Cost/Revenue Optimisation of Enhanced UMTS Cellular Planning in Urban Scenarios

Cátia Franco, Ricardo Rei, Fernando J. Velez
Instituto de Telecomunicações-DEM, University of Beira Interior
Calçada Fonte do Lameiro, 6201-001 Covilhã, Portugal
c_franco@megamail.pt, rrei@megamail.pt, fjv@ubi.pt

Based in a definition of simulations scenarios, traffic behaviour, and QoS (Quality of Service) aspects, a SLS (System Level Simulator) is used for obtaining system capacity results for urban scenarios, when overload conditions are considered. Optimum values of the cell coverage distance that maximise the profit by unit area were found. For prices of 5 and 7 Euro cents/MB, optimum values of 70 % and 140 %, respectively, were found for profit (for a coverage distance of ~414 m).

Introduction

This paper focuses the possible enhancements to 3rd Generation mobile communications systems for the downlink direction (with HSDPA, High Speed Downlink Packet Access) as well as for the uplink one (with HSUPA, High Speed Uplink Packet Access). It deals with a UMTS, Universal Mobile Telecommunication System, and its evolution to E-UMTS, Enhanced UMTS. Enhancements will allow supporting data rates up to 8-10 Mb/s in both directions, and include, among others, advanced modulation and radio transmission techniques, improved strategies for IP routing and QoS (Quality of Service) assurance at the radio access and core networks. The effect of these enhancements will be evaluated by means of simulation.

UMTS/E-UMTS services classification and characterisation [4] were proposed in the context of the European project IST-SEACORN (Information Society Technologies – Simulation of Enhanced UMTS Access and Core Network). This work included aspects regarding quality of service, as well as a definition of simulation scenarios to be used within the System Level Simulator, SLS, developed by the project [2].

The purpose of this work is to optimise the cellular planning process for multi-service E-UMTS in urban environments by using results for system capacity as an input for a cost/revenue function, e.g., to choose the best coverage distance of cells.

One starts by presenting the simulation parameters and scenario, the supported fraction of active users for a given grade of service, and the supported throughput as well. Then, the cost/revenue model is presented, and its components are described. Taking simple hypothesis for costs and revenues into account, the range of coverage distances that optimise urban E-UMTS in economic terms are found. Finally, conclusions are drawn.

System capacity

System capacity results were obtained for the urban scenario, including blocking probability, handover failure probability, end-to-end delay (latency) and throughput. In this work one only presents the results for the urban scenario. The urban scenario represents urban and suburban environments (outside the city centre). Its main simulation parameters/characteristics [8] are presented in Table 1. The mobility model is the Gauss-Markov mobility model, which is an entity mobility model, as it defines individual and not group movement patterns.

Table 1 – Main simulation parameters.

Parameters	**Values**
Average user velocity	50km/h
Direction update	20m
Probability to change direction in position update	0.2
Maximum angle in position update	45º
Number of base stations	7
Cell coverage distance	[350, 600]m
BS Antenna	Tri-sectorial
Maximum BS Tx power	16dBW
Antenna gain	17.5dBi
UE transmit power class	33,27,24,21(default) dBm
Number of users	5000
Interval between successive calls	0.005s
Simulation time	180s

The pattern is confined within the predefined grid area. As in all mobility scenarios, the users are confined within this area and return to a point inside the topology when they reach the boundaries. It is defined to be between the random walk (slow speeds) and the fluid flow (very high speeds) models. The two models, random walk and fluid flow are labelled as extremes. Most of the nodes moves somewhere in between those speeds.

Parameters for the Gauss-Markov model include the mobile speed at 50 km/h (13.89 m/s), and a random seed, a number that is fed into a random number generator, as this model aims to assign pseudorandom paths to the mobile users, Table 1 (first four parameters). The position actualisation is performed within relatively larger space steps, at each 20 meters, due to higher velocities [3].The Radio Propagation model used is the Hata propagation model [1].

