Manual and Automatic Design for UMTS Networks

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1 Introduction

The expected commercial opening of UMTS networks in Europe emphasizes the need for high performance design tools and methodology. UMTS networks are interference-limited with frequency resources shared among users [1]. High quality design is therefore crucial to optimally utilize the limited available resources to maximize coverage, capacity, and Quality of Service (QoS). This paper focuses on the design in terms of antenna parameters: antenna tilt, azimuth and type, and common channel powers. The design depends on the objectives defined by the operator: The dimensioning service, the penetration margins, the coverage target for the different services, the pricing or throughput policies, etc. Network optimization is required throughout the lifetime of the network: Roll-out stage and densification of an existing network. The design quality is of particular importance since it impacts the investments of the operator, and the network performance in terms of coverage, capacity and QoS.

Two design strategies are described in this paper: The first one is a manual design guided by an expert system which identifies the most effective modifications for the designer; The second strategy uses a combinatorial optimization approach for an automatic design procedure. A Genetic Algorithm (GA) is adapted to guide an Automatic Cell Planner (ACP). Detailed examples of network optimization illustrate the performance of the design approaches.

2 Network design

The development of an efficient design methodology requires a deep understanding of UMTS characteristics. Network parameters could be strongly interdependent, and a change of one parameter in a given sector could influence several sectors, in particular its neighbors. The number of parameters to optimize in the network could be large, and typically varies from a few hundreds to a few thousands. The following objectives guide the design process, and will be used by all models described hereafter:

- *Satisfy coverage objectives for different services and penetration margins*. Both UpLink (UL) and DownLink (DL) coverage of traffic channels and DL coverage of common channels should be considered.
- *Maximize capacity*. For a single service, capacity can be defined as the number of mobiles that can be served. In case of multi-service traffic, one can approximate capacity in terms of global throughput.
- *Ensure handover* (*HO*) *zones* (*macrodiversity zones*). A predefined proportion of the surface of each sector should satisfy HO conditions. HO zones are essential to guarantee continuity of service between the sectors. It also strengthens the radio link against fast fading and shadowing.
- *Minimize economic cost related to the solution implementation*. An economic cost is associated with a modification of each type of parameter.

2.1 Manual design strategies

The first approach considered here is a manual design approach based on an expert system developed in FTR&D. At each step of the manual process the expert system analyzes different quality criteria and guides the designer by identifying the most effective parameter modifications to be carried out. It aims at reducing the loads and excess of interference in the loaded sectors. Manual intervention is slow and the number of modifications that could be considered is limited to a few tens. For this reason, the initial network should be well parameterized, and typically one could choose an optimal default (uniform) parameterization that ensures coverage objectives as a starting point.

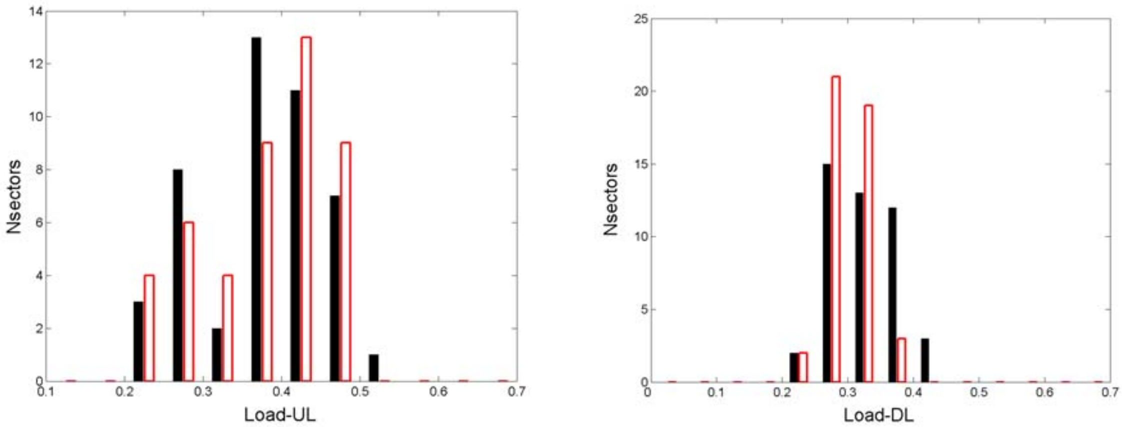
As an example, a network with 45 sectors in a dense urban environment is considered, with mixed traffic: 80% voice (12.2 kbps) service, 15% 64 kbps service and 5% 144 kbps service, with mixed outdoor and indoor mobiles. The UL and DL load histograms of the initial and optimized network after 20 modifications are presented in Figure 1. The following definitions for theUL load, L_{UL}, and DL load, L_{DL}, are used:

$$L_{UL} = \frac{I_{total}}{I_{total} + N_{th}} \tag{1}$$

$$L_{DL} = \frac{P_{total}}{P_{max}} \tag{2}$$

where I_{total} stands for the total interference received at the base station, N_{th} is the thermal noise at the receiver, P_{total} is the total power transmitted by the base station and P_{max} is the maximum possible power at the base station.

The reduction of the number of sectors in the higher part of the histogram illustrates the added value of the design process. It is noted that performance degradation (HO failure, blocking and dropped calls, bad BER and BLER etc.) typically occurs at highly loaded sectors and therefore the results are particularly interesting. The network in this example is down link limited, which is often the case in dense urban environment, and for this reason improvements are more significant in DL than in UL.



b. UL load histogram

b. DL load histogram

Figure 1. Comparison of load histograms for the initial (black) and the manually designed (white) networks.

Figures 2 and 3 show comparisons between traffic demands as a function of the satisfaction rate for the initial network and those obtained using manual and automatic (Oasys V2, see Sect. 2.2) optimization. The traffic demand is related to the total number of mobiles positioned in the network, namely, to mobiles trying to establish communication. The comparison is carried out using two traffic distributions: voice traffic (12.2 kbps) and high bit rate traffic (144 kbps). In the first case (Figure 2), a capacity gain of more than 6 percents is obtained using both optimization approaches. In the second case (Figure 3), no gain is obtained for the manual optimization, whereas a gain of about 8 percents is achieved for the optimization with Oasys V2. In fact, since the manual optimization is carried out using a mixed traffic with 80% of voice mobiles, it is more adapted to a low bit rate level traffic. In addition it is noted that for larger networks, capacity gain using the ACP is larger (see section 2.2).

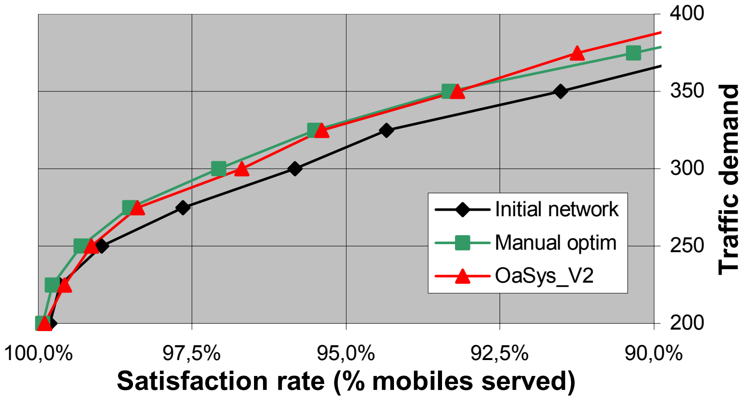


Figure 2. Traffic demand of as a function of satisfaction rate for voice service (12.2 kbps). Traffic demand is related to the total number of mobiles in the network trying to establish communication.

