Self-Organizing Networks on LTE System:

Antenna Parameters Configuration Effects On LTE Networks Coverage with Respect to Traffic Distribution

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Abstract— **The new OFDMA-based technology is referred to as the Evolved UMTS Terrestrial Radio Access (E-UTRA) through the Long Term Evolution (LTE) system. This paper proposes to add Self-Organizing functionalities on the antenna architecture, so that the network will be more responsive to changes in traffic and environment. This paper also shows the interest of a robust approach due to the uncertainty of the traffic distribution. First, we develop and validate the interference model based on SINR metric for the deployment of the LTE network, and then we use greedy algorithms to show how the antenna parameters settings such as frequency, tilt and output power, can highly impact the networks coverage due to the traffic changes.**

Keywords-LTE; SON; SINR; interference; parameter setting; optimization; robustness

I. INTRODUCTION

The Long Term Evolution (LTE) is a new air-interface designed by the Third Generation Partnership Project (3GPP) [6]. The 4th generation of mobile system is aimed to achieve additional substantial leaps in term of service provisioning and cost reduction [3]. In addition, to make the network design process time-efficient, Self-Organizing Network (SON) functionalities added within LTE architecture by incorporating automated optimization, can significantly reduce deployment and maintenance costs (CAPital EXpenditure and OPerating Expenditure, respectively). The self-organization capability of a mobile network mainly includes three aspects: self-configuration, self-optimization and self-healing [17]. Focus in this paper is on self-optimization to achieve better network performance goals. The self-optimization phase is preceded by a step of measurements carried out on all the resources to recover data as different as the workflow [18]. This will include assessing network performance toward the user request such as traffic and mobility. Measures may include the characteristics of radio channels, admission, congestion, handover, etc. These measures serve as input data for the self-optimization. In the self-optimization phase, considered as the intelligent phase in SON, effective methods are applied to the previous data to carry out the management of the network based on user needs in traffic demand and quality of service. The optimization involves the physical parameters of antennas (frequency allocation, tilt, azimuth radiation, power, etc.).

In wireless networks, the main key to improve the achievable average throughput by user is to mitigate the inter-cell interference [1, 2] caused by using the same frequency within adjacent cells. Various frequency reuse schemes have been proposed in literature [3, 4, 5].

Resource allocation in radio networks essentially depends on the quality of some reference signals received by the User Equipment (UE). In LTE, they are the Reference Signal Received Power (RSRP) and the Reference Signal Received Quality (RSRQ) corresponding, respectively, to Received Signal Code Power (RSCP) and Ec/No in UMTS (Universal Mobile Telecommunications System). Each user is assigned a portion of the spectrum depending on RSRP and RSRQ. The more complex optimization of reference signal is the RSRQ, which is based on Signal to Interference plus Noise Ratio (SINR) [2, 6]. SINR is an important performance indicator for estimating the achievable throughput, taking into account the interference received from the neighboring cluster of first-tier cells. The estimation and optimization of the SINR are well-known problems in radio communication systems such as the 802.11, the Global System for Mobile Communications (GSM) or the UMTS [11, 12, 13], and LTE needs also a good estimation and control of SINR. Optimizing antenna parameters configuration to meet variant of services and performance requirement is one of main targets of next generation networks. It can significantly improve the coverage and the capacity of the network dealing with the lack of available bandwidth in base stations. Several studies have been done in this direction to understand the impact of parameters on antennal quality of service offered by the network [6, 7]. Didan et al. in [14] have measured the impact of azimuth and tilt inaccuracies on network performance considering three main quality parameters: service coverage, soft handover areas and the ratio of chip energy to interference *Ec/No*. Many simulation results show that azimuth error in the range of ±8 degrees is tolerable to improve the Networks performance.

Tilt parameter has the same effect on Network performance while setting tolerance is just about ±0.5 degrees. The approach of simulated annealing is used by Siomina et al. [7] to study the number of network configuration parameters (the Common PIlot CHanel power, CIPCH, the downtilt and the antenna azimuth) effects toward coverage service in UMTS network. In modern communication systems, further parameters investigations

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have been developed to meet requirement set. Various combinations of antenna have been studied in term of SINR and throughput performance in LTE case, outlined for example in [6, 15].

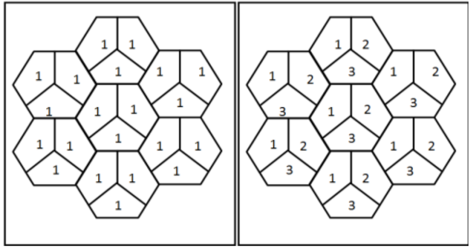
The interference model developed in this paper takes into account the load factor of cells to measure the impact of the traffic on the SINR metric. Our aim is to study the influence of the frequency, tilt and output power parameters on the coverage performance metrics (quality of the SINR, users in outage…), and also emphasize the interest of robust optimization considering frequency, tilt and output power as important design parameters when tuning live network. The choice of the robust approach is mainly due to the uncertainty of the traffic distribution due to the traffic change. Our contribution for SON feature is designed to monitor the performance of the network operation. Following data analysis step, optimization algorithms and corrections will be triggered automatically to make decisions on how to operate the system and this according to the objectives of operators and users needs. We show here the "interest" of using robust approach based on simple greedy descent algorithm. Further work must be done on algorithmic approach.