In the urban scenario, simulations consider seven macrocells (N_{cells}=7), Figure 1, using tri-sectorial antennas, and a variation of the cell coverage distance, R, from 350m to 600m. The user density (number of users per square meter), σ, remains unchanged during simulations, thus the number of users varies because the geometry area increases with R. In Table 2, R_b represents the data rate for each considered application and usage represents the percentage of E-UMTS applications users for the urban scenario [4].

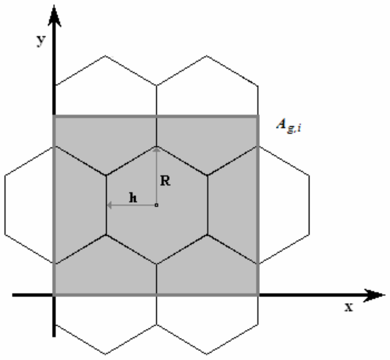

Figure 1 – Cell geometry for the urban scenario.

Table 2 – E-UMTS applications usage for the urban scenario and data rates.

Application	R_b **[kb/s]**	**Usage [%]**
Sound (e.g., voice)	12	79.2
Multimedia (e.g., Videotelephony)	144	11.6
Narrowband (e.g., Multimedia Web Browsing)	384	4.1
Wideband (e.g., Assistance in Travel)	768	5.1

During simulations, active users start their sessions in a small initial period, remaining active during all the simulation time (180s), unless call losses occur (e.g., due to handover failure). By varying *f*, and for each cell radius ($R \in [350, 600]$ meters) several values were obtained where at least one of the QoS parameters (latency, blocking and handover failure probabilities) exceeds its maximum threshold (150 ms, 2%, and $(P_{hf})_{max}$, respectively, the latter corresponding to a maximum call dropping probability of 0.5%). The minimum values of the overlapping curves for the three restrictive conditions represent the maximum fraction of active users supported, Figure 2.

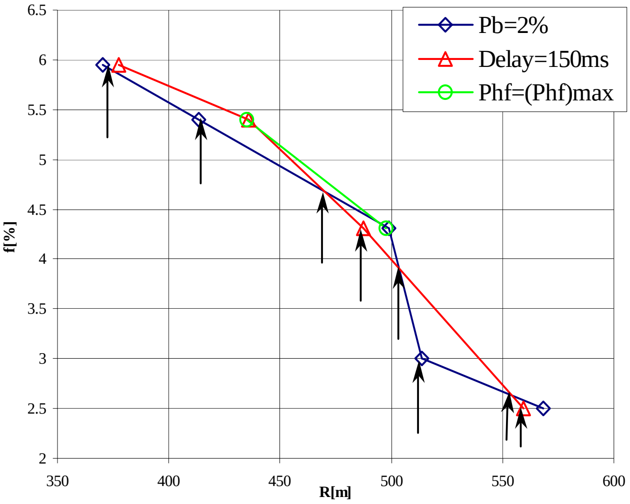

Figure 2 – Fraction of active users, *f*, as a function of *R*, for the three restrictive conditions considered.

These values of *R* will be considered in the computation of system throughput (by using results for throughput obtained from the simulation), Figure 3, which, in turn, will be used as an input for the revenue function. Figure 4 presents the resulting throughput per square kilometre, as a function of *R*. It is approximately constant from 370 to 420 m, with an optimum around 410-420m, where a throughput of 2546kb/s/km^2 is achieved.

