UNIVERSITAT POLITÈCNICA
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BARCELONATECH

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Wireless Laboratory

230689 - WLAB

Practice 1
Planning and optimization of LTE networks
Laboratory work

Authors :
Thomas Bruyère
Louis Delait

Professor :
Anna Umbert Juliana

Polytechnic University of Catalonia
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1 Objectives

The objective is this case study is to carry out, using ATOLL, the planning and dimensioning of a LTE network in order to meet coverage and application / service performance requirements. The considered service region ranging must be included between 30 and 50 km^2.
This work includes decision making on the type of infrastructure to be deployed (macrocells and / or small cells) and their locations as well as the specification of the traffic demand maps.

The sections of this report will cover :

* Configuration of the deployed network (sites, transmitters, antennas, frequency band, channel bandwidth, etc.).
* Configuration of the services and user densities (service types and parameters, user types and densities).
* Coverage analysis.
* Capacity analysis and service performance.

2 Model Configuration

2.1 Covered Area

We decided to cover the district of **Sant-Celoni** for this project (See Fig 1).

Figure 1 – Area of interest - location in Spain

The covered area is findable on Fig 2. It envelopes 31.499 km^2 an respect therefore the problem specifications.

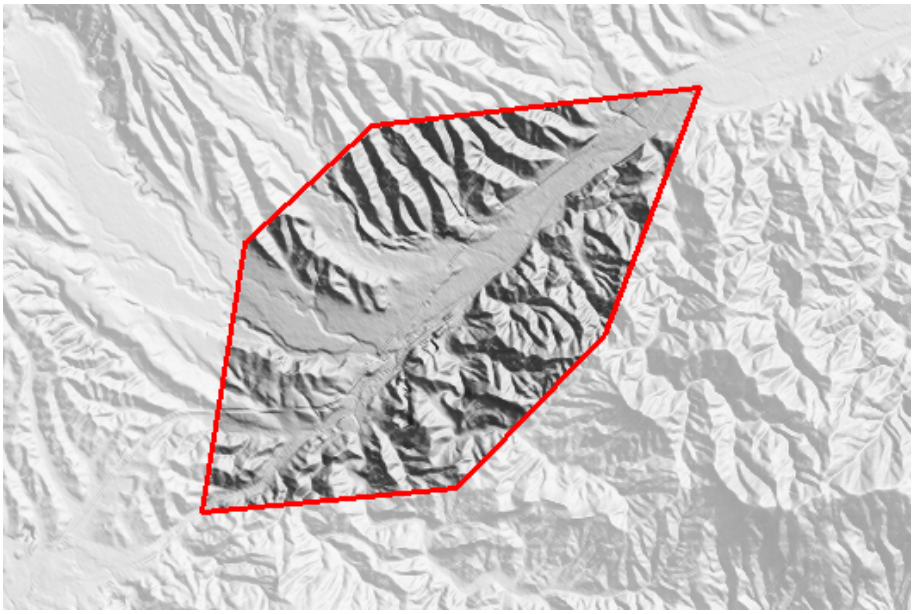

Figure 2 – Area of interest - Precise Area

2.2 Performance requirements

The section describes the performance requirements of our communication network.

2.2.1 Users

The section describes the user density and the kind of services needed on the covered area.

2.2.1.1 Typer of users

The map is filled by standard and business users with the **performance requirements** of Fig 3 and 4.

	Service	Terminal	Calls/hour	Duration (sec.)	UL Volume (KBytes)	DL Volume (KBytes)
	High Speed Internet	MIMO Terminal	0.05		2,000	15,000
	Video Conferencing	MIMO Terminal	0.01	600		
	VoIP	Mobile Terminal	0.2	240		
	Mobile Internet Access	MIMO Terminal	0.1		700	4,500
*						

Figure 3 – Business profile requirement

	Service	Terminal	Calls/hour	Duration (sec.)	UL Volume (KBytes)	DL Volume (KBytes)
	Mobile Internet Access	MIMO Terminal	0.1		700	4,500
	VoIP	Mobile Terminal	0.2	240		
*						

Figure 4 – Standard profile requirement

2.2.1.2 Population density

St-Celoni population density is fixed to 279 $\frac{people}{square\ meter}$(see *this link*).