For this aim, the paper is structured as follows. Section II introduces the system model and basic assumptions. Section III extends this paper and shows the performance metrics and test assumptions. Subsequently, Section IV presents some results to highlight the use of SINR interference model and shows the utility of robust optimization toward the change in the traffic demand. Conclusion and perspectives are drawn in Section V.

II. SYSTEM MODEL

A. Basic Assumptions

In this paper, we consider the downlink transmission and illustrate the interference schemes using a theoretical model of seven-cell hexagonal layout as shown in Figure 1. Three sectors are considered in each site (center of the cell) with three evolved Node Bases (eNB), which is the base station in LTE system. Each sector is covered only by only one eNB. Figure 1(a) represents the frequency reuse 1x3x1 pattern where 1 site with 3 sectors use 1 frequency set called sub-band or carrier, that is the same frequency set for all sectors.



a) b)

Figure 1. Seven-cell hexagonal layout. a) 1x3x1 b) 1x3x3

Figure 1(b) represents the frequency reuse 1x3x3 pattern where 1 site with 3 sectors use 3 frequency sets, that is different frequency set for all sectors. The 1x3x3 requires a frequency plan but should avoid interference when the network load becomes too high to apply the 1x3x1 pattern.

The features of our computational model are the following:

- Intra-frequency interference is avoided due to the use of the Orthogonal Frequency Division Multiple Access (OFDMA) technique in downlink transmission. In LTE the orthogonality between subcarriers insures that the interference inside the cell can be ignored.
- The basic resource element in OFDMA is the Physical Resource Block (PRB), which spans both frequency and time dimensions. In this paper, we do not take into account PRB to estimate the inter-cell interference; we only consider the frequency sub-band (or carrier) reuse scheme. Two adjacent cells are scrambling with each other if they are using the same sub-band to transmit data. It gives a fast estimation of the SINR.
- Scenarios are used to represent the traffic distribution of our model. Since LTE network traffic is unpredictable now, we adapt the real UMTS network to simulate the LTE system. The interference model defined here and based on SINR depends not only on antenna parameters (frequency, tilt, azimuth, etc.) but also on traffic load along day; then in our computation the users available in target sector or adjacent sectors can affect the received signal from other users. As we consider that all users communicate at the same time, a scenario of traffic shows the distribution of demand at a given time.
- We introduce a performance indicator to measure occupancy rate on each sector, the load factor. This indicator is a ratio between used bandwidth and the maximum available bandwidth. It is measured for each sector of the network. The feature of the load factor is to determine the bottlenecks of the network and the overloaded sectors. This indicator will be used in the interference model.

B. Case Study and Problem Formulation

The considered network for this study consists of tri-sectors sites in the city of Belfort, located in the north-eastern of France. The service area is a 40km x 20km area with a lot of big industrial companies. For our model the service area is divided into a grid of equally sized test points. A test point is a 25x25 meters area. Due to the very small size of the test point, we assume the same signal propagation conditions for all users within the same test point; it means that all users located inside a test point have the same signal and the same RSRP, SINR and RSRQ. Thus, a test point determines the resolution of the computation and the amount of data on signals. A test point is characterized by its number of users and the category of required services for each user (voice, data, etc.). Each sector in the network is equipped with one directive antenna. Each antenna is characterized by its parameters: radiation pattern, azimuth, electrical and mechanical tilts, gain in transmission and reception, frequency and output power in downlink. Due to the dynamic aspect of the network and changes in traffic demand, we introduce the concept of traffic scenarios. A scenario is a given distribution and load of the traffic demand at a given time for each test point of the map.

Several scenarios allow us to compute different situations of network performance to study the robustness problem. The problem formulation is given by the following sets of data, parameters and functions.

Let: $B = \{1,...,n^B\}$, the set of n^B base stations eNB of the network; $T = \{1,...,n^{TP}\}$, the set of n^{TP} test points of the map; and $C_{t,s}$, the number of users located on the test point t in scenario s.

The interference model based on SINR is thus calculated as defined in (1):

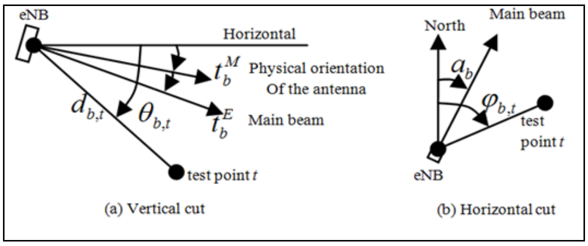
$$\gamma_{b,t,s} = \frac{p^R_{b,t} f_b}{\sum\limits_{b' \neq b,\, f_b = f_{b'}} p^R_{b',t} f_{b'} \delta_{b,s} \delta_{b',s} + n_0 w} \qquad (1)$$

where, $\gamma_{b,t,s}$ is the SINR received by the test point t and issued from the eNB b in scenario s; f_b and $f_{b'}$ are binary variable frequencies used by eNB b and b', respectively. It means $f_b = f_{b,n} = 1$ as we consider that the eNB b is using the carrier n. and $f_{b'}$ is a binary variable, which is set to 1 if it uses the same carrier as f_b and 0 otherwise. $\delta_{b,s}$ and $\delta_{b',s}$ are load factors that corresponds to the target eNB b and interfering eNBs b' in scenario s. Both load factors $\delta_{b,s}$ and $\delta_{b',s}$ are added in the model because we assume that users inside target and interfering cell could impact the quality if the SINR. Base station b is said to be saturated in scenario s if its load factor $\delta_{b,s}$ is equal to 1. The term w represents the total bandwidth used by b and n_0 is the thermal noise over the bandwidth w. The terms $p^R_{b,t}$ and $p^R_{b',t}$ are the end power received by UE located in test point t from, respectively, b and b'. Note that the load factor in the interference pattern is introduced because we believe that users scramble neighboring cells transmitting on the same frequency, causes more interference and suddenly, penalizes the SINR.