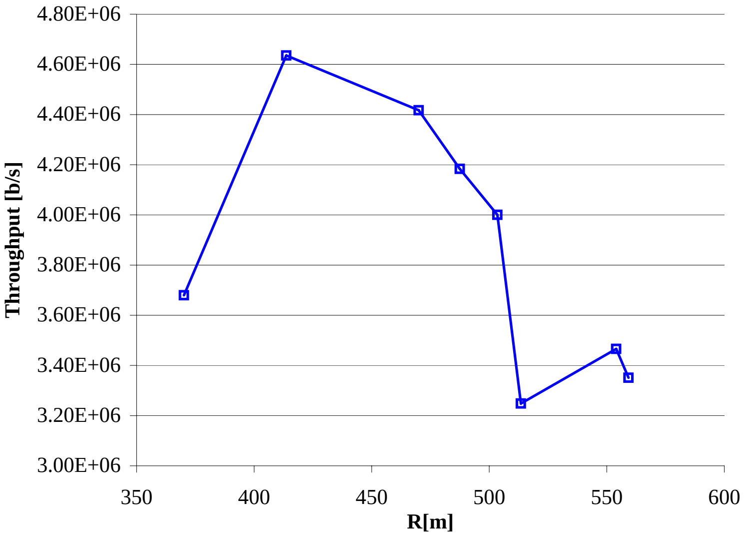

Figure 3 – Throughput as a function of *R*.

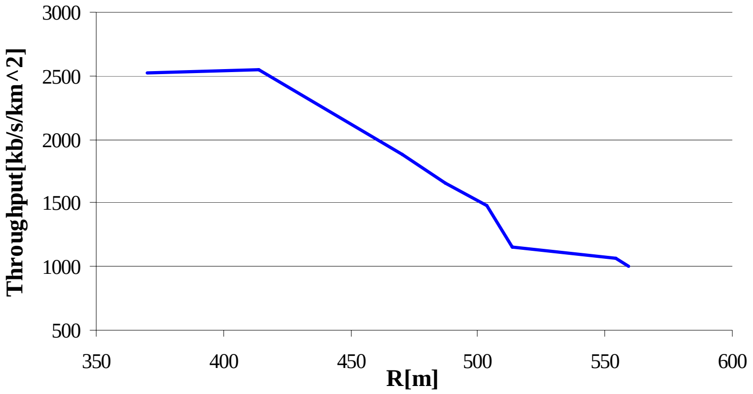

Figure 4 – Throughput per km^2 as a function of *R*, for the urban scenario.

Cost/Revenue Model

The economics of cellular systems can be viewed from the points of view of different entities: the subscribers, the network operators, the service providers, the regulator, and the equipment vendors [5]. In this work, although we are aware that in future mobile multimedia systems the network operator and the service providers can be different entities, we do not distinguishing them. Thus, we consider the operator/service provider's point of view [5].

In urban scenarios, a cost/revenue function has to be developed taking into account the cost of building and maintaining the infrastructure, and the way the number of channels available in each cell affects operators' revenues. Fixed costs for licensing and bandwidth auctions (or beauty contests) should also be taken into account. Although one considers a project duration of five years as a working hypothesis, one will analyse costs and revenues on an annual basis. Furthermore, the analysis is made under the assumption of null discount rate [7].

The system costs includes a fixed term that represents the fixed costs, C_f, and one term proportional to the number of base stations, C_b (although there is a term proportional to the number of carrier of a base station, in this work approach, only one carrier is considered, and this is incorporated in C_b). The total cost per unit area is given by

$$C_{[€/km^2]} = C_{f[€/km^2]} + C_{b[€]} \frac{N_{cells}}{A_{g,i[km^2]}}, \tag{1}$$

Where N_{cells} is the number of cells in a given geometry area, $A_{g,i}$.

The annual revenue per area unit is given by

$$R_{v[€/km^2]} = \frac{p_{[€/kb]} \cdot Q_{[kb]}}{A_{g,i[km^2]}} \tag{2}$$

where p represents the price per kb of data, and Q the load of system that is obtained by

$$Q_{[kb]} = Thr_{[kb/s]} \cdot t_{BHCA[s]} \tag{3}$$

where Thr is the throughput of system, and t_{BHCA} is the total time of the busy hour call attempts, i.e., one considers an equivalent daily period in overload conditions that represents the average situation. The annual period corresponding to this busy hour call attempts, t_{BHCA}, is obtained by considering 6 equivalent busy hours per day during 250 days per year, i.e., 5400000 seconds per year.

