ABSTRACT

Mobile telecommunications are in strong development. The total number of mobile subscriptions is reaching the world’s population alongside with the exponential escalation of the data traffic. However, there are countries still dominated by second-generation networks, which are not sufficient to follow this continuous growth. The purpose of this work is to develop a radio network planning design project for a third-generation network, based on the requirements of a real Alcatel-Lucent’s customer, which are related to coverage, quality and interference. Network configuration inputs and assumptions are presented, in order to perform services predictions with Alcatel-Lucent design tool. Initial third-generation design is based on the already existing second-generation network configurations. Optimization processes had to be developed not only to optimize the network to have best fitted third-generation configurations, but also to achieve the requirements of both Alcatel-Lucent and the customer. There are three optimization phases described in the project: tilt optimization, new sites proposal and power optimization phase. Electrical tilt optimization was performed to improve signal level covered area. Then new 3G sites were proposed within the already existing 2G only sites of the network, as the requirements had not yet been achieved. Finally, power optimization was performed, only in urban and dense urban areas, to sectors with low covered area. After all the optimization phases, it can be concluded that all the design project requirements were achieved.

Keywords — Radio Network Planning, Signal Coverage, Quality, Interference, Optimization

I. Introduction

In the past few years the growth in the number of mobile subscribers has been enormous. One of the factors that led towards this evolution was the continuous development of mobile phones. Of the mobile phones sold worldwide, in the first quarter of 2014, 65% were smartphones. So, this evolution translates into a 65% growth in mobile data traffic amid the first quarters of 2013 and 2014 [1].

Although the total number of mobile subscriptions is reaching the world’s population, around 7200 million people, there are still countries that have a low penetration percentage of mobile network coverage. Each region’s maturity level is reflected in its radio technology mix. Emerging regions are mainly dominated by second-generation technologies like GSM/EDGE, while developed regions are strongly dominated by WCDMA/HSPA. Not forgetting, that both operators and subscribers are very quickly adopting LTE. In all regions, second-generation networks will stand as fall-back technology for third and fourth subscriptions where coverage is missing.

One of the regions that are still dominated by GSM/EDGE-only subscribers is Africa. At the end of 2013 there were 500 million GSM/EDGE subscriptions, which represent 90% of African mobile subscriptions [2]. With a strong second-generation dominated network, Africa only had a little more than 100 million WCDMA/HSPA subscriptions, by the end of 2013. With the increasing middle class and low cost smartphones becoming a reality in these regions’ mobile market, mobility came to be indispensable to people’s lives. WCDMA/HSPA technology is strongly starting to be the best option to overcome this situation. Thus, it is predicted that by the end of 2019 the number of WCDMA/HSPA subscriptions will reach 600 million.

The paper work was developed at Alcatel-Lucent Portugal, which is part of a multinational company that is a global communications solutions provider, with the most complete,
end-to-end portfolio of solutions and services in the industry. This project is a real network planning project requested by one of Alcatel-Lucent’s customers in Africa. The motivation of this paper project is to design and optimize a third generation network for a mobile operator in Cameroon. The Cameroon is an African country with 22 million people and a total area of 475 thousand kilometers. Yaoundé is the capital city, but its largest and most populated city is Douala.

The customer already has a second-generation mobile network implemented in the country. For the new third-generation project, the essential goal is to ensure good coverage, quality and interference for the customer desired services.

Section II will approach the UMTS Fundamentals, with a particular focus on the HSDPA, HSUPA and propagation models that are the foundation for this work. In section III the 3G Radio Network Planning (RNP) design project is introduced with a description of the utilized tools, the inputs and assumptions, with special focus on the design goals. The network optimization phases and the results analysis are described in section IV, with a specification of the optimization criteria used. Finally, in section V, an overall conclusion is exposed based on the optimization results.

