* cannot be scheduled in sub-band *j*
cellAllocSubBand	*cellNbr x nSubBands*	0 , 1	In position 'i''j', 1 →AP *i* can schedule its associated UEs in sub-band *j* 0 → AP *i* cannot schedule its associated UEs in sub-band *j*
subBandSpec	*2 x nSubBands*	[1 – nPRBs]	Position '1''i' and '2''i' indicates the initial and final PRB index, respectively, of sub-band *i*
nCC	*N/A*		Number of CC
userAllocCC	*ueSystem x nCC*	0, 1	In position 'i''j', 1 →UE *i* can be scheduled in CC *j* 0 → UE *i* cannot be scheduled in CC *j*
cellAllocCC	*cellNbr x nCC*	0, 1	In position 'i''j', 1 →AP *i* can schedule its associated UEs in CC *j* 0 → AP *i* cannot schedule its associated UEs in CC *j*
ccSpec	*1 x nCC*		In position 'i', bandwidth of CC *i* terms of number of PRBs
ueDefinition	*ueSystem x 1*	0, 1	In position 'i': 0 → UE *i* is associated to a MAP 1 → UE *i* is associated to a PAP not being the UE a CRE UE 2 → UE *i* is associated to a PAP being the UE a CRE UE
Sigma2	*N/A*		Noise power per RE
PociDl	*ueSystem x 1*		Average received interfering power that each UE receives from non simulated APs at each RE in the DL.
PociUl	*cellNbr x 1*		Average received interfering power in the UL
gsPath	*cellNbr x ueSystem*		Signal gain between each simulated AP and UE
sinrDldB	*ueSystem x 1*		Average SINR in dB for each UE in the DL
sinrUldB	*ueSystem x 1*		Average SINR in dB for each UE in

		the UL
PtApW	*cellNbr x 1*	Average transmission power for each simulated AP
PtUeActW	*ueSystem x 1*	Average transmission power for each UE with FPC in the UL

Table 2. Description of generated output variables

5. Acronyms

AP	Access Point
BPP	Binomial Poisson Process
CC	Component Carrier
CRE	Cell Range Extension
DL	Donwlink
FFR	Fractional Frequency Reuse
FPC	Fractional Power Control
LTE-A	Long Term Evolution Advanced
MAC	Medium Access Control
MAP	Macro Access Points
PAP	Pico Access Point
PFR	Partial Frequency Reuse
PPP	Poisson Point Process
PRB	Physical Resource Block
PSD	Power Spectral Density
RE	Resource Element
SIR	Signal to Interference Ratio
SINR	Signal to Interference Noise Ratio
UE	User Equipment
UL	Uplink
WiMo-SIM	Wireless Mobile SIMulator

6. References

[1] Params_Description_v2.1.pdf