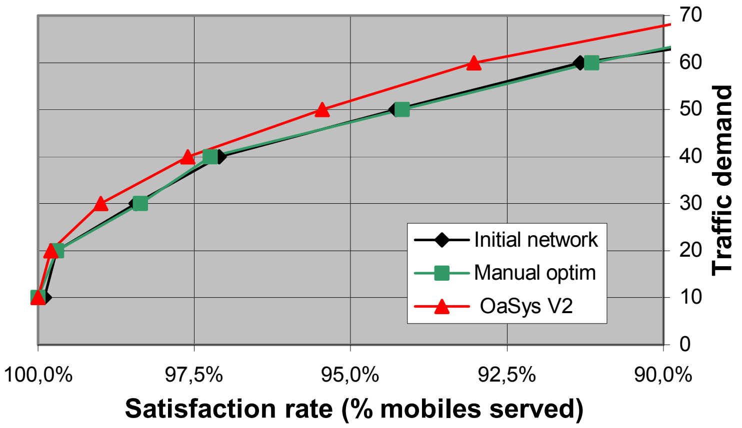


Figure 3. Traffic demand of as a function of satisfaction rate for for 144 kbps service.

2.2 *Automatic design strategies*

The large number of parameters to optimize and the inter-dependency of these parameters make the design process a complex optimization problem that belongs to the class of NP-hard problems and can be solved utilizing a combinatorial optimization technique. An Automatic Cell Planner (ACP), *Oasys*, has been developed in FTR&D to automatically design UMTS networks. The ACP is orchestrated by a Genetic Algorithm (GA) [2], which simultaneously processes a population of networks, each of which is defined by a set of parameters to be optimized. The GA uses the Darwinian evolution as an optimization model that guides a population of networks towards better solutions through repetitive applications of genetic operators till high performance networks are obtained. The GA can test thousands of network configurations and typically outperforms manually design networks. A block diagram describing the optimization procedure is shown in Figure 4.

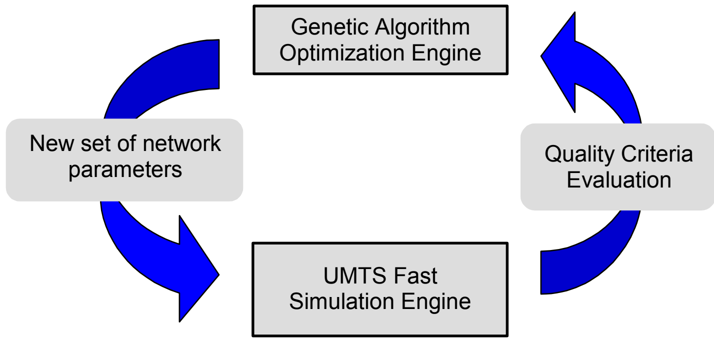


Figure 4. Block diagram describing the GA based ACP.

Two models have been studied:

Roll-out model: Traffic distribution is not yet known, and is implicitly introduced via fixed UL and DL load values utilizing geo-marketing forecasts. Based on the roll-out model, a first version of the ACP, *Oasys V1* has been developed [3-4].

Traffic-based model: Traffic distribution is explicitly introduced in the model (using forecasts or measurements). Ultra-rapid evaluation algorithms have been developed, allowing the model to accurately compute basic UMTS quantities such as powers, loads, interferences etc. Based on this model, a second version of the ACP, *Oasys V2* has been developed. Non-homogeneous traffic distributions can be introduced via hot spots, linear traffic objects and superposition of surface traffic objects.

Performance analysis is of particular importance in the design process since it allows the designer to evaluate the quality of the network and the improvement brought about by the optimization. A set of deterministic quality criteria has been elaborated based on coverage, capacity, service continuity, and probabilistic quality criteria such as probability of access, link upholding and good quality.

Consider next a network with 115 sectors in a dense urban environment. 74 sectors are set for possible modifications, whereas the parameters of the remaining 41 sectors are kept unchanged and constitute a buffer zone to minimize the effect of truncation (see Figure 5).