II. UMTS FUNDAMENTALS

The UMTS system lies in a number of logical network elements where each has a defined functionality. According to the standards, network elements are defined at the logical level and can be classified based on similar functionality. The UTRAN is also composed by two separate elements. The NodeB, that converts data flow between the Iub and Uu interfaces and the Radio Network Controller (RNC) that maintains and controls the radio resources in its domain, basically the NodeBs that are connected to it. RNC is the service access point for all services UTRAN provides to the Core Network (CN), for example, management of connections to the user equipment (UE). [3] Core Network (CN) has a very significant position in UMTS architecture. It was adapted from the GSM Core Network, and its mission is to switch and route calls and data connections to external networks. These networks can either be Circuit Switched (CS), such as Integrated Services Digital Network (ISDN) and Public Switched Telephone Network (PSTN), or Packet Switched (PS), such as the Internet.

Figure 1 - UTRAN Logical Architecture [3]

The main radio technology employed in UMTS is WCDMA whose variants Frequency Division Duplex (FDD) and Time Division Duplex (TDD) were selected by the European Telecommunications Institute (ETSI). Although, likewise traditional Code Division Multiple Access (CDMA), the spread spectrum forms the fundamental technique for WCDMA but employing a different control channel and signalling, wider bandwidth, and a set of enhanced futures for fulfilling the requirements of 3G systems, it is significantly different from its equivalent.

In UMTS, capacity depends on the number and type of users that are connected to the NodeB. The number of users is limited by three factors: the number of channelization codes, the transmitted power from the NodeB and the system load. The number of available channelization codes restricts the number of simultaneous active users within the cell sector, because these codes are given by the Spreading Factor (SF). As data rate increases, Spreading Factor (SF) must decrease to allow higher data rates, leading to a decrease of the allowed number of users in the network. The spreading factor is a multiplier describing the number of chips used in the WCDMA radio path per 1 symbol. The spreading factor (SF) can be expressed mathematically as follows:

\[ SF = 2^k, \quad \text{Where } k = 0, 1, 2, \ldots, 8 \quad (1) \]

Concerning system load, it is essential to distinguish the uplink (UL) from the downlink (DL), since in the DL there is a limit on the transmission power, and traffic flow is not symmetric between UL and DL. As the load rises in UL, a larger interference margin is needed, leading to a decrease of the cell coverage area. The network load is defined by the UL and DL load factors. The UL load factor can be defined as:

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1 The operator will be referred from now on as the customer.
\[ \eta_{UL} = \left(1 + i_{UL}\right) \sum_{j=1}^{N_U} \frac{1}{G_{P_j} \left(\frac{E_b}{N_0}\right)_j} \cdot V_j \]  

(2)

Where: \(i_{UL}\) is the ratio of inter-to-intra-cell interference ratio for UL, \(N_U\) is the number of users per cell, \(G_{P_j}\) is processing gain of user \(j\), given by \(\frac{R_c}{R_{bj}}\), \(E_b\) is the bit energy, \(N_0\) is the spectral noise density, \(V_j\) is Activity factor for user \(j\), \(R_c\) is the WCDMA chip rate and \(R_{bj}\) is the bit rate for user \(j\).

Regarding the DL load factor, it can be defined as:

\[ \eta_{DL} = \sum_{j=1}^{N_U} \left(\frac{E_b}{N_0}\right)_j \cdot \left[\left(1 - \alpha_j\right) + i_j\right] \]  

(3)

Where: \(\alpha_j\) is the DL channel orthogonality of user \(j\) and \(i_j\) is the ratio inter-to-intra-cell interference ratio for user \(j\). The interference margin (\(M_I\)) qualifies the interference caused by all users’ interference. When the load factor tends to one, the system reaches its pole capacity and the noise tends to infinity.

\[ M_{I[db]} = -10 \cdot \log(1 - \eta) \]  

(4)