The estimation of this power is based on the Hata propagation model [16] in (2):

$$\begin{aligned} p^R_{b,t}(dBm) = {} & p_b - PL_{b,t} + g_b^{MAX} \\ & - a_b^{VER}(\theta_{b,t} - t_b^M - t_b^E) - a_b^{HOR}(\phi_{b,t} - a_b) \end{aligned} \qquad (2)$$

where, p_b is the power in *dBm* issued from the eNB b. g_b^{MAX} is the antenna gain while a_b^{VER} and a_b^{HOR} are the vertical and horizontal radiation pattern due to the position of the test point from the main beam of the antenna. As shown in Figure 2(a), a_b^{VER} depends essentially on the antenna tilt, which is the angle of the main beam below the horizontal plane. We distinguish two different tilts: the mechanical tilt t_b^M to adjust the physical angle of the antenna brackets and the electrical tilt t_b^E, which does not change the physical angle, but adjusts the radiating currents in the antenna elements to lower the beam in all horizontal directions.



(a) Vertical cut (b) Horizontal cut

Figure 2. Horizontal and vertical angles

The right part of Figure 3 shows the impact of azimuth parameter on the horizontal radiation pattern. The azimuth is the horizontal angle a_b between the north and the antenna main lobe direction.

In 3GPP LTE tests, we apply the two formulas [6] given by (3) and (4) for the computation of $a_b^{VER}(\theta_{b,t}, t_b^M, t_b^E)$ and $a_b^{HOR}(\varphi_{b,t}, a_b)$:

$$a_b^{VER}(\theta_{b,t}, t_b^M, t_b^E) = -\min\left[12\left(\frac{\theta_{b,t} - t_b^M - t_b^E}{\theta_{3dB}}\right), SLA_v\right] \qquad (3)$$

and $SLA_v = 20dB$

$$a_b^{HOR}(\phi_{b,t}, a_b) = -\min\left[12\left(\frac{\phi_{b,t} - a_b}{\phi_{3dB}}\right), A_m\right] \qquad (4)$$

and $A_m = 25dB$

where, SLA_v is the Side Lobe Attenuation and A_m is the front-to-back attenuation [10]. θ_{3dB} and φ_{3dB} are the half power beam width in vertical and horizontal plan respectively.

Finally, the path loss based on Hata model [16] for urban areas is formulated as in (5):

$$\begin{aligned} PL_{b,t} = {} & 69.55 + 26.16\log(f_0) - 13.82\log(z_b) \\ & - a(z_t) + \left(44.9 - 6.55\log(z_t)\right)\log(d_{b,t}) \end{aligned} \qquad (5)$$

And for small or medium sized city the value of $a(z_t)$ is:

$$a(z_t) = 0.8 + \left(1.1 \times \log(f_0) - 0.7\right) z_t - 1.56\log(f_0) \qquad (6)$$

where, $PL_{b,t}$ is the path loss (dB) in urban area between the eNB b and the test point t, f_0 is the frequency (MHz), z_b and z_t are the height of the base station b and the test point t (m), $d_{b,t}$ is the distance between the base station b and the center of the test point t (m), while $a(z_t)$ is the correction factor for mobile unit antenna height (dB).

In the current work, we will consider three antenna parameters setting. The study focuses on the impact of the frequency, tilt and power parameters on the number of non covered users in the service area. The robust approach uses the mean robustness over three different demand scenarios in a traffic day. The proposed evaluation methodology aims to show the effect of the antenna parameters configuration on the coverage performance metric, with respect to traffic distribution. Considering the study presented in this paper, the formulation of the overall problem is done in the following.

C. *Problem formulation*

a. Decision variables (parameter settings)

\- t_b is the tilt orientation of the eNB $b : t_b \in T_b$ where T_b is the set of possible values of the tilt parameter. For each antenna, we define a set of all possible antennas tilt configurations. We denote this set by $K = \{1,...K\}$ and assume that the range of possible tilts is the same for all antennas. To describe the current network configuration, we use a set of binary variables, $\Lambda = \{\lambda_b^{(k)}, b \in B, k \in T_b\}$ defined as follows:

$$\lambda_b^{(k)} = \begin{cases} 1 \text{ if antenna } b \text{ uses tilt configuration } k \\ 0 \text{ otherwise} \end{cases}$$

\- p_b is the power issued from the eNB *b*: $p_b \in P_b$ where P_b is the set of possible values of the output power parameter. We denote by $L = \{1,...,L\}$ as a set of all possible antennas power configurations. We also assume that the range of possible output power is the same for all antennas. We use a set of binary variables, $A = \{\alpha_b^{(l)}, b \in B, l \in P_b\}$ defined as follows:

$$\alpha_b^{(l)} = \begin{cases} 1 \text{ if antenna } b \text{ uses output power } l \\ 0 \text{ otherwise} \end{cases}$$