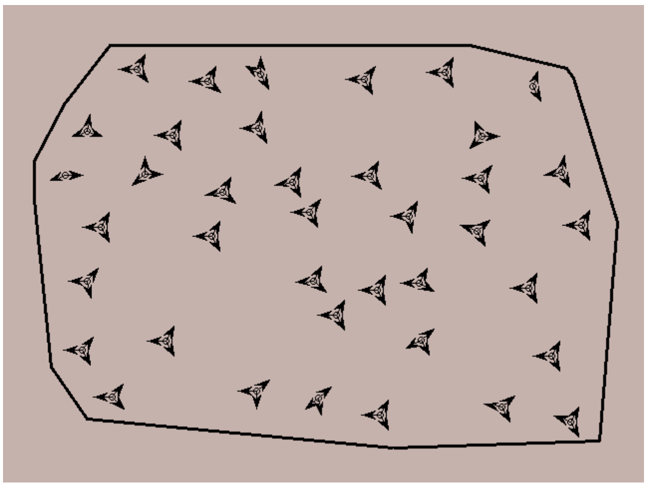


Figure 5. A network with 115 sectors in a dense urban environment.

Figures 6, 7 and 8 show comparisons between the traffic demand as a function of the satisfaction rate for the initial network and those obtained using Oasys V1 and Oasys V2, for 144, 64 and 12.2 kbps respectively. Each figure corresponds to mobiles of a distinct service. The ACP has been set to optimize high bit rate services so that the capacity improvement are significant for 144 and 64 kbps services with a gain of above 15 percents obtained using the traffic based model (Oasys V2).

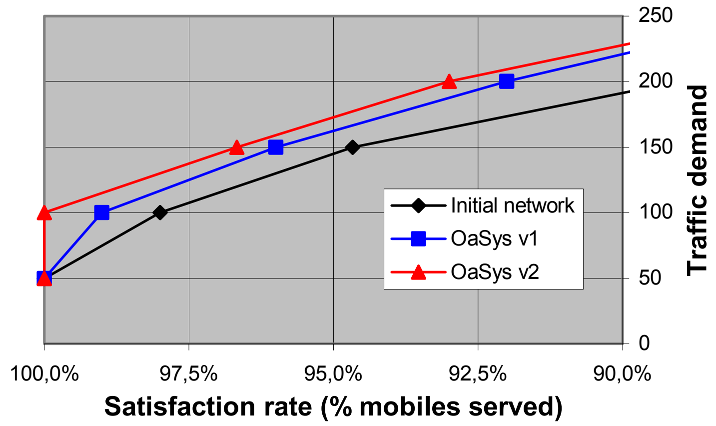


Figure 6. Traffic demand of as a function of satisfaction rate
for 144 kbps service.

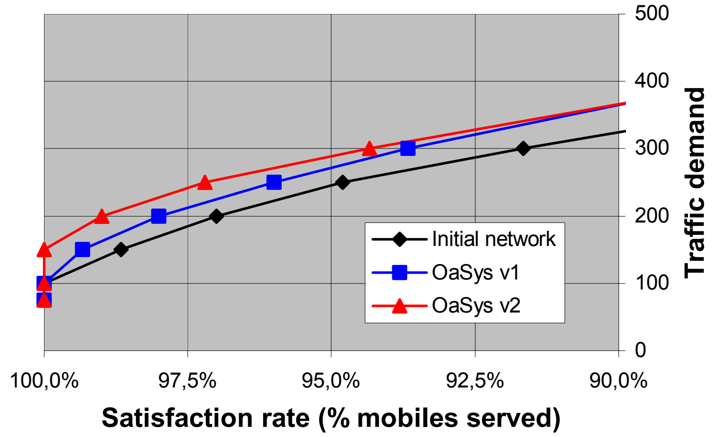


Figure 7. Traffic demand as a function of satisfaction rate
for 64 kbps service.