Now it is important to specify the new features that HSDPA and HSUPA bring to WCDMA networks. HSDPA upgrades capability and spectral efficiency, being implemented herewith Release 99, sharing all network components. Software improvement is demanded for network’s elements and yet a new MT on the user’s behalf. While in Release 99 the scheduling control is based on the RNC, and the NodeB only has power control functionality, in HSDPA, scheduling and fast link adaptation based on physical layer retransmissions were moved to the NodeB, minimizing latency and changing the RRM architecture. To achieve upper data rates is applied a new higher order modulation, the 16 Quadrature Amplitude Modulation (16 QAM) with 4 bits per symbol, which can just be utilized over great radio channel circumstances, due to the extra decision boundaries: phase and amplitude balance. In order to set HSDPA in function it was introduced a new user data channel. The High-Speed Downlink Shared Channel (HS-DSCH) designed for the High-Speed Physical Downlink Shared Channel (HS-PDSCH). For signalling two different channels were introduced: the High-Speed Shared Control Channel (HS-SCCH) in the DL, and the High-Speed Dedicated Physical Control Channel (HS-DPCCH) in the UL.

The Signal to Interference plus Noise Ratio (SINR) is utilized as an alternative of \(E_{P/N_0}\) for HSDPA connection budget planning and network proportion. In network dimensioning, the pilot \(E_{P/N_0}\) which stands for energy per chip to interference, based on the average wideband Primary-CPICH (P-CPICH), is also used to measure the average single user throughput.

\[ SINR = \frac{SF_{16}}{P_{P_{HSDPA}} / P_{P_{HSDPA}}} / (1 - \alpha_j) \]  

(5)

Where \(SF_{16}\) is the HS-PDSCH spreading factor of 16, \(P_{P_{HSDPA}}\) is the HSDPA transmission power, \(P_{TX}\) is the total Node B transmission power, \(P_{pilot}\) is the P-CPICH transmitted power, \(\rho_{pilot}\) is the P-CPICH Ec/I0 when HSDPA is active and \(\alpha\) is the downlink orthogonality factor. The principal objectives of HSUPA were to enhance UL capacity, and to reach higher data rates, compared to Release 99’s 384kbps, reaching 1 to 2 Mbps in early phases. HSUPA upgrades the radio interface, preserving each networking components unaltered. Like in WCDMA, power control is vital for HSUPA operation, along with support for Soft Handover (SHO). To guarantee HSUPA performance were presented new channels: the Enhanced Dedicated Physical Data Channel (E-DPDCH) for user data, and the Enhanced Dedicated Physical Control Channel (E-DPCCH) for control information. For scheduling objectives, the E-DCH Relative Grant Channel (E-RGCH) and the E-DCH Absolute Grant Channel (E-AGCH) were created. The E-DCH HARQ Indicator Channel (E-HICH) was added for retransmission feedback. The DCH channels from Release 99 were left unaltered. The modulation, SF and structure are identical as for the E-RGCH, with 40-bit long orthogonal sequence and admitting up to 40 E-HICH/E-RGCH on a single code channel, the differentiation being produced over high Radio Resource Control (RRC) signalling. All E-HICH transmitted from the same Radio Link Set (RLS) transport the same content and are soft combinable.

For HSUPA, new measurements were introduced: the UE Power Headroom (UPH), informing the Node B of the available power resources, and the E-DCH Transport Format Combination Indicator (E-TFCI), indicating the transport format being transmitted simultaneously on E-DPDCHs. Propagation models are particularly important to assure a good coverage and capacity planning, once they can be used to determine propagation characteristics. Propagation models can be theoretical or empirical. Theoretical propagation models deliver an approximation of the real environment founded on assumptions that simplify the problematic. Empirical propagation models are based on measurements, which leads to best fitting equations, taking into account several parameters. The use of models requests
an environment classification, which takes into account some parameters like terrain morphology, vegetation concentration, building density and height, open areas and water areas density. Consequently, the environments are usually divided into three types: rural, urban and dense urban. Classifying the cell type is also an important issue. For that reason, the cells used in the defined environments are usually classified respectively to their radius range and to the relative position of the base station antennas. In consequence, the cell type can be divided into four different types [5]: large macro-cell, small macro-cell, micro-cell and pico-cell. 