\- $f_{b,n}$ is the variable for carrier assignment to eNB;

$$f_{b,n} = \begin{cases} 1 \text{ if carrier } n \text{ is assigned to eNB } b \\ 0 \text{ otherwise} \end{cases}$$

N, set of available sub-carriers (sub-bands).

b. ***Constraints:*** The main constraints of our model are:

\- minimum and maximum number of neighborhood cells for *b*. for this study |*v*$_b$| is set to the value 5. $|V_b| = 5$.

$$v_b^{MIN} \le |v_b| \le v_b^{MAX}, \quad \forall b \in B \tag{9}$$

\- a test point is associated with exactly one eNB.

$$\forall t \in T, \ \sum_{b \in B} u_{b,t} \le 1 \tag{10}$$

where, $u_{b,t} = \begin{cases} 1 \text{ if test point } t \text{ is associated to eNB } b \\ 0 \text{ otherwise} \end{cases}$

\- each eNB *b* can use one and only one carrier *n*.

$$\forall b \in B, \sum_{n \in N} f_{b,n} = 1 \tag{11}$$

\- eNB *b* can use only one antenna tilt configuration *k:*

$$\forall b \in B \sum_{k \in T_b} \lambda_b^{(k)} = 1 \tag{12}$$

\- eNB *b* can use only one antenna output power configuration *l*.

$$\forall b \in B, \sum_{l \in P_b} \alpha_b^{(l)} = 1 \tag{13}$$

c. Objective functions

- ***Fitness function***

Let $n_{0,s}^C$ be the number of non covered users in scenario *s*.

$$n_{0,s}^C = \sum_{t \in T_0^C} n_{t,s}^C \tag{14}$$

where, $n_{t,s}^C$ is the number of non-covered users in test point *t* for scenario *s*.

- ***Robustness function***

$$f^{Rob} = \sum_{s \in S} n_{0,s}^C \tag{15}$$

where, f^{Rob} is the sum of non-covered users in all considered scenarios together.

- ***Fitness function optimization***: minimize the number of non covered users in one scenario *s:*

$$Min \sum_{t \in T_0^C} n_{t,s}^C \tag{16}$$

- ***Robustness function optimization***: minimize number of non covered users in all considered scenarios:

$$Min \sum_{s \in S} n_{0,s}^C \tag{17}$$

III. TEST ASUMPTIONS AND PERFORMANCE METRICS

The main parameters and assumptions we used are those selected by 3GPP for LTE as shown in Table I. Evaluations are performed by a static snapshot of the network level.

TABLE I. TEST ASSUMPTION FOR LTE DOWNLINK

Parameters	Simulation setting
Network layout	36 sites and 88 sectors
Required service/user	2Mbps
System frequency	1800 Mhz
System bandwidth	20 Mhz
Frequency reuse factor	1x3x1 and 1x3x3
eNB heights range	[17m, 46m]
UE height	1.5 m
Propagation loss model	Hata model [16]
TX power range	[39 dBm, 46 dBm]
Mechanical tilt range	[0°,6°]
Electrical tilt range	[0°,10°]
Azimuth range	[0°,360°]
Horizontal HPBW	+70°
Vertical HPBW	+10°
Antenna gain range	[14dBi , 18.9dBi]
Traffic distribution	Distribution in proportion to UMTS traffic load

In addition to Table I, further assumptions are used for robust optimization tests. Three realistic traffic scenarios are tested (8am, 3pm and 6pm). Frequency scheme reuse 1x3x3 is retained. Deterministic allocation of sub-bands as showed in the right part of Figure 1 is now used. The antennas are grouped by site and stored on the basis of an index in ascending order of the x-axis (the coordinate of the position (x, y, z) of the antenna in the network). The performance metric considered is the *Signal to Interference plus Noise Ratio* (SINR).

The SINR, expressed in (1), is an important indicator to evaluate cellular networks. The SINR choice is motivated by the fact that: it takes into account all the parameters of the antenna; it depends on the traffic distribution and the load factor of the network; it resizes the network and determines which base station controls each user; and it allows us to estimate the total throughput of the network. We define two intermediate performance indicators that allow us to evaluate the SINR at each point of the network.

A. *The load factor*

The load factor of the sector/cell is the ratio between the total allocated bandwidth to the cell, which is the required bandwidth and the maximum total bandwidth available in the cell, which are the resources allocated to the cell. Let $\delta_{b,s}$ be the load factor, then: $\delta_{b,s} = w_{b,s}^{S}/w$ where, $w_{b,s}^{S}$ is the total allocated bandwidth to the base station *b* in the reference scenario *s*, and *w* is its maximum available bandwidth. It is worthwhile to mention that load factor is one of the main key indicators in cellular networks. It has been suggested that the downlink cell load for a stable network should not exceed 70% [7]. Huge loaded cells are those for which $\delta_{b,s} > 0.7$ and overloaded cells are those for which $\delta_{b,s} > 1$.

B. *Throughput*

We used the SINR to determine the throughput offered by a base station to the set of users who are located in the cell test points: the higher the SINR, the greater the quality of the channel and the throughput.