2.2.1.3 User Areas Definition

The area we choosed covers different types of lands (valley with the village and hills with less population). The population density has then to be arranged to match as close as possible to the reality and is depicted on figure 5.

The population density is then as defined in the TAB 1.

2.2.1.4 User repartition

Furthermore we decide to separate this population density between 10% of business users and 90% of standard users for urban area. For the other areas no business users are defined, leading to the result of TAB 1

Type of Area	rural	suburban	urban
population density $[/km^2]$	150	300	450
Strd User Density $[/km^2]$	150	300	405
Business User Density $[/km^2]$	0	0	45

Table 1 – Population Density Table

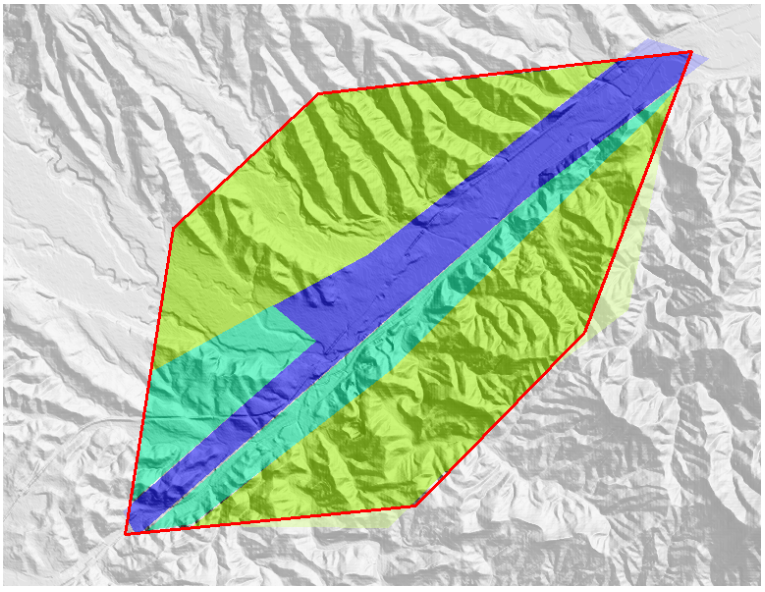

Figure 5 – User Areas
Green = rural | light blue = suburban | blue = urban

2.2.2 Services

The service required in our case are High Speed Internet, Mobile Internet Access, MTC, Video Conferencing and VoIP. Detailled service demand is findable on Fig 6.

Name	Type	Priority (0:lowest)	Min DL throughput demand (kbps)	Min UL throughput demand (kbps)	Max Throughput Demand (DL) (kbps)	Max Throughput Demand (UL) (kbps)	Average Requested Throughput (DL) (kbps)	Average Requested Throughput (UL) (kbps)	Min Number of PRBs (UL)	Multicarrier Support
High Speed Internet	Data	1	0	0	1,024	128	256	32	1	1
Mobile Internet Access	Data	0	64	32	128	64	64	32	1	1
MTC		0	0	0	0	0	0	0	31	0
Video Conferencing	Voice	2	64	64	64	64	64	64	1	0
VoIP	Voice	3	12.2	12.2	12.2	12.2	12.2	12.2	1	0

Figure 6 – Services Definition

Seeing the topology of the area of St Celoni, we target to reach 90 % of validation for this services demand.

2.3 Radio Network Equipement definition

We first decided to place 13 sites on the map, each made of 3 transmitters. The antennas operate at 30 [m] with the beamforming parameters set to 60deg 16dBi 2Tilt 2600MHz.
The transmitters position is represented in figure 7.