COST 231 has prolonged Hata’s model to the frequency $1500 \leq f \leq 2000$ MHz band by studying Okumura’s propagation curves in the upper frequency band. This combination is called "COST-Hata-Model" and the basic transmission loss, $L_{B}$, is:

$$L_{B} = 46.3 + 33.9 \cdot \log f - 13.82 \cdot \log h_{base} - a(h_{Mobile})$$

$$+ (44.9 - 6.55 \cdot \log h_{base}) \cdot \log d + C_{m} \quad (6)$$

Where:

$$a(h_{Mobile}) = (1,1 \cdot \log f - 0.7) \cdot h_{Mobile} - (1,56 \cdot \log f - 0.8) \quad (7)$$

$f$ is the frequency, $d$ is the distance, $h_{base}$ is the base station antenna height, $h_{Mobile}$ is the mobile antenna height and $C_{m}$ is 0dB for a medium size city and 3dB for the metropolitan centres.

III. 3G RADIO NETWORK PLANNING

The project consists in a third generation network deployment, with Alcatel-Lucent third generation network solution, in Cameroon. The plan, decided by the customer, was divided into three stages. The first stage was to do the radio network planning for Douala city with a particular focus in a pilot cluster, proposed by the customer. The second stage was to do the planning for the Cameroon’s capital city, Yaoundé. The third and final stage of the project consisted of making the network planning for the rest of the country. Douala was selected as this paper’s main focus.

Radio network deployment, for this third generation network, has involved two new hardware components. First was the integration of a Multi-Carrier Remote Radio Head (MC-RRH), which is one of the core building blocks of the Alcatel-Lucent Converged Radio Access Network. The second is a new tri-band antenna with higher gain, which supports the second and third generation layers. The antenna is a RFS WindMaster™ cross-polarized triple band antenna, model name APXVERR26-C.

Radio network planning design is important to evaluate and estimate the initial third generation coverage, based on some preliminary assumptions accorded with the customer. The starting point was to use tilt and azimuth configuration of the second-generation layer. After the first design, with the defined initial inputs, the next phase was to optimize the entire third generation network with the purpose to improve signal level coverage and quality.

To produce the network planning project some Alcatel-Lucent tools were used. The link budget tool is an Alcatel-Lucent tool that provides the Radio Network Planning (RNP) design level Common Pilot Channel (CPICH) Received Signal Code Power (RSCP) for the required service and terrain morphology. The link budget is executed for the most limiting service in the uplink. Uplink link budget consists in calculating the Maximum Allowable Propagation Losses (MAPL) that a mobile at cell edge can reach while meeting the sensitivity level at the base station. Uplink link budget calculations consider all the gains and losses between the mobile transmitted power and the base station received power. A9955 is an Alcatel-Lucent tool that allows the user to create and work on a planning project, but also offers a wide range of options for creating and exporting results based on user’s project. The starting point for every project is to create the network. Sites, transmitters and cells must be specified with all the required information. Then clutter classes and terrain morphology information, usually granted by the customer, should be imported to the project file. The propagation model adopted in this project was the A9955 Standard Propagation Model (SPM). The Standard Propagation Model is a propagation model based on the Hata formulas and is suited for predictions in the 150 to 3500 MHz band over long distances, from one to 20 km.

To start design project some inputs and assumptions must be taken into account in order to have the best defined network possible.

Cameroon network configuration is illustrated in Table 1, it can be seen that for Douala the third-generation network has 135 sites.

```
<table>
<thead>
<tr>
<th>City</th>
<th>Total Sites</th>
<th>2G Only Sites</th>
<th>2G/3G Sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douala</td>
<td>218</td>
<td>83</td>
<td>135</td>
</tr>
<tr>
<td>Yaoundé</td>
<td>180</td>
<td>75</td>
<td>105</td>
</tr>
<tr>
<td>Rest of the country</td>
<td>135</td>
<td>92</td>
<td>43</td>
</tr>
<tr>
<td>Total</td>
<td>533</td>
<td>250</td>
<td>283</td>
</tr>
</tbody>
</table>
```

Clutter refers to a land use or land cover classification of surface features which impact on radio wave propagation.Douala’s populated area is mainly residential in suburban and rural areas. Associated with the defined areas for the Radio Network Planning (RNP) project is the Standard Propagation Model (SPM) definition. In other words, the
sites inside dense urban and urban areas will use the Standard Propagation Model - Dense Urban / Urban. The remaining ones will use the Standard Propagation Model – Sub-Urban / Rural. These particular Standard Propagation Models have different defined parameters to calculate the path loss. With all link budget inputs defined it is possible to compute the design levels for the required services. This design levels will be used to make coverage predictions in the A9955 tool. The main design threshold levels obtained with link budget are presented in Table 2.