Optimisation

The values for the costs and prices may vary meaningfully from country to country and between network operators. In this research one considers hypotheses for the Portuguese case. On the one hand, one considers C_f=361.7 €/km^2/year, and C_b= 12500 €/year [6]. On the other, revenues depend on the volume of information. One considers the hypotheses from Table 3 for the price per MB, *p* (in €/MB).

Table 3 – Hypotheses for the price per MB.

Hypotheses	*p* [€/MB]	*p* [€/kb]
Hyp. I	0.03	3.66E-06
Hyp. II	0.05	6.10E-06
Hyp. III	0.07	8.54E-06

The variation of Costs/revenues per km^2 was obtained as a function of *R*, Figure 5, for the three hypotheses for prices, Table 3, (n.b. costs does not depend on the hypothesis for revenues). One verifies that only for a price of 5 and 7 cents per MB (Hyps. II and III), the revenues totally overcome the considered costs, Figures 5-6. Hence, in urban scenarios it is possible to obtain a profit near to 150% for the most optimistic hypothesis. It was obtained for a cell coverage distance is near to 414m, Figure 6.

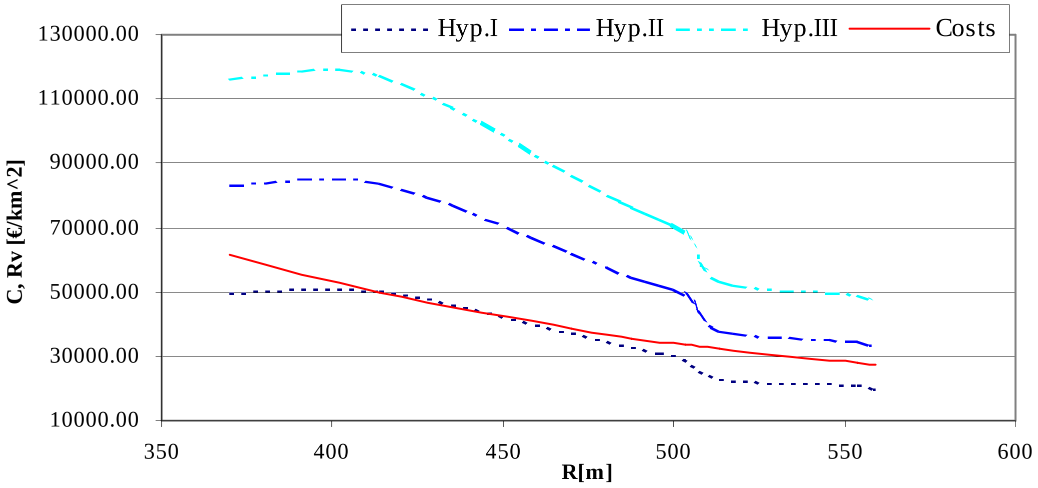

Figure 5 – Costs/revenues per km^2 as a function of *R* for the three hypotheses for prices.