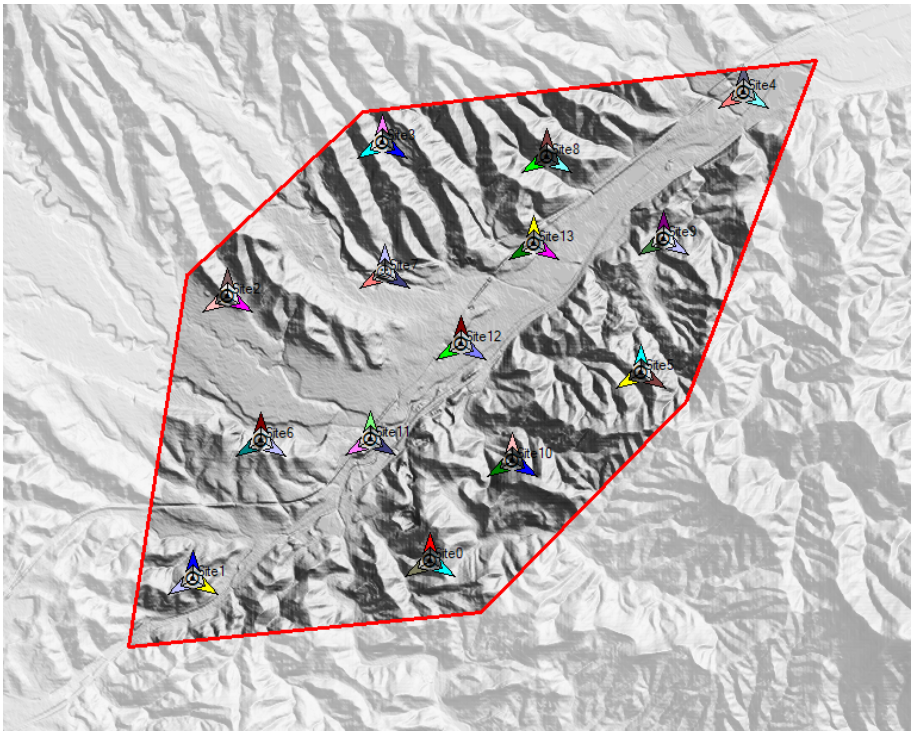

Figure 7 – Map with Transmitters

The goal of the previous sections will then to check this disposition and make it evolve such that the requirements are full-filed if it is not the case.

3 Model Performances

3.1 Coverage Prediction

This section is focused on the performances of the previously defined model.

Based on the defined parameters, we get the following **Throughput coverage predictions for the High Speed internet** :

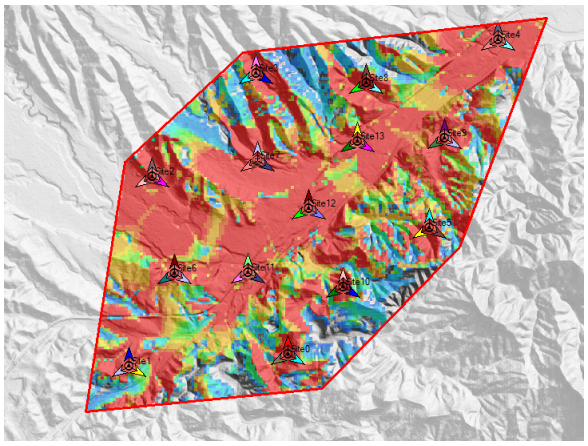

Figure 8 – Downlink Prediction Coverage

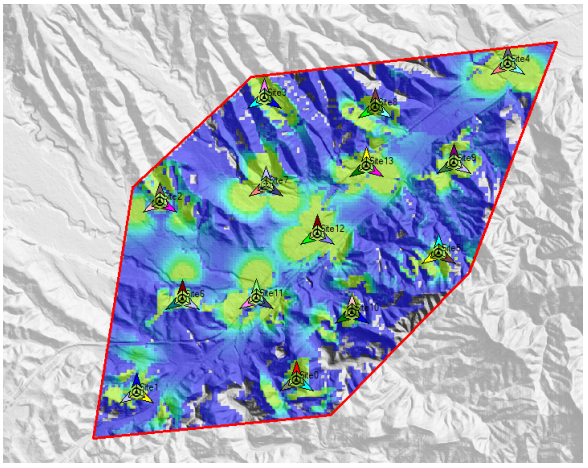

Figure 9 – Uplink Prediction Coverage

With the following legend :