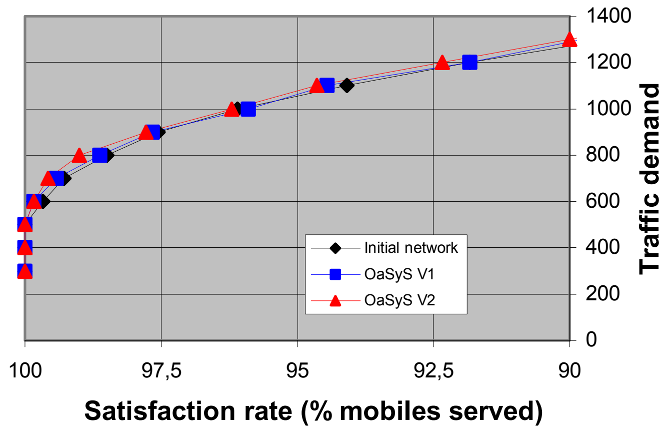


Figure 8. Traffic demand as a function of satisfaction rate
for voice service (12.2 kbps).

The total DL power distribution of the sectors is presented in Figure 9. The ACP strives to reduce the sector powers, and in particular the power of the highly loaded sectors. It is noted that the ACP which includes traffic in the evaluation and optimization process (Oasys V2) further alleviates the power of the most loaded sectors in the network with respect to the Roll-out ACP, Oasys V1. This improvement in resource utilization results in a gain in capacity.

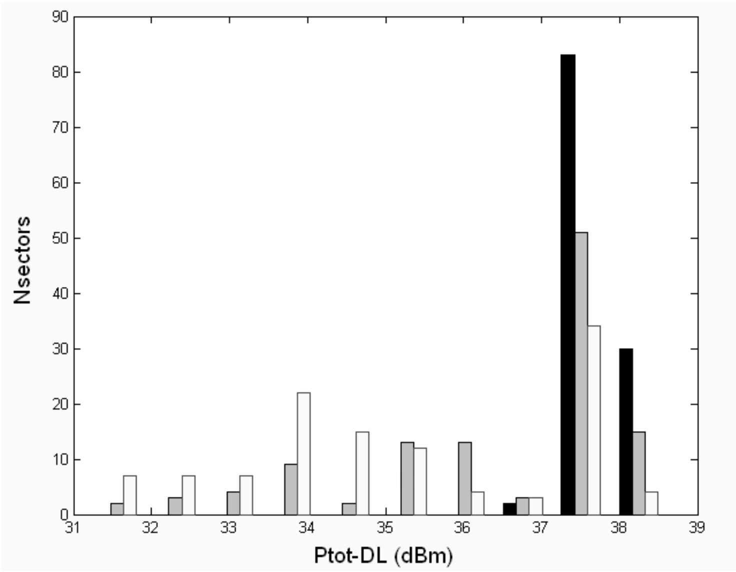
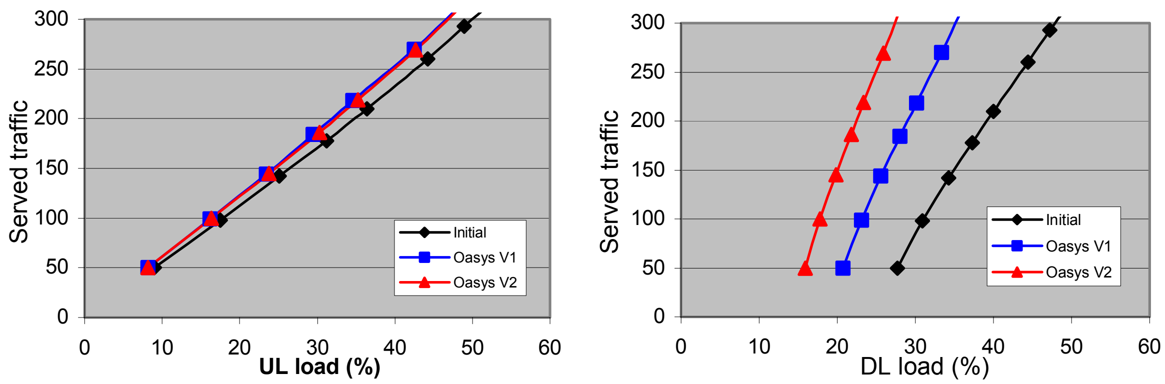


Figure 9. Total DL power distributions for the initial network (black), and the networks optimized using Oasys V1 (gray) and Oasys V2 (white).