Table 2 - Link Budget Calculations per Service

<table>
<thead>
<tr>
<th>RNP Design Level</th>
<th>Link Budget - 2100 MHz</th>
<th>Speech</th>
<th>PS128</th>
<th>PS128 &amp; HSDPA 2 Mbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Urban</td>
<td>-82.5 dBm</td>
<td>-78.7 dBm</td>
<td>-67.56 dBm</td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>-85.4 dBm</td>
<td>-81.7 dBm</td>
<td>-74.45 dBm</td>
<td></td>
</tr>
<tr>
<td>Incar</td>
<td>-94.4 dBm</td>
<td>-90.7 dBm</td>
<td>-81.45 dBm</td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td>-102.4 dBm</td>
<td>-98.7 dBm</td>
<td>-89.45 dBm</td>
<td></td>
</tr>
<tr>
<td>Rest</td>
<td>-110 dBm</td>
<td>-110 dBm</td>
<td>-110 dBm</td>
<td></td>
</tr>
</tbody>
</table>

Each RNP Design Level, specified in Table 2, have a color scheme associated. So the A9955 will use this color scheme for the predictions calculation. The color scheme was an input from the customer and is illustrated in Table 3.

Table 3 - RNP Design Level Color Scheme

<table>
<thead>
<tr>
<th>Coverage by Signal Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Urban (Deep Indoor)</td>
</tr>
<tr>
<td>Urban (Daylight Indoor)</td>
</tr>
<tr>
<td>Incar</td>
</tr>
<tr>
<td>Outdoor</td>
</tr>
<tr>
<td>Rest</td>
</tr>
</tbody>
</table>

Alcatel-Lucent has design principles and criteria to achieve the main goal for third generation network design. The first criterion is related to the Received Signal Code Power (RSCP). Usually, the recommended dimensioning service is PS128. The goal is to have 95% of surface covered with outdoor RNP design level. However, in this project, the customer was more restrictive. The goal is also to have 95% of covered area with outdoor RNP design level, but in the PS128 & HSDPA 2 Mbps service. In addition, the customer introduced a new design goal that is to have more than 70% of surface covered with urban (daylight indoor) RNP design level, for PS128 & HSDPA 2Mbps. Another criterion defined by Alcatel-Lucent is related with the pilot quality, more specifically with Ec/I0 value. The goal is to have 95% of coverage area with an Ec/I0 value of -15dB. From the quality point of view, if an area has good signal coverage but has a poor Ec/I0 value the provided service will not be at the desired level, in other words, it will be a poor service. The Alcatel-Lucent design level threshold and color scheme for Pilot Quality are specified in Table 4.

Table 4 - Pilot Quality Design Level Threshold

<table>
<thead>
<tr>
<th>Pilot Quality (Ec/I0)</th>
<th>Ec/I0 (dB) ≥ -8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -9</td>
</tr>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -10</td>
</tr>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -11</td>
</tr>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -12</td>
</tr>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -13</td>
</tr>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -14</td>
</tr>
<tr>
<td></td>
<td>Ec/I0 (dB) ≥ -15</td>
</tr>
</tbody>
</table>

The final criterion defined is related to interference. The target is to minimize interference without impacting coverage and at the same time enhance quality. The interference criterion relies on the surface with cells within 4dB best server. The surface with 4 servers should be less or equal to 2%. Table 5 illustrates the color scheme used in the A9955 predictions.

Table 5 – Overlapping Areas Threshold

<table>
<thead>
<tr>
<th>Overlapping for 4dB criteria from best server</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Servers ≥ 4</td>
</tr>
<tr>
<td>Number of Servers ≥ 3</td>
</tr>
<tr>
<td>Number of Servers ≥ 2</td>
</tr>
<tr>
<td>Number of Servers ≥ 1</td>
</tr>
</tbody>
</table>

The initial design predictions needed for the evaluation of these requirements are now presented.