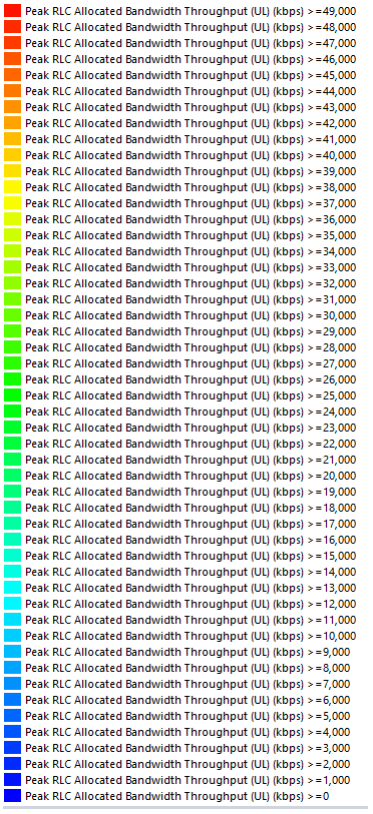

Figure 10 – Coverage Prediction Legend

Although the coverage as first seen looks good in DL but not in UL, this could be explained as the service requirement for the service (High Speed Internet) is low in UL (less than 128 kbps).
we will then launch a simulation to see if the transmitter disposition or characteristics need to be reevaluated.

3.2 Simulation

3.2.1 Results

The simulation 1 demonstrates pretty good results with 92.8 % of the users connected. The demand and results are shown below : We can then launch more predictions to validate this simulation.

