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Enhanced UMTS Cost/Revenue optimisation in officeS scenarios

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In this paper Enhanced UMTS offices scenarios and classes of services up to wideband are taken into account. A model is proposed for optimising Enhanced UMTS based in costs and revenues. A system level simulator is used to obtain the blocking probability, and other QoS measures, e.g., handover failure probability and delay. Using these results, one obtains the system capacity, i.e., the supported fraction of active users and throughput for a given grade of service. The profit (in percentage) was obtained, and the optimum (most profitable) cell radius was found. A higher number of pico-cells (with a cell radius around 34 m) will be a profitable solution for the optimisation of network planning. This will also allow for increasing system capacity and reducing prices.

Keywords

Enhanced UMTS, economic aspects, offices scenario, optimisation, profit.

Working Group 1 & 3

ENHANCED UMTS COST/REVENUE OPTIMISATION IN OFFICES SCENARIOS

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1 Introduction

Indoor wireless communication networks are an emerging market in Europe, and IEEE 802.11 is appearing as the leading technology. However, it still lacks seamless connectivity to outdoor environments, and it does not provide universal access to public telecommunications networks as customers are traditionally used to, e.g., voice and fax.

UMTS has an enormous potential in answering to the challenge of supporting data, video, and multimedia communications together with voice in all kind of environments, including the indoor business ones, such as offices, airports, commercial zones, tunnels, etc. However, because of limitations of the first releases of UMTS, innovations have to be sought, e.g., for making higher data rates available in both links. HSDPA/HSUPA (High speed downlink/uplink packet access) seek for these solutions, and IST-SEACORN (Simulation of Enhanced UMTS Access and Core Networks) proposed a so-called, E-UMTS (Enhanced UMTS), which is a UMTS all-IP evolution step that provides bit rates higher than 2 Mbit/s in the uplink and downlink directions over a 5 MHz frequency carrier [1].

A cellular E-UMTS network consists of several cells covering a service area. Like in all WCDMA (Wideband Code Division Multiple Access) systems, each BS (base station) or sector has a given a primary scrambling code assigned to it which allows for the BS or sector resources to be represented by an OVSF (Orthogonal Variable Spreading Factor) tree. WCDMA systems are interference limited, and there is an inter-dependence between capacity and coverage which causes the cell size to decrease when the traffic load carried by the cell increases. Therefore, traffic peaks generated by hot spots, such as highly crowded offices with high data rate services can run into coverage problems for macro and micro indoor coverage, and they can jeopardise the entire network quality. In indoor hot spots a solution to overcome these limitations can be to deploy a large number of pico cell, which will guarantee higher system capacity [9].

In order to optimise E-UMTS networks and make simulation-based cellular planning tools available for network design, economic aspects, in the form of cost/revenue functions, are an essential issue. They will also allow for the quantification of the viability of E-UMTS in comparison with IEEE 802.11.

One of the major features of a cellular network, in contrast with a traditional public switched telephone network is user mobility, i.e., when a subscriber moves from one cell to another, the call in progress has to be handled to ensure continuity of service. If no OVSF codes are available in the adjacent cells the call might be interrupted and dropped. Although handover in E-UMTS is flexible since a call can be supported by several BS at the same time, handover failure can also happen either due to high interference (e.g., because of a larger number of users) or to high path loss (e.g., because of an high distance from the BS). This call drops due to handover failure have several implications in QoS (Quality of Service), and the expected net revenue. In addition, there are other very important indicators for the QoS such as delay, call blocking probability, BER (bit error rate), and BLER (block error rate).

In Section 2, the offices scenario is characterised. In Section 3, it is proposed and described a cost/revenue model along with its particular application to the offices scenario. In Section 4, the system capacity is estimated, the main features of the system level simulator are described, and results are presented for several QoS measures. Section 5 discusses assumptions and results regarding cost/revenue and profit optimisation. Finally, conclusions are presented in Section 6.

2 Scenarios and Parameters

To meet the technical demands of the simulation tools a reduced set of services and environments were selected [7], distributed among different service classes (Sound, High Interactive Multimedia, Narrow-, Wide-, and Broadband, depending on data rates). As a result we have three operation environments (offices, business city centre, and vehicular), with four or five services each [7]. In this work only the offices scenario and classes of service up to wideband are taken into consideration, Table 1, with slightly different assumptions. The data rate, R_b, and average duration, τ, are also defined in this table.

Session activity parameters describe the detailed aspects of traffic within a call. This is accomplished by means of an alternating active/inactive state model (ON/OFF). By defining an average duration of each period, together with an adequate statistical distribution (e.g., reflecting long-range dependence), the activity within a call can be modelled. The model is based on population and service penetration values in order to determine call generation rates for the constituent services within each of the selected scenarios.