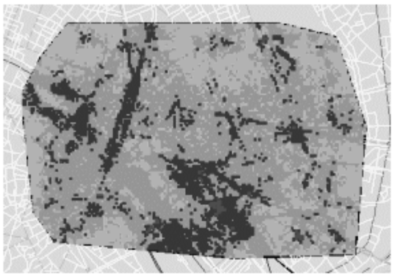
One can relate the number of served mobiles to the average UL and DL loads in the network, as shown in Figure 10. For a given average load, the optimized network serves more mobiles, and conversely, for a fixed number of mobiles, the average load of the optimized network is reduced. Since optimizing the common channels affects mainly DL performance, and in addition, the network is DL limited, the decrease in average load values is particularly apparent in DL, although it is also clear in UL.



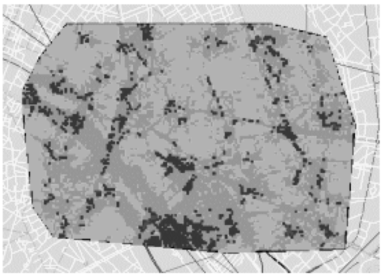
(a) (b)

Figure 10. Number of served mobiles for the 144 kbps service as a function of the average UL (a) and DL (b) loads of the network sectors.

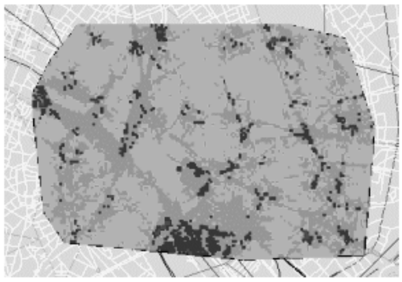
In interference-limited networks, reduction of interference is directly related to gain in capacity and service quality. For this reason, the impact of optimization on interference distribution is of particular interest. In Figure 11 the DL inter-cellular interference maps for the initial and optimized networks are presented. The color of each mesh corresponds to a received power calculated at its center. The optimized networks appear lighter than the initial one due to lower interference levels. Furthermore, Oasys V2, which takes traffic into account in the optimization, allows to further reduce excess of interference with respect to Oasys V1 which uses a fixed load hypothesis.



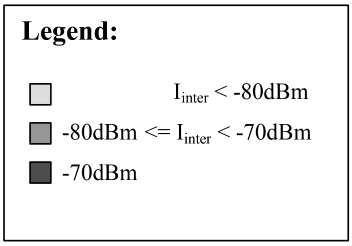
(a)



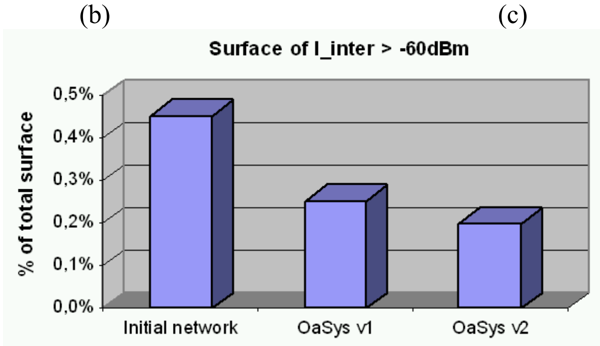
(b)



(c)