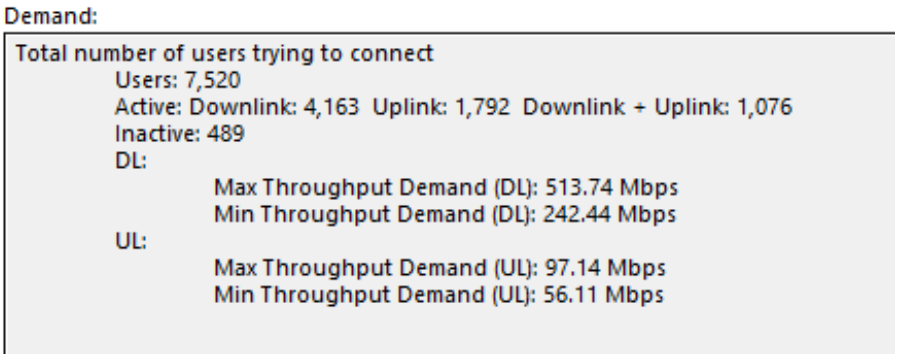

Figure 11 – Simulation Demand

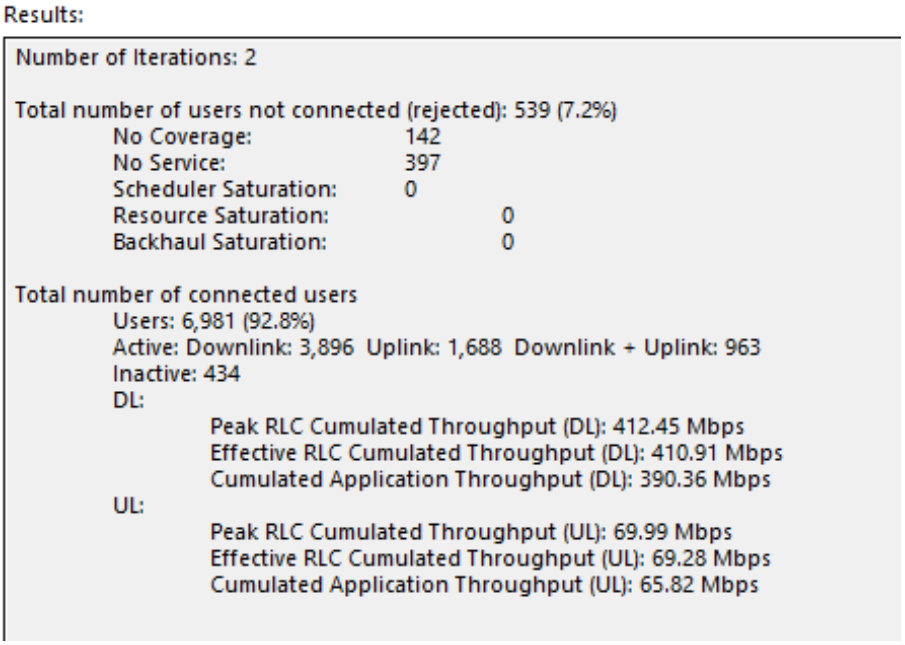

Figure 12 – Simulation Results

To go more into details, let´s look at the High Speed Internet throughput informations that where discussed above in the prediction : We see that both in UL and DL the figures are good enough for our requirements.

The percentage of connected users of 92.8 % is quite good, seeing the topology of the area that we selected. The communication network matches then our requirements.

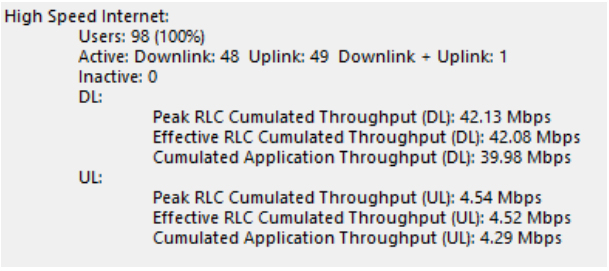

Figure 13 – HSI throughput

3.2.2 network Improvement

Transmitter	Traffic Load (DL) (%)	Traffic Load (UL) (%)
Site0_1	9.54	2.81
Site0_2	15.12	4.2
Site0_3	25.18	5.94
Site1_1	56.57	13.89
Site1_2	42.08	10.49
Site1_3	27	7.26
Site10_1	22.08	5.94
Site10_2	1.52	0.88
Site10_3	11.28	5.77
Site11_1	51.52	13.14
Site11_2	18.36	4.8
Site11_3	44.46	13.09
Site12_1	35.61	8.44
Site12_2	24.84	7.52
Site12_3	39.13	10.59
Site13_1	17.41	3.83
Site13_2	40.27	13.24
Site13_3	27.53	7.27
Site2_1	7.66	2.1
Site2_2	19.33	3.46
Site2_3	11.35	3.17
Site3_1	2.36	0.98
Site3_2	10.41	3.49
Site3_3	4.17	0.17
Site4_1	11.57	1.82
Site4_2	31.96	7.67
Site4_3	74.4	17.57
Site5_1	26.97	5.79
Site5_2	7.32	1.72
Site5_3	14.68	4.64
Site6_1	24.97	7.15
Site6_2	12.03	1.57
Site6_3	11.89	1.9
Site7_1	16.73	5.65
Site7_2	25.08	4.14
Site7_3	18.05	3.92
Site8_1	7.44	4.06
Site8_2	26.92	7.01
Site8_3	5.9	2.21
Site9_1	18.75	6.06
Site9_2	10.09	2.91
Site9_3	10.55	2.31

Figure 14 – Cell average Trafic load

A pist to improve the network could be to look at the cells trafic and delete the cell that are used with lower than 5 % of traffic load in DL and UL.

For example looking at the Cell average activity (Fig 14) we see that the sites

- site10_2
- site3_1
- site3_3
- site8_3

could be deleted.

Doing it we get the following simulation results statistics : We can then launch more predictions to validate this simulation with the 4 antenna deactivated (See Fig 16.