TABLE II. MODULATION, THROUGHPUT AND REQUIRED SINR [8]

Index	Modulation and coding	Throughput [Bits/s/Hz]	SINRmin [dB]
0	Outage	0	<0.9
1	QPSK 1/3	0.75	0.9
2	QPSK 1/2	1	2.1
3	QPSK 2/3	1.25	3.8
4	16QAM 1/2	2	7.7
5	16QAM 2/3	2.75	9.8
6	16QAM 5/6	3.25	12.6
7	64QAM 2/3	4	15.0
8	64QAM 5/6	5	18.2

The Table II below gives the current correspondences between SINR, throughput and modulation [8]. The user is in outage if its SINR is below the required threshold for the most robust Modulation and Coding Scheme (MSC).

IV. RESULTS EVALUATION

In order to evaluate the SINR model presented in Section II, we focus on frequency reuse 1 (1x3x1 pattern) and 3 (1x3x3 pattern). The baseline network used for our study is the city of Belfort described in Section II.B. The UE are randomly dropped in each cell in proportion to UMTS traffic load regard to Belfort city. Due to the unavailability of data for LTE networks, we used data from a real GSM/UMTS and adapted it to a 4G-LTE system.

We present now the methodology to evaluate the SINR model taking into account traffic data of the baseline network. Firstly, we assume that the base station is engaged to communicate with a UE if the SINR received by the UE is high enough, i.e., achieve the required SINR threshold to establish a communication. So, the UE is allocated to a base station according to the quality of the received SINR. Then we assume that the load factor is considered to calculate the SINR as mentioned in (1).

A cell is defined as a set of test points of the map; a test point is assigned to the base station, which provides the best SINR. As a first step we assign the test point to the base station on the basis of the best RSRP and define the initial cell coverage for each station. Then we determine the number of UE per cell and the traffic demand as well. We compute the load factor for each station, and finally we estimate the SINR, which depends on the RSRQ. As a second step we assign again the test point to the base station on the basis of the best SINR. From there we estimate again the load factor for each station. This second step is repeated several times (10 times) to try to reach a stable network configuration. The collected traffic data come from a real UMTS network. The tests consider three different scenarios originating from one-day traffic, as shown in Figure 3. The *x* axis unit is a set of time intervals of 15 minutes each.

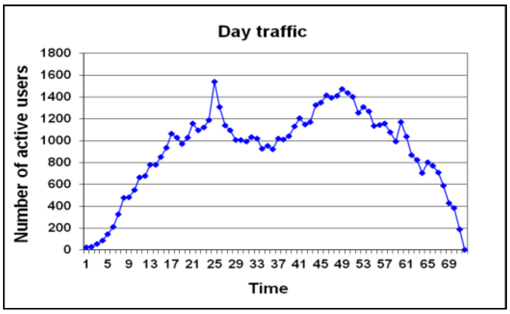


Figure 3. One-day traffic with three chosen scenarios

Three scenarios were selected at different times of the day as follows: a first scenario at 8am with low traffic and 482 users dropped randomly in the network; a second scenario at 3pm with medium traffic and 1,019 users; and a third scenario at 6pm with high traffic and 1,471 users. We are considering that all users are accessing the network at the same time (saturated traffic condition).

A. *Interference model results*

To compare the performances of both reuse 1x3x1 and reuse 1x3x3 patterns, the number of users in outage is used as a performance metric. The minimum required SINR is equal to 0.9 dB. Below this value of SINR, one user cannot establish a communication as defined in (18):

$$\gamma_{b,t,s} < \gamma^{MIN} \tag{18}$$

where, γ^{MIN} is the required threshold.

Figure 4 depicts the number of users in outage obtained with both reuses pattern: scheme 1x3x1 and scheme 1x3x3. In the network design we test for scheme 1x3x3, the sub-band assignment depends on the azimuth orientation of the sectors. Sectors in opposite direction from neighbor sites are assigned different frequency groups.

The program implementing our model is developed in C++. We run the program 10 times to check the convergence of the SINR computation (the difference is below 5%). An example of three scenarios of traffic is presented in Figure 4 to show the interest of using the reuse scheme 1x3x3 in a real network design and traffic load. We see that the number of users in outage is more important in scheme 1x3x1 (13, 36, and 40) than in scheme 1x3x3 (8, 18 and 17) for the three scenarios of traffic load considered here (8am, 3pm and 6pm, respectively).

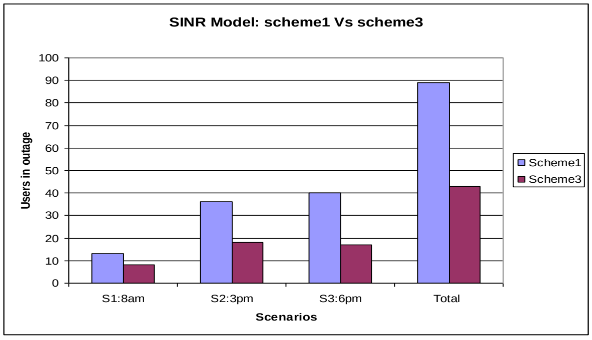


Figure 4. Reuse scheme 1 Vs scheme 3 with 3 scenarios

These results are consistent since the total bandwidth used in pattern 1 can assign more resources, but would jeopardize the rate offered by the network. This is due mainly to the undesirable inter-cell interference generated by neighboring cells using the same frequency set. Such a dense frequency reuse is an obvious pitfall, which limits the throughput at the cell edge. We can also note according to these results that, the higher the traffic, the higher the number of outage users, whatever the frequency pattern solution.