E-UMTS optimisation can be achieved by seeking optimum values of a merit function taking into account both costs and revenues. The optimisation of costs and revenues provides a mean of joining together several contributions from cellular planning. IST-SEACORN [1] proposed scenarios that include cellular topology, expected population density, deployment and mobility characteristics, other characterisation parameters, and usage of service mix for each environment [7]. From these, an offices scenario with omni directional pico-BS with a maximum power of 3 dBW was chosen. It considers a floor with 140 m x 60 m, as shown in Figure 1, and 1260 users (corresponding to a density factor of 0.15 user/m^2 taken from Table 1).

Services	R_b *[kb/s]*	*Usage*	τ *[min]*
Sound	12.2	58.0	3
High Inter. Mult., HIMM	144	22.3	3
Narrowband	384	8.0	15
Wideband	768	11.7	15
Density Factor (users / m^2)	0.150		

Table 1: Proposal for Applications Usage in the offices scenario.

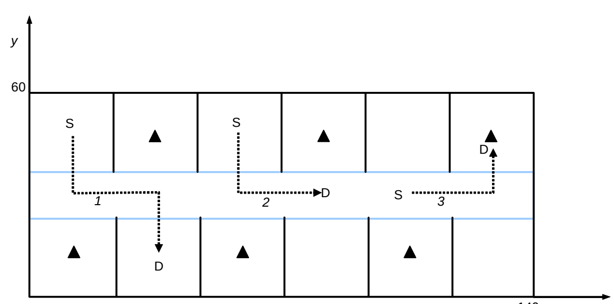

Figure 1: Offices topology (triangles represent BSs).

The offices scenario is characterised by a "boxy" topology, where office rooms are inter-connected by corridors. Users will spend considerable time stationary at a desk and when in motion will move towards a particular destination using a given path. Destinations may be chosen randomly, using a uniform distribution. Two cases may be considered, concerning the nature of movements. In the first one, both source and destination are an office room, while, in the other, either source or destination is a corridor position. The important parameters are the mean ratio of room- to-corridor situated mobile terminals, r, the average time in office room, T_r, and the mobile speed, v_m [6].

3 Cost/Revenue Model

A cellular system can be analysed from different perspectives: the subscriber’s, the network operator’s, the service provider’s, the regulator’s, and the equipment vendor’s. In this work we consider only the perspective of the network operator, whose primary interest is to increase profit. Typically, network operator’s investments relate to radio and transmission equipment, license fees, site build outs and installation of equipment. The running costs, in turn, include mainly transmission, site rentals, marketing, terminal subsidies, and operation and maintenance. The final cost has a fixed part (e.g., license fees, marketing) and a variable part (e.g., radio and transmission equipment, site rentals, maintenance, installation) proportional to the number of BSs per unit length or per unit of area, depending on the geometry. A part proportional to the number of carriers in a BS (i.e., proportional to the cost of the equipment to support a carrier) can also be assumed but as the cells in the offices scenario are omni directional and only one carrier is considered, this cost is incorporated in the cost proportional to the number of BSs. The cost of the connection between BSs and the RNC is not a fixed cost. Instead one considers that is proportional to the number of BSs, which can be true, e.g., if the mobile operator contracts service from a fixed network operator. The cost of a RNC is proportional to the number of BS although the number of RNC can also depend on the throughput [11].

The costs and revenues will be taken in an annual basis. The offices scenario has a linear geometry with two levels, i.e., two rows of offices (located side by side) along a central corridor. In this geometry, with an area $w \times l$, where w is the width and l is the length, and BSs are alternately located inside offices at each side of the corridor, Figure 1, the number of cell per hectometre is given by

$$N_{c/\text{hm}} = \frac{l_{[\text{hm}]}}{R_{[\text{hm}]}} - 1 \, , \qquad (1)$$

where $l_{[\text{hm}]}=1$.

The system cost will contain a fixed term C_{fi} and a term proportional to the number of cells/BSs, C_{fb}. So, the overall cost of the network per unit length per year is [8, 14]

$$C_{0\,[€/\text{hm}]} = C_{fi[€/\text{hm}]} + C_{fb\,[€]} \cdot N_{c/hm} . \qquad (2)$$

From the revenue point of view, nowadays UMTS has two basic methodologies for charging, one depending on the call/session duration, and another depending on the amount of traffic. In this work we consider the latter. However, it is faced in a compound way: we consider the price per minute of a connection at a given data rate, e.g., 144 kb/s; hence, the price per minute that corresponds to a given throughput is obtained by multiplying the revenue per minute for 144 kb/s by the ratio between the total throughput in kb/s and 144kb/s.