Results:

Number of Iterations: 2

Total number of users not connected (rejected): 558 (7.3%)
No Coverage: 167
No Service: 391
Scheduler Saturation: 0
Resource Saturation: 0
Backhaul Saturation: 0

Total number of connected users
Users: 7,084 (92.7%)
Active: Downlink: 3,981 Uplink: 1,666 Downlink + Uplink: 988
Inactive: 449
DL:
Peak RLC Cumulated Throughput (DL): 429.44 Mbps
Effective RLC Cumulated Throughput (DL): 427.92 Mbps
Cumulated Application Throughput (DL): 406.51 Mbps
UL:
Peak RLC Cumulated Throughput (UL): 69.65 Mbps
Effective RLC Cumulated Throughput (UL): 69 Mbps
Cumulated Application Throughput (UL): 65.55 Mbps

Figure 15 – Simulation Results with improved model

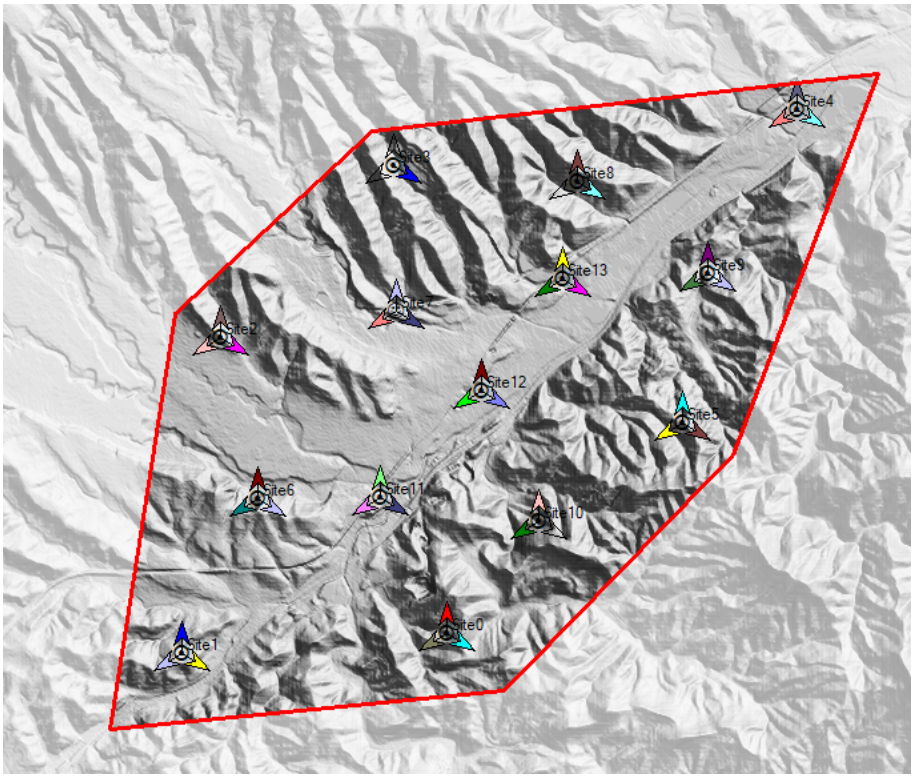

Figure 16 – Improved Network with deqctivated antennas

3.3 Further predictions

All the following predictions are made for downlink as the uplink results are very close and evolve in the same way.

