Simulation Outputs

The resulting outputs of a simulation run are the coordinates of the enabled TNs, NTNs or UAVs, the coordinates of the EDs and the metrics Signal-to-Interference-plus-Noise Ratio (SINR), Block Error Rate (BLER) and Channel Quality Indicator (CQI). By default (print_scenario_outputs = True; print_metrics_outputs = True), the outputs are printed out in the Run console of the chosen simulator environment (In our case PyCharm 2023.2.8, Community Edition). Moreover, you can decide to save or not the metrics the corresponding coordinates and metrics as independent .xlsx files by enabling save_scenario_xlsx = True and save_metrics_xlsx = True. Such output files are stored in the project file output under the paths:

- output/scenario/ …
- output/metrics/…

The names of each one of the files are clearly differentiated and easy to identify and include the date and time for each simulation run. Regarding the metrics output files is also generated a .pkl file that gathers all the metrics information in a unified format.

As an output it is also possible to show (show_video = True) and save (save_video = True) a .gif video file with the simulated grid and nodes movements. The saved video can be found in:

- output/scenario/recreated_scenario.gif

To better understand the outputs of a simulation run, we generate a toy simulation example. First, we uncomment in the main.py file the following commands, fixing the random variables from run to run and obtaining consistent outputs:

```
49|     np.random.seed(42)
50|     random.seed(42)
```

We define a **grid of 100 x 100 meters**, with **five seconds of simulation** with a **resolution of one** second. We enable **four EDs** with a **Random Waypoint mobility**. We enable **one UMa** in the middle of the grid and **one satellite** with a desired elevation angle of 85°. The only purpose of the selected simulation settings is to show the corresponding outputs for a simple scenario. The printed outputs in the Run Console of our PyCharm environment are as follow:

File: main

```
C:\Users\cperra\AppData\Local\Programs\Python\Python39\python.exe "D:\PostDocTrabajo\LLS 5G-MBS-BF\LLS_from_git\main.py"
```

general_simulation_parameters

	grid_xy	grid_center_latitude	grid_center_longitude	simulation_time	simulation_resolution	downlink	uplink	d2d_link	ntn_link	save_scenario_xlsx	save_metrics_xlsx	show_video	save_video	video_format	video_velocity	print_scenario_outputs	print_metrics_outputs
0	[100, 100]	39.2338	9.11558	5	1	True	False	False	True	True	True	True	True	gif	0.1	True	True

general_channel_modeling

	dynamic_loss	dynamic_ntn	o2i	inside_what_o2i	penetration_loss_model	shadowing	fast_fading	fast_fading_model	atmospheric_absorption	desired_delay_spread
0	True	False	False	dynamic	low-loss	True	True	jakes	False	Very short

general_parameters

	thermal_noise	n_ceiling	block_density	channel_type	target_bler
0	-174	10	0.2	real	0.1

bs_parameters

	x	y	z	type	scenario	antenna_mode	ax_panel_polarization	fast_fading_los_type	fast_fading_nlos_type	fc	numerology	n_rb	p_tx	ax_gain	cable_loss	noise_figure	v_tilt	desired_elevation_angle
0	50	50	25	tbs	UMa	three_sectors	dual	E	B	28	2	50	20	10	2	7	15	nan
1	39.2338	9.12154	50000	sat	HAPS	Sat_ax	dual	E_ntn	A_ntn	2	2	50	36	30	2	7	nan	85