B. Parameter setting optimization

The second part of this study is dedicated to robust optimization. It shows that optimizing a number of network configuration parameters like antenna frequency, tilt orientation and power transmission helps considerably to meet variant of services and performance requirement.

A greedy algorithm on frequency, tilt and output power is used to examine how the solution of the antenna configuration, behaves under realistic scenarios.

Algorithm description

In order to show the interest of robust optimization, we present an algorithm able to quickly find a good solution. We were not looking for the best solution at this stage. An iterative algorithm is used; the purpose is not to find an optimal solution but to get the benefit of robust optimization for 3 scenarios in comparison with local solution based on a single scenario. The algorithm with several variants is proposed for each parameter: frequency allocation, tilt and power configuration. We measure the effect of each parameter toward the network coverage performance metric.

-Frequency parameter optimization

It can be proved that frequency assignment problem is NP-hard as it is a graph-coloring problem [19]. For such problems, guaranteeing optimum requires, in the worst case, an enumeration of all possible configurations. The number of possibilities is enormous; in our case study, for 36 cells, 88 antennas and 3 frequency groups, the number of possibilities is $6^{36} = 1.03*10^{28}$. The robust optimization function takes into account the three scenarios considered above. The used algorithm is described in the following. We run the optimization with different varying conditions:

- The scenarios of traffic: several traffic hours.
- The initial frequency assignment to the base stations: deterministic or stochastic per sector from the same site.
- The sites neighborhood search to test the permutation of frequency: sites ranked from the input file or randomly chosen during optimization.

The algorithm starts with a solution using the reuse scheme 1x3x3. The optimization algorithm is run for each scenario to show the best configuration of the frequency parameter setting with respect to the performance metric given by the (14). For each explored site, we evaluate the 6 (3! =6) possibilities of permutations for each sector of the site. The algorithm evaluates 6x88 permutations at each iteration. If a frequency permutation improves the evaluation function of the current solution, the algorithm keeps the last modification and goes through the next sector configuration. The algorithm stops once the current iteration brings no improvement. This is achieved by the following algorithm, which was used for all cases.

Algorithm for antenna parameters optimization

Input parameters

Set B of n^B base stations; Set T of n^{TP} test points; Set S of scenarios: s_1=8am, s_2=3pm and s_3=6pm; Frequency reuse scheme 1x3x3 (3 groups of frequency to assign to base station), tilt and output power operating settings from the real UMTS network.

Variables

-Frequency assignment to base stations.

-Tilt configurations (discrete values from 0° to 12°).

-Output power configurations (discrete values from 36dBm to 46dBm).

Fitness function

Fitness(Config $Fitness(Config_p)$ = Number of outage users for the current configuration of parameter p, $p=\{frequency, tilt, output\ power\}$

in s, for non robust optimization

in s_1, s_2 and s_3 ,for robust optimization

Algorithm:

```
Initialize $Config_p$ // $Config_p$ is the initial configuration of a chosen parameter
$Config_p^* = Config_p$ // $Config_p^*$ is the current best configuration for parameter $p$.
Repeat
Improve=False
    For each site b of the network
        For each possible values of a chosen parameter,
            Generate the new frequency plan $Config_p$ from $Config_p^*$
            IF $Fitness(Config_p) < Fitness(Config_p^*)$
                $Config_p^* = Config_p$
                Improve =True
            End IF
        End For
    End For
Until Improve=False
Stopping criteria if there is no improvement
```

Figure 5. Optimization algorithm

-Tilt and power parameters Optimization

The same algorithm is implemented to optimize the tilt parameter and transmission power of the antennas. Different configurations are tested using a discretization of the possible values. We aim at finding good antenna configurations among a range of possible values for both tilt and power. For 36 cells and 88 antennas, we have $13^{88} = 1.06 * 10^{98}$ possibilities. For the tilt parameter, the range of values is [0°, 12°] in degrees, and for power parameter, the range of values are [36dBm, 46dBm]. It is impossible in such case to guarantee an optimum solution; we aim then at finding an acceptable solution and show the tilt and power transmission effects on the traffic demand scenarios. We assume that: three scenarios of traffic are considered; the starting solution on the tilt and output power parameters are those given by the realistic GSM/UMTS network (operating data); the sites in neighborhood search are chosen first in the order of storage as it is in the data file and then, randomly during optimization phase. So, we have two variants of the algorithm for each parameter.

We evaluate the possible values of each parameter for each antenna to meet better number of covered users, using the same starting solution and the same scenarios of traffic (8am, 3pm, and 6pm).

In the first variant of our algorithm, sites are processed in the order of storage in the data file, all possible configurations are tested at each iteration for both tilt and output power parameters. If the current configuration improves the evaluation function of the current solution, we maintain the solution and then process the next neighborhood site chosen in the data file. The algorithm stops once the current iteration brings no improvement (stopping criteria). In the second variant, we keep the same assumptions (same scenarios of traffic and same starting solution) but sites are processed randomly instead of the order in the data file. In this case, the stopping criteria considered here is the running time duration.