PS128 service already achieves the Alcatel-Lucent coverage design target for radio network planning which is more than 95% covered area with outdoor design level. Even so, as
Douala city is mainly dense urban, this service still can be optimized to achieve the best deep indoor coverage possible. Pilot quality is estimated by the ration of energy chip over interference (Ec/I0). With a defined CPICH power ratio of 10% the target Ec/I0 is -15 dB. With the prediction computation of PS128 pilot quality it will be possible to see if this requirement is fulfilled. The Figure 3 illustrates this prediction.

Figure 3 - PS128 Pilot Quality, Initial Design [6]

Although the existence of interference issue in some coverage areas, it can be concluded that the Alcatel-Lucent goal for the interference criteria is satisfied. The percentage of covered focus zone with Ec/I0 grater than -15 dB is more than 95%. So, in future optimization work the goal is to at least maintain the same pilot quality and improve signal coverage.

Figure 4 - Overlapping areas 4 dB criteria, Initial Design [6]

The percentage of area with 4 servers within 4dB of the best server is 3.5%. Which means that Alcatel-Lucent interference criterion is not fulfilled and optimization must be done to achieve these requirements. The starting point for this optimization process is to ensure that best server area is continuous and there is no interruption in best serving zone by a neighbour cell, which would have higher signal strength. Then, check if the more distant sites, which create interference, have the maximum down-tilt value applied. The highest sites must be the most down-tilted ones compared to low height sites.

Figure 5 - Coverage by Signal Level, PS128 & HSDPA 2 Mbps Service, Initial Design [6]

With the observation of Figure 5 it is clear that PS128 & HSDPA 2 Mbps is the most constraint service. Thus, this service will be the chosen dimensioning service and the optimization process focus. From figure 5 it can also be concluded that customer high requirements can not be achieved. The outdoor percentage of covered area for PS128 & HSDPA 2 Mbps is less than 95%, which was a customer requirement.

Since, both Alcatel-Lucent and customer design goals are not entirely fulfilled an optimization should be done to the network in order to accomplish the radio network planning design project objectives.

IV. OPTIMIZATION & RESULTS ANALYSIS

In a radio network planning design project the ambition is not only to accomplish all the project requirements but also to provide the best service possible. For Cameroon network, optimization criteria are limited to electrical up tilt / down tilt. The reason is because third-generation antenna is the same tri-band antenna for the second-generation. Second-generation layer is the most mature and critical network. Hence, physical optimizations for third-generation may impact second-generation coverage.

The optimization criteria are based on three points: Sectors in cluster border, with high electrical down tilt, may be optimized by decreasing the down tilt, in order to increase coverage area. Sectors, which are overshooting, may be optimized in order to improve quality, reduce interference to other sectors and address coverage in the best way. Sectors with an excessive electrical down tilt may be up tilted in order to improve coverage. In this case, is important not to do over up tilting regarding the neighbour sectors.

Based on the optimization criteria there are three main optimization phases. In tilt optimization phase the main point is to make electrical tilt optimization, not forgetting that the main goal is to increase the covered area by service and at the same time at least maintain the same quality (Ec/I0) level. Tilt optimization will be conducted by the most restrictive service, PS128 & HSDPA 2 Mbps. Because,
if there is coverage increase in this service the other services coverage will increase as well. After evaluating services predictions with tilt optimization and if design project requirements were not reached yet, a second optimization phase is needed. This second optimization phase consists in proposing the original second-generation only sites to become third generation sites, especially in coverage hole areas. A coverage hole area is considered to be an area that is not covered with the minimum outdoor design level by service. This second optimization phase is entitled new sites proposal optimization. Lastly, if the design project requirements were not achieved after the new sites optimization phase a third optimization phase must be defined. So, the intention is to increase the power in areas with coverage holes. This optimization phase is considered the power optimization phase.