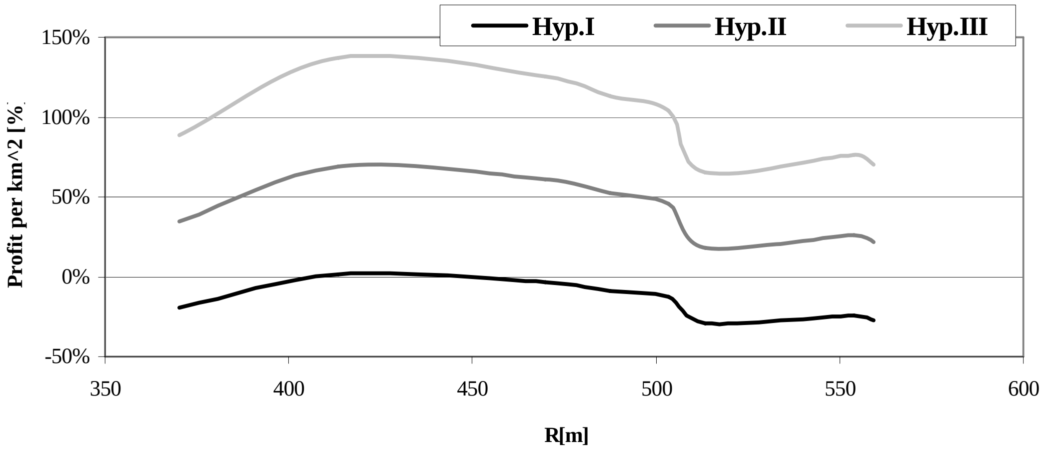

Figure 6 – Profit per km^2 as a function of *R* for the three hypotheses for prices.

Conclusions

Conclusions on Enhanced UMTS cellular planning optimisation were obtained when overload conditions are considered in urban scenarios. These conditions are blocking probability equal to 2%, handover failure probability equal to $(P_{hf})_{max}$ (corresponding to a maximum call dropping probability of 0.5%) and end-o-end delay equal to 150ms. From the results for the throughput per km^2, which is flat from 370 to 420 m, and then decreases substantially, optimum values were found for the cell coverage distance that maximizes the profit by unit area, in percentage. By defining the profit as the difference between revenues and costs optimum values between 405 and 440m were obtained for the coverage distance, the maximum being obtained for R=414m.

Acknowledgments

This work was partially funded by MULTIPLAN and CROSSNET (Portuguese Foundation for Science and Technology POSI and POSC projects with FEDER funding), and by “Projecto de Re-equipamento Científico” REEQ/1201/EEI/2005 (a Portuguese Foundation for Science and Technology project).

References

[1] J. Antoniou, *A System Level Simulator for Enhanced UMTS Coverage and Capacity Planning*, MSc Thesis, Department of Computer Science, University of Cyprus, Nicosia, Cyprus, June 2004.

[2] J. Antoniou, V. Vassiliou, A. Pitsillides, G. Hadjipollas and N. Jacovides, “A Simulation Environment for Enhanced UMTS Performance Evaluation,” in *Proc. of ATNAC 2003 - The Australian Telecommunications, Networks and Applications Conference*, Melbourne, Australia, Dec. 2003.

[3] Jaime Ferreira (Editor), *Final Report on traffic estimation and services characterisation*, IST SEACORN CEC Deliverable 34900/PTIN/DS/014/d6, IST Central Office, Brussels, Belgium, 2003.

[4] J. Ferreira and F.J.Velez, “Deployment Scenarios and Applications Characterisation for Enhanced UMTS Simulation”, in *Proc. of 3G 2004 - 5th IEE International Conference on 3G Mobile Communication Technologies*, London, UK, Oct. 2004.

[5] B. Gavish and S. Sridhar, “Economic Aspects of Configuring Cellular Networks”, *Wireless Networks*, Vol. 1, No. 1, Feb. 1995.

[6] Klas Johansson, Anders Furuskär, Peter Karlsson and Jens Zander, “Relation between cost structure and base station characteristics in cellular systems,” in *Proc. of PIMRC’ 2004 - 15th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, Barcelona, Spain, Sep. 2004.

[7] F.J. Velez and L.M. Correia, **“**Optimisation of mobile broadband multi-service systems based in economics aspects”, *Wireless Networks*, Vol. 9, No. 5, Sep. 2003, pp. 525-533.

[8] V. Vassiliou, G. Hadjipollas, M. Stylianou, J. Antoniou and A. Pitsillides “Performance of E-UMTS in Outdoor Environments”, in *Proc. of SEACORN Workshop*, Cambridge, UK, Mar. 2004.