The estimation of the variation of system capacity is an input for the revenues. The supported throughput corresponds to a given supported traffic, and was obtained for a grade of service P_b=2%. The revenue per cell per year, $(R_v)_{cell}$ can be obtained as a function of the throughput per BS, $thr_{\text{BS [kb/s]}}$, and of the revenue of a channel with a data rate $R_{b[\text{kb/s}]}$, $R_{Rb[€/\text{min}]}$,

$$(R_\text{v})_{cell\,[€]} = \frac{thr_{\text{BS[kb/s]}} \cdot T_{bh} \cdot R_{R_b[€/\min]}}{R_{b[kb/s]}}\,, \qquad (3)$$

where T_{bh} is the equivalent duration of busy hours per day.

The revenue per hectometre per year, R_v, is obtained by multiplying the revenue per cell by the number of cells per hectometre

$$R_{v[€/\text{hm}]} = N_{c/hm} \cdot (R_\text{v})_{cell\,[€]} = N_{c/hm} \cdot \frac{thr_{BS[\text{kb/s}]} \cdot T_{bh} \cdot R_{R_b[€/\text{min}]}}{R_{b[\text{kb/s}]}}\,. \qquad (4)$$

The net revenue, R_n, in €/hm/year results from (2) and (4)

$$R_{n[€/\text{hm}]} = N_{c/hm} \cdot \left(\frac{thr_{BS[\text{kb/s}]} \cdot T_{bh} \cdot R_{R_b[€/\text{min}]}}{R_{b[\text{kb/s}]}} - C_{fb[€]} \right) - C_{fi[€/\text{hm}]}. \quad (5)$$

If we further considered C_{fi}=0, in order to simplify the analysis, one would get

$$R_{n[€/\text{hm}]} = N_{c/hm} \cdot \left(\frac{thr_{BS[\text{kb/s}]} \cdot T_{bh} \cdot R_{R_b[€/\text{min}]}}{R_{b[\text{kb/s}]}} - C_{fb[€]} \right). \qquad (6)$$

The analysis of the case $C_{fi} \neq 0$ can then be done by comparing the net revenue obtained by using (5) with the fixed cost threshold, C_{fi}. If R_n is higher than C_{fi} there is profit.

4 Capacity estimation

The SEACORN simulator is a SLS (System Level Simulator) [2, 3, 5] that captures the dynamic end-to-end behaviour of the all network, including the dynamic user behaviour (e.g., mobility and variable traffic demands), radio interface, radio access network, and core network, at an appropriate level of abstraction. The SLS is separated into three parts: mobile environment, control mechanisms, and performance evaluation [2]. Control mechanisms involve PC (power control), CAC (call admission control), handover control, load control, and packet scheduling. PC consists of open-loop PC and inner-loop PC, outer-loop PC in both UL (uplink) and DL (downlink) directions, and slow PC applied to the DL common channels. When a new call is required, the CAC checks if there is an OVSF code, and if there is enough power, PC. Hard handover is the only one supported by the simulator. Details on load control and packet scheduling are given in [14]. Enhancements to UMTS are mainly applied to the radio link and the IP infrastructure. These enhancements include Multi-path Interference Canceller, MPIC, Space Time Transmit Diversity, STTD, and MIMO systems.

When the cell radius decreases more BSs are needed to cover the same area as illustrated in Table 2. In order to find the maximum capacity of the network, a certain QoS needs to be guaranteed. The measures for QoS are call blocking probability, P_b, handover failure probability, P_{hf}, and delay. Regarding GoS (grade of service), the maximum acceptable values for delay is 150ms, the maximum acceptable P_b is 2%, while the maximum P_{hf} is obtained as a function of the maximum call dropping probability. From the results, one concludes that handover failure problems can only occur for low values of the coverage distance, and that maximum values of delay never overcome the threshold. Hence, while handover failure probability can be limitative for lower Rs, blocking probability is limitative for all Rs.

A set of results, regarding the blocking probability, P_b, was obtained using the SLS [4] for a maximum transmitted power of 3 dBW, Figure 2, and aimed to seek for results for the throughput of the system as a function of the cell radius maintaining $P_b \leq 2\%$. The values for the cell radius to be chosen in order to have $P_b \leq 2\%$ can be extracted from Figure 2, and are obtained using a linear interpolation for successive values of R and P_b. Hence, for fractions of active users f = 1, 2, 3, 4%, maximum cell radius are 38.5, 17.8, 7, and 5.6 m, respectively. Taking the results from Figure 2 into account, by an inversion procedure, the most suitable f for each value of R (previously obtained for a threshold P_b=2%) was found, Figure 3. Using these values of R and f the total throughput, $thr_{[\text{Mb/s}]}$ is extracted from the simulation results, Figure 4. By using a curve fit approach, a curve for the supported throughput can be found: $thr_{[\text{Mb/s}]} = 37.145R^{-0.7225}$.