As described, the optimization starts with the first optimization phase, the tilt optimization. The process is simple, in the A9955 map window, the user has to select the sector that needs to be optimized and choose a better fitting electrical tilt. This process is a manual process and it was done in sections. When a section is optimized a prediction is done to check if the process reaches the desired optimization level. Figure 6 illustrates the section tilt optimization process.

![Figure 6 - Tilt optimization process](image)

As PS128 coverage and pilot quality Alcatel-Lucent requirements had already been achieved, it is important to evaluate if remaining requirements were achieved after this tilt optimization phase without degradation in quality.

In comparison with the initial design results, it can be seen an overall increase in coverage area. Even so, the customer high requirements were not yet achieved with tilt optimization. The covered area with outdoor design level is still less than 95%.

From the quality perspective, it can be concluded that, after the tilt optimization phase, the overall quality was maintained.

From the observation of Figure 8, it can be immediately seen a decrease in interference. Compared with the initial scenario prediction, the areas with more than 4 servers within 4dB of the best server were reduced. This is a remarkable result considering that the overall quality level was maintained and the coverage area was enhanced.

When tilt optimization phase was over the need for additional optimization is still a reality. The Alcatel-Lucent proposal to the customer, in order to improve the network coverage area, was to introduce the 2G only sites in the optimization process. Consequently, the new sites proposal optimization phase consists in two processes. First to introduce the 2G only sites in the A9955 project as 2G/3G sites. Then, start the tilt optimization phase for these sites and for their neighbours in order to reduce interference and have the best covered area possible.
At this time, the only remaining requirement to be fulfilled is the coverage requirement regarding the customer, PS128 & HSDPA 2 Mbps service.

The new sites proposal optimization phase has contributed to an overall significant increase in all the RNP design levels. This was expected due to the new added sites. Even though the covered area with urban design level has registered a great increase, the customer requirement of 70% covered area was not met yet. So, future optimization will still be needed. Pilot quality and interference levels were not modified with this optimization, mainly due to the tilt optimization that was done alongside the new sites proposal. The final optimization phase is power optimization. Power optimization was agreed with the customer to be done only in dense urban and urban areas with coverage holes. The optimization process involves three points: first to identify the sectors in dense urban (deep indoor) and urban (daylight indoor) areas. Then, identify the sectors that are pointing to an area with a coverage hole and finally, change the power in the identified sectors. The main optimization was to increase the power in the identified sectors.

Predictably, it can be seen an overall increase in the coverage area by design level. With this result, the customer requirement of more than 70% covered area with urban design level for PS128 & HSDPA 2 Mbps service was finally accomplished. After evaluation the pilot quality and interference it can be concluded that the power optimization had a minimum impact.

In this manner, it can be declared that all project requirements were achieved. Alcatel-Lucent Pilot Quality requirement of a covered area of 95% with an Ec/I0 level of -15 dB is fulfilled. As well as interference requirement of an area with 4 servers within 4 dB of the best server less or equal to 2% is accomplished. Finally, customer requirements regarding the PS128 & HSDPA 2 Mbps service were also achieved. Which were a covered area with outdoor design level of 95% and, the most restrictive requisite, a covered area of 70% with urban (daylight indoor) design level.

V. CONCLUSIONS

The main motivation for this paper was to execute a third-generation radio network planning design project for a mobile network operator in the Cameroon. The main design project goal was to plan a third-generation network with the best coverage, quality and interference levels possible. To establish the project coverage, quality and interference thresholds some requirements were defined, by the Alcatel-Lucent and the customer. Achieving these demands became the main design project goal. After several optimization phases, all the design project requirements were fulfilled either with respect to coverage, quality and interference. Therefore, the project delivered to the customer had the best-suited network configuration for this new third-generation network.

Although this paper had Douala as the focus city for the design project, the entire project count with nine more cities with a total of 533 sites and 1301 sectors. The procedures presented in this paper, from the definition of the parameters to the optimization phases, were the procedures used in each city. All the optimization processes, for all the cities, were done within the partnership with Alcatel-Lucent. The customer was, also, provided with a report, for each city, describing the services predictions and improvements.

REFERENCES