3.3.1 Coverage Prediction C/I+N

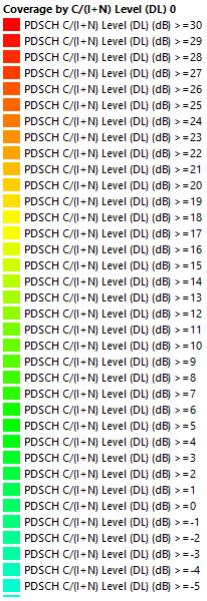

Figure 17 – Coverage Prediction C/I+N Legend

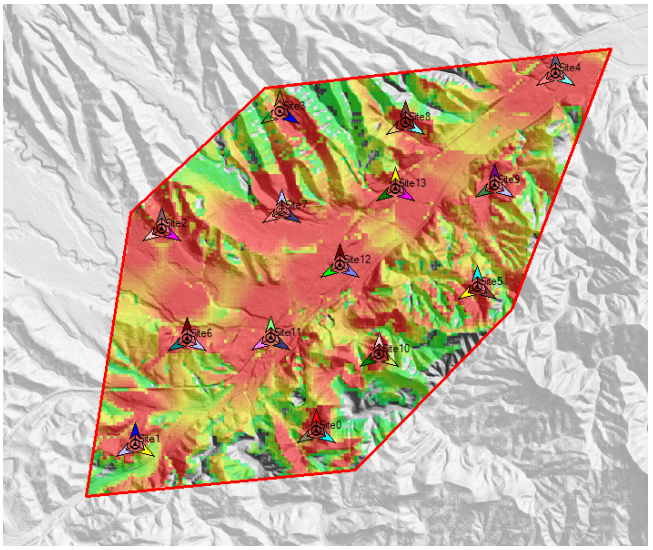

Figure 18 – Coverage Prediction C/I+N

We notice that, taking the simulation into account, the Coverage prediction taking into account noise and cell inteference is still very good.

3.3.2 Overlapping zones

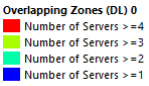

Figure 19 – Overlapping zones Legend

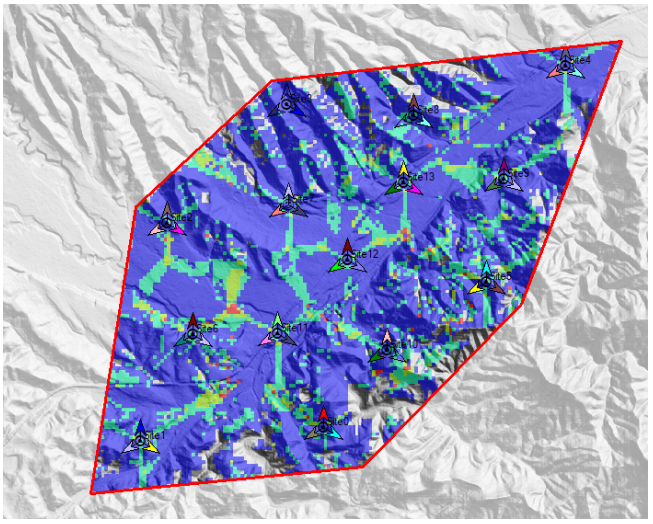

Figure 20 – Overlapping zones

We notice that there is very few overlapping, leading to a transmitter location and direction close to optimum in term of Overlapping.

3.3.3 Coverage by RSRP Level

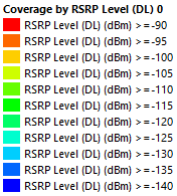

Figure 21 – Coverage by RSRP Level Legend

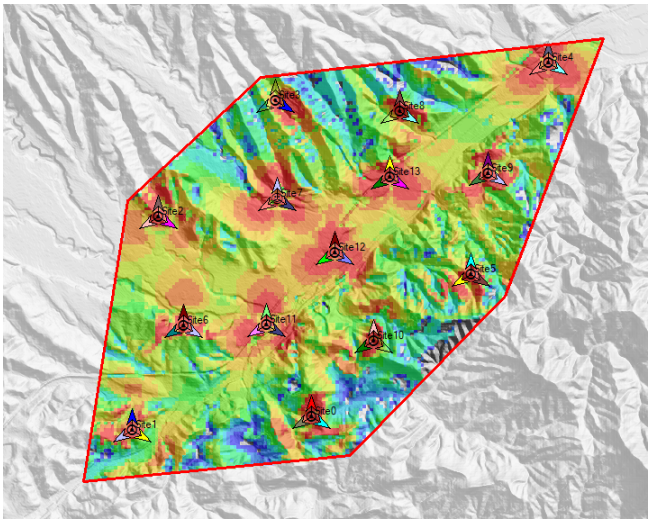

Figure 22 – Coverage by RSRP Level zones

We notice that, taking the simulation into account, the Coverage prediction taking into account the RSRP (the Reference Signal Received Power is a measurement of the received power level in an LTE cell network) is almost on all the area over -120 dBm.

3.4 Conclusion

After this predictions, simulations and model imprevement, we can conclude that there is no more need of an enhancement of the transmitters features or locations as the services requirements are fulfilled.