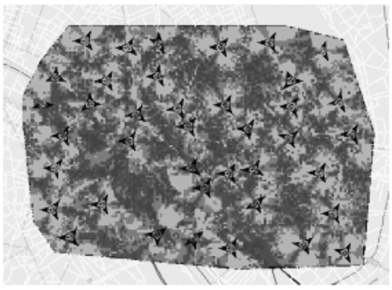
(d)



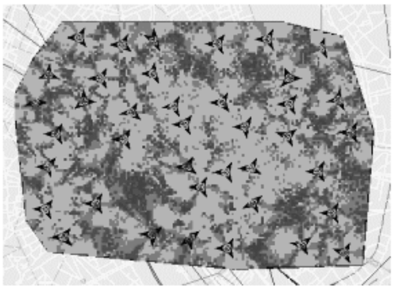
(e)

Figure 11. DL inter-cellular interference maps utilizing the initial network (a), Oasys V1 (b) and Oasys V2 (c). The legend is presented in (d) and the comparison between highly interfered surfaces is shown in (e).

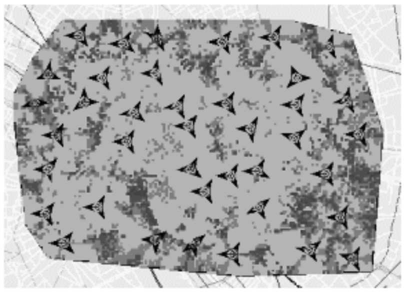
The optimized network requires less radio resources, namely, transmitted power, to achieve the required signal to noise target ratio. Figure 12 presents DL coverage maps of 144 kbps service for traffic channels. The color of each mesh corresponds to the transmitted power of the traffic channel that serves a mobile located at the center of the mesh. It can be seen (see Figure 12e) that the portion of the area with high DL powers, namely in the limit of coverage, is considerably reduced for both optimization models.



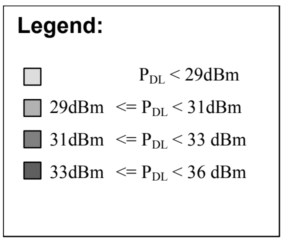
(a)



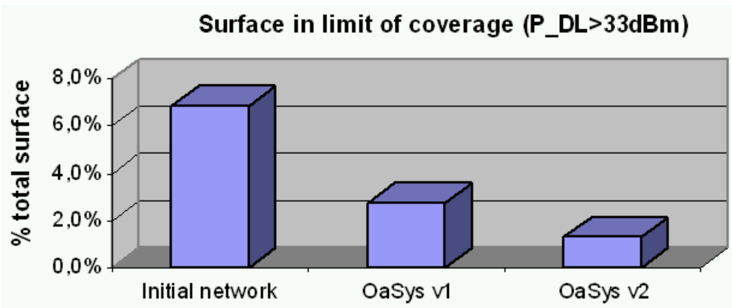
(b)



(c)



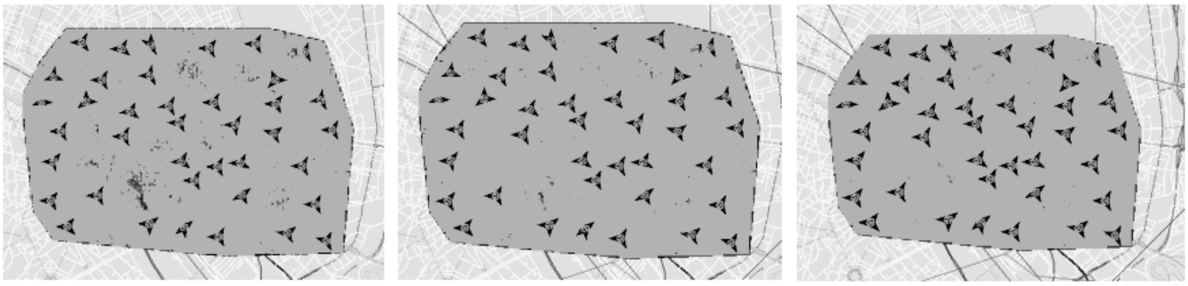
(d)



(e)

Figure 12. DL coverage maps for traffic channels for the initial network (a), Oasys V1 (b) and Oasys V2 (c). The legend is presented in (d), and the comparison of the surfaces in limit of coverage is shown in (e).