Results with non robust and robust optimization

-Frequency optimization results

The results of optimization are shown in the Figures 6 and 7. We emphasize that for the non robust (each scenario tackled alone) and for the robust optimization (the 3 scenarios together) we use the same algorithm but in case of robustness the evaluation function is given by (15) and takes into account the configuration of the frequency considering all the scenarios simultaneously.

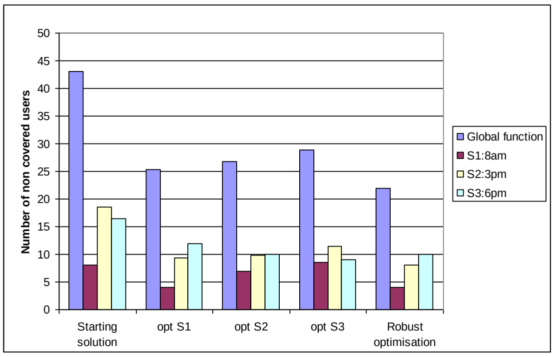


Figure 6. Three scenarios of robust optimization with deterministic frequency allocation

It means that, for each frequency of the network, we evaluate the non-covered users in the three scenarios on one run. So, we run the same algorithm 4 times (one run for each optimization *s1*, *s2*, *s3* and robust case), we use the evaluation function (14) to optimize the 3 scenarios separately; then we use the evaluation function (15) for the robust optimization using the 3 scenarios at the same time.

The x-axis represents the starting solution and the optimization of scenarios s_1, s_2 and s_3 separately and the robust optimization at the end. The y-axis shows the number of users in outage for each scenario s_1, s_2, s_3 and total number. We can note that scenario1 optimization has the smallest number of non-covered users when evaluating s_1 (4 users) comparing to the other cases (8, 7, 9). The same analysis can be done for the scenario s_3 and it is different for s_2 but not far away from the best one. We fixed the run to 20 minutes for random frequency allocation, so there is no guarantee on the solution quality (the convergence is not definitive). We observe that the result of the robust optimization is a trade off between the three scenarios, the best for s_1 and s_2 but not the best for s_3. Finally, the fitness function value of non-covered users for all cases corresponds to the global best solution (blue color in the right part), while in other situations, starting solution and non robust cases, the global function values are 43, 25, 27 and 29, respectively, from left to right part of the Figure 6. The robust optimization does a better compromise between all scenarios. This result shows how the robust approach is important for the remaining of this study. Different variants of the algorithm have been tested by varying several conditions. We run the program 20 minutes for each optimization in Test 2 and Test 3, and keep the best solution for the considered fitness function (so the test conditions are the same for all cases). Test 1 (Figure 6): the initial frequency plan is deterministically assigned and the sites are processed respecting their rank in the input file. Test 2: the initial frequency plan is deterministically assigned and the sites are randomly processed during optimization. The results are similar to the test 1 so we do not plot it. Test 3 (Figure 7): the initial frequency plan is randomly assigned to the co-site sectors and the sites are randomly processed during optimization.

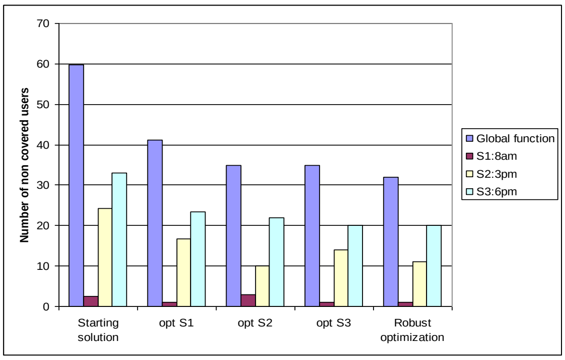


Figure 7. Three scenarios of robust optimization with random frequency allocation

-Tilt optimization results

Robust optimization results for the tilt parameter are highlighted in the right part of each test (Figures 8 and 9). Several tests have been made to show the tilt parameter effect on the number of non covered users, we limit at showing 2 tests varying the neighborhood sites process and the stopping criteria.

Test 1 (Figure 8): the algorithm presented in Figure 5 is implemented. It means that with the same starting solution (3 scenarios of traffic and the operating tilts in real network), the site neighborhood search is done according their storage in the data file. In addition of sites search, the algorithm stops once there is no improvement of the fitness solution. Results are shown in Figure 8. It shows 5 parts, from the right to left: starting solution, optimization of scenarios s_1, s_2 and s_3 separately, and then robust optimization. The starting point of the algorithm is the starting solution (43, 8, 18 and 17), which represents the number of non-covered users in the global function (15) and scenario function (14) for each scenario.

We emphasize that the optimization of each scenario brings better results when each scenario is tackled separately (7, 11, 12) respectively, but impacts the global function. In robust optimization, we can easily note that the configuration found by the algorithm is a better compromise between all scenarios, $f^{Rob} = 31$ comparing with starting solution and the scenarios optimization (43, 41, 33 and 34).