4 Limit of the model

In this bonus section we will increase the population density by a factor 10 to simulate a day of big occupation in Sant-Celoni, as example the day of market in St Celoni (*this link*). We will then see to what value the mean percentage of connected users goes.
The simulation map is on Fig 23

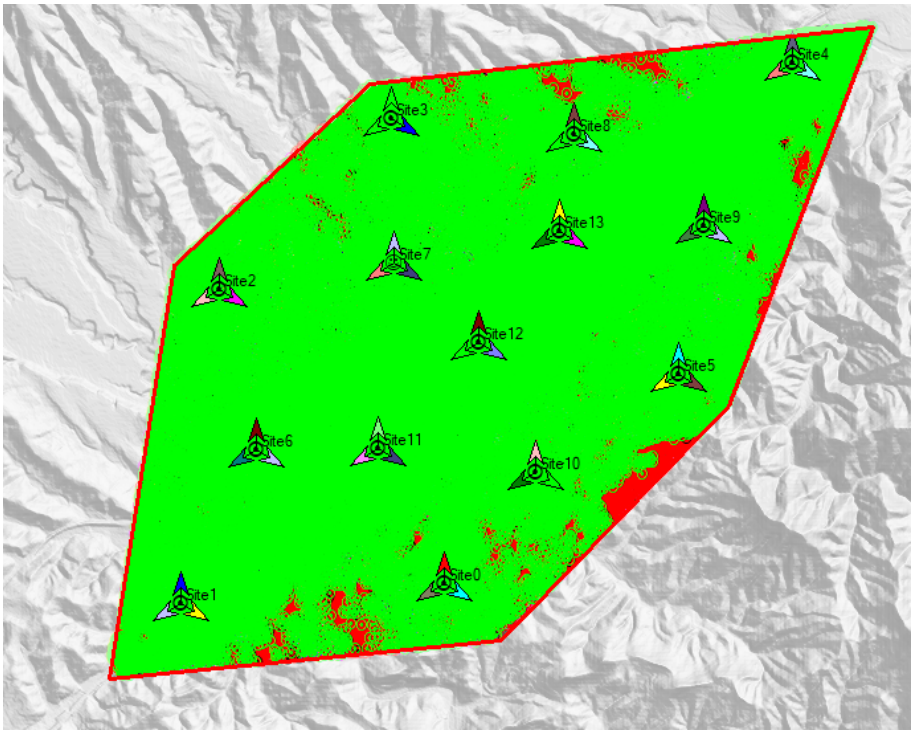

Figure 23 – Simulation Results with x10 people comapared to defined user density

As shown on the Fig 25, the mean percentage of connected users falls to 71.4 % for around 75000 people, we then have a still good coverage unless this strong increase of population density.

Demand:

Total number of users trying to connect
Users: 76,576
Active: Downlink: 42,529 Uplink: 18,428 Downlink + Uplink: 10,759
Inactive: 4,860
DL:
Max Throughput Demand (DL): 5,235.87 Mbps
Min Throughput Demand (DL): 2,464.54 Mbps
UL:
Max Throughput Demand (UL): 1,000.02 Mbps
Min Throughput Demand (UL): 568.47 Mbps

Figure 24 – x10 users - Demand

Results:

```
Number of Iterations: 2

Total number of users not connected (rejected): 21,911 (28.6%)
        No Coverage:                1,520
        No Service:                 4,140
        Scheduler Saturation:       0
        Resource Saturation:                16,251
        Backhaul Saturation:                0

Total number of connected users
        Users: 54,665 (71.4%)
        Active: Downlink: 24,280  Uplink: 16,396  Downlink + Uplink: 9,613
        Inactive: 4,376
        DL:
                Peak RLC Cumulated Throughput (DL): 1,439.92 Mbps
                Effective RLC Cumulated Throughput (DL): 1,430.79 Mbps
                Cumulated Application Throughput (DL): 1,359.3 Mbps
        UL:
                Peak RLC Cumulated Throughput (UL): 629.19 Mbps
                Effective RLC Cumulated Throughput (UL): 622.46 Mbps
                Cumulated Application Throughput (UL): 591.34 Mbps
```

Figure 25 – x10 users - Results