sub_groups_parameters

	type	k_sub	antenna_mode	p_tx	ax_gain	cable_loss	noise_figure	d2d	fixed_height	grid_size_ratio	reference_location	min_max_velocity	exit_time	mobility_model	aggregation	number_mg_rpg_model	min_max_height	rx_scenario
0	pedestrian	4	omni	0	0	0	7	True	True	[1, 1]	[50, 50]	[0.4, 1.2]	1	Random Waypoint			[1.5, 1.5]	urban

```
INFO:matplotlib.animation:Animation.save using <class 'matplotlib.animation.PillowWriter'>
data frame with the x coordinates of the simulated end-devices
    0     1     2     3     4
0  0.0  69.19  67.81  25.09  77.43
1  1.0  68.95  68.50  26.34  77.82
2  2.0  68.72  69.19  26.80  76.62
3  3.0  68.49  69.88  27.26  76.22
4  4.0  68.26  70.57  27.72  75.82
data frame with the y coordinates of the simulated end-devices
    0     1     2     3     4
0  0.0  62.18  71.89  19.93  4.84
1  1.0  61.02  72.52  19.74  4.84
2  2.0  59.86  73.15  19.54  4.84
3  3.0  58.70  73.78  19.35  4.84
4  4.0  57.54  74.41  19.15  4.83
data frame with the z coordinates of the simulated end-devices
    0    1    2    3    4
0  0.0  1.5  1.5  1.5  1.5
1  1.0  1.5  1.5  1.5  1.5
2  2.0  1.5  1.5  1.5  1.5
3  3.0  1.5  1.5  1.5  1.5
4  4.0  1.5  1.5  1.5  1.5
data frame with the x,y,z coordinates of the simulated terrestrial base-stations
   TBS    X     Y   Z
0    1  50.0  50.0  25.0
data frame with the x,y,z coordinates of the simulated aerial base-stations (UAV)
   ABS  X  Y  Z
0    0  0  0  0
data frame with the lla: latitude, longitude, and altitude of the simulated satellites (Sat)
   SAT  latitude  longitude  Altitude  Elevation angle
0    1     39.23       9.12   50000.0            87.10
data frame with the downlink sinr of the end-devices regarding the base-station: 1 (tbs)
    t     0     1     2     3
0  0.0  21.12  19.31  11.02 -1.66
1  1.0  21.27  17.41  13.57 -3.09
2  2.0  19.41  19.45  14.25 -1.72
3  3.0  20.09  19.74  13.94 -1.70
4  4.0  20.31  18.16  12.56 -2.74
data frame with the downlink CQI of the end-devices regarding the base-station: 1 (tbs)
    t     0     1     2     3
0  0.0  12.0  12.0  8.0  3.0
1  1.0  12.0  11.0  9.0  2.0
2  2.0  12.0  12.0  9.0  3.0
3  3.0  12.0  12.0  9.0  3.0
4  4.0  12.0  11.0  9.0  2.0
data frame with the downlink bler of the end-devices regarding the base-station: 1 (tbs)
    t     0         1         2         3
0  0.0  0.00  7.10e-02  7.90e-01  0.06
1  1.0  0.00  1.42e-02  1.12e-02  0.03
2  2.0  0.07  6.80e-02  3.00e-03  0.06
3  3.0  0.06  6.42e-02  6.59e-03  0.06
4  4.0  0.05  6.70e-02  2.70e-01  0.02
data frame with the downlink sinr of the end-devices regarding the base-station: 2 (sat)
    t     0     1     2     3
0  0.0  1.18  2.69  7.07 -0.51
1  1.0  1.68  1.40  8.02 -1.68
2  2.0  1.03  3.79  7.99 -1.51
3  3.0  1.75  4.55  7.23 -2.10
4  4.0  2.30  2.85  6.63 -1.54
data frame with the downlink CQI of the end-devices regarding the base-station: 2 (sat)
    t     0    1    2    3
0  0.0  4.0  5.0  7.0  3.0
1  1.0  4.0  4.0  7.0  3.0
2  2.0  4.0  5.0  7.0  3.0
3  3.0  4.0  5.0  6.0  3.0
4  4.0  5.0  5.0  6.0  3.0
data frame with the downlink bler of the end-devices regarding the base-station: 2 (sat)
    t     0         1         2         3
0  0.0  0.04  8.46e-02  7.79e-02  0.01
1  1.0  0.03  3.36e-02  6.34e-02  0.06
2  2.0  0.04  2.16e-02  6.58e-02  0.05
3  3.0  0.02  4.80e-03  6.20e-03  0.08
4  4.0  0.10  7.80e-02  1.24e-02  0.05

Process finished with exit code 0
```