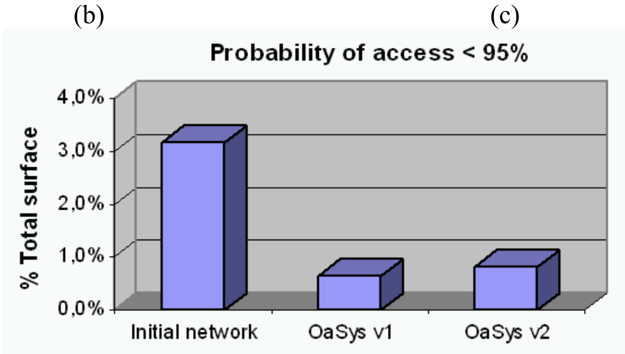
Probabilistic quality criteria are of particular importance for performance analysis of mobile networks due to random phenomena related to traffic position and mobility, shadowing, fast fading, etc. Figure 13 shows the probability of access for 144 kbps mobiles evaluated at the center of each mesh. Both optimization models reduce the surface of low probability of access.



(a) (b) (c)

Legend:

- $0,95 <= P_{acces} < 1$
- $0,85 <= P_{acces} < 0,95$
- $0 \quad <= P_{acces} < 0,85$



(d) (e)

Figure 13. Probability of access for the initial network (a), Oasys V1 (b) and Oasys V2 (c). The legend is presented in (d), and the comparison between the surfaces with lower probability of access is shown in (e).

3 Conclusions

This paper presents efficient manual and automatic design approaches for UMTS networks. The design consists in adjusting antenna types, tilts and azimuths, and common channel powers to improve the network performances: capacity, coverage, QoSe, and service continuity.

Manual design is a complex and a time-consuming task that can be made efficient by the use of an expert system that, by processing quality criteria, identifies the problematic sectors and suggests the most effective parameter modifications. Due to the limited number of modifications that can be treated manually, the expert system focuses on the most loaded and interfered sectors.

An automatic cell planner guided by a genetic algorithm has been developed for automatic optimization. Two models have been considered: a roll out model using fixed load hypothesis, and a traffic based model. The latter includes traffic in the optimization process that allows to accurately evaluate basic UMTS quantities such as powers, loads and interference. The ACP can handle large networks with a number of sectors varying from few tens to several hundreds, corresponding to a few thousands of parameters, and with computational time of several hours. The automatic optimization allows to increase capacity, to reduce excess of interference, and improve quality of service. Further more, the ACP produces cost efficient solutions by including economic cost in the optimization process.

4 References

[1] H. Holma and A. Toskala, *WCDMA for UMTS, Radio Access for Third Generation Mobile Communications*, John Wiley & Sons Ltd, England, 2000.

[2] D. E. Goldberg, *Genetic Algorithms in Search, Optimization and Machine Learning*, Addison-Wesley Publishing Comp. Inc., New York, 1989.

[3] Z. Altman, J.M. Picard, S. Ben Jamaa, B. Fourestié, A. Caminada, T. Dony, J.F. Morlier, and S. Mourniac, "OaSys: FTR&D UMTS automatic cell planning tool", *IEEE Inter. Symp. AP-S*, San Antonio, June, 2002.

[4] Z. Altman, J.M. Picard, S. Ben Jamaa, B. Foursté, A. Caminada, T. Dony, J.F. Morlier, and S. Mourniac, "New challenges in automatic cell planning of UMTS networks", *IEEE Inter. Symp. VTC*, Vancouver, Sept. 2002.