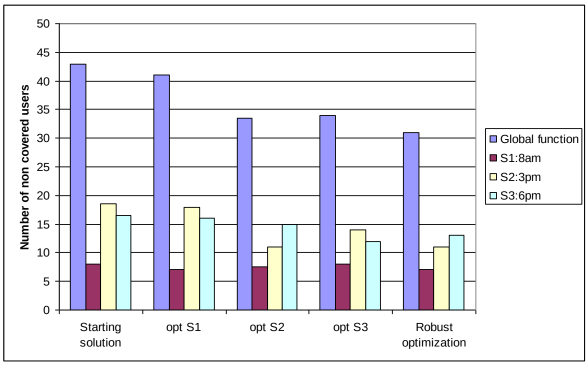


Figure 8. Three scenarios of robust optimization with deterministic tilt configuration

Test 2 (Figure 9): we keep the same initial conditions; but vary the sites neighborhood search (random search) and stopping criteria (an hour of run).

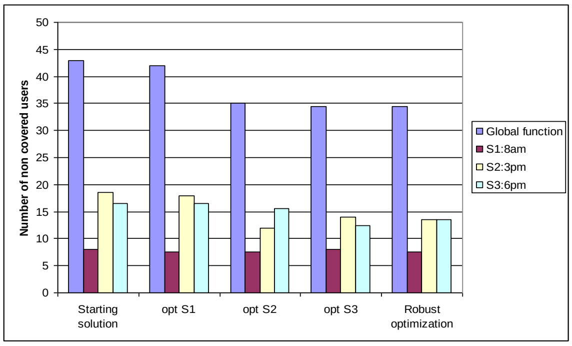


Figure 9. Three scenarios of robust optimization with random tilt configuration

Figure 9 shows the same results as in Figure 8. It confirms that optimizing by means of robust function can improve the network coverage with regard to traffic distribution.

- *Output power optimization results*

Initial output powers used for the starting solution are those operated by the GSM / UMTS network. The same initial conditions, as in the optimization of tilts, were used. Results are shown in the Figure 10.

As in the case of frequencies and tilts, robust optimization of power offers a solution that is a good compromise between the three traffic scenarios (Figure 10). This shows the interest of robust optimization due to the uncertainty of traffic and confirms the results already obtained in the previous cases.

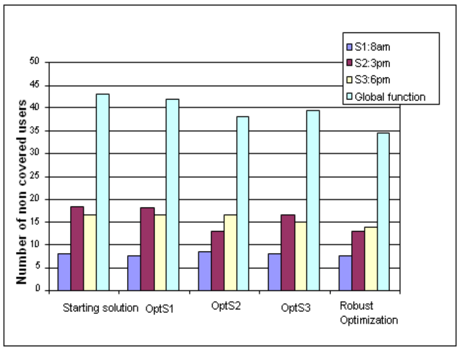


Figure 10. Output power optimization with sites ranked from the input file

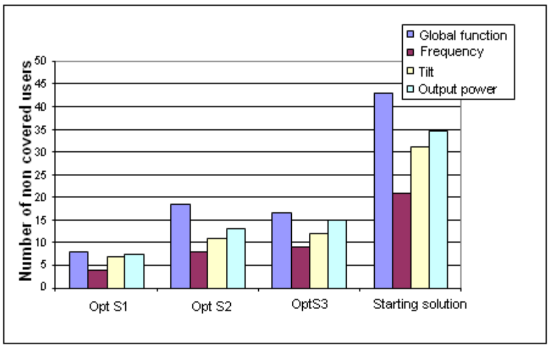


Figure 11. Comparison between frequency, tilt and output power optimization: Sites processed according their storage in data file; stopping criteria when there is no improvement

The Figure 11 represents a comparison between the 3 parameters setting optimizations; with the same initial conditions, using the same greedy algorithm. According to these results, we note that optimizing the frequency parameter provides better results while taking coverage as a performance indicator: less uncovered users for s_1 case (4<7<7.5); s_2 (8<11<13) and s_3 (9<12<15) and also in robust optimization (21<31<34.5). This is due mainly to the undesirable inter-cell interference generated by neighboring cells using the same frequency set. It impacts more the SINR quality comparing to the tilt and output power parameters.

V. CONCLUSION

This paper focuses on the self-organizing networks to automate the configuration of the antenna parameters and shows the interference model and the interest of robust approach with respect of traffic distribution in LTE downlink system. The analysis has been carried out using model radiation pattern and simple model of system performance. We proposed an interference model, which has been validated based on SINR computation and comparing two reuse schemes (1x3x1 and 1x3x3) under realistic scenarios. With respect to coverage, it has been observed that the reference reuse 1x3x3 present best results with respect to the number of covered users, independently on the traffic demand. It shows also that the load factor could impact the quality of signal at end users. It is an important indicator because it highlights the overloaded cells, which represent the bottleneck of the network. Using system simulations, we studied how the frequency, tilt, and output power parameters setting affect the coverage of the macro-cellular scenario. Different combinations of frequency, tilt and output power are used and obtained results show how coverage indicator is sensitive to the combination, and also to the traffic inaccuracies. Simple algorithms used here confirm the interest of robust approach respective of realistic traffic load.

As perspectives, we aim in further studies at analyzing the impact of the parameter settings configuration on the interference model and different performance metrics (throughput, capacity, and coverage). Furthermore, robust optimization approaches like the Variable Neighborhood Search and Tabu Search are under development to highlight the impact of the traffic uncertainty in the deployment of the network.

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