These results just consider the blocking probability threshold and do not consider either handover failure aspects or delay.

R [m]	35.0	20.0	15.6	12.7	10.8	9.3	8.3	7.4	6.7	6.1	5.6
N_c	3	6	8	10	12	14	16	18	20	22	24

Table 2: Cell radius versus the number of BS, N_c.

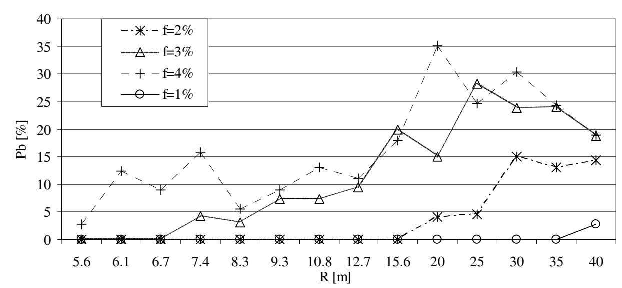

Figure 2: Blocking probability for different values of the fraction of active users f = 1, 2, 3, and 4%.

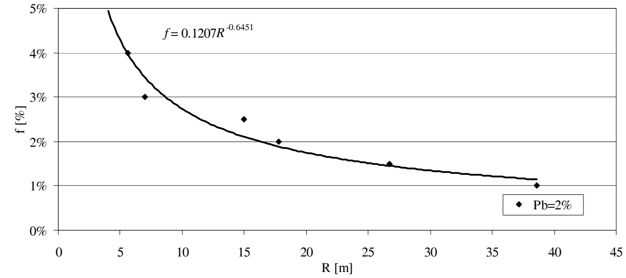

Figure 3: Active users as a function of cell radius, R.

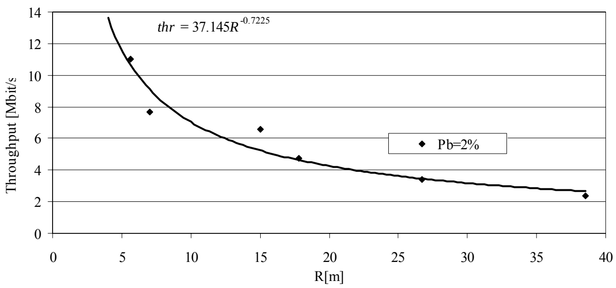

Figure 4: Total throughput of the system as function of R.

However, other important simulator outputs such as SHOF (Soft Handover Failure) and delay have also been obtained. They are important to achieve input values for the optimisation process, since a worst-case situation between blocking probability, handover failure probability, and delay constraints has to be considered. From the analysis of the results, one can also conclude that actual values for handover failure probability (for cell radius that preserve $P_b < 2\%$) are approximately equal to zero. By analysing delay as a function of the simulation time, the worst case occurs when the $f = 4\%$ (the case of higher load), and it never overcomes the 150ms threshold, Figure 5.

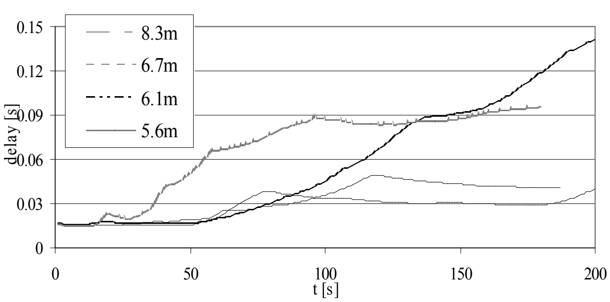

Figure 5: Delay for f=4% and for several cell radius, R.

5 Economic impact

5.1 Assumptions

Although usually operators consider a project duration of five years as a working hypothesis, we will analyse costs and revenues on an annual basis. Furthermore, the analysis is made under the assumption of null discount rate. This work by no means is intended as a complete economic study, but only to present initial contributions. Appropriate changes would be needed to perform a complete economic analysis based on discounted cash flows (e.g., to compute the net present value [12]). By considering six busy hours per day, 240 busy days per year [13], and the revenue/price of a 144 kb/s "channel" per minute (corresponding to information truly transferred, i.e., obtained by discounting the off periods of the traffic), $R_{144[€/min]}$, the revenue per hectometre can be obtained as

$$R_{v[€/hm]} = \left(\frac{l_{[hm]}}{R_{[hm]}} - 1\right) \cdot \left(\frac{thr_{BS[kb/s]} \cdot 60 \cdot 6 \cdot 240 \cdot R_{144[€/min]}}{144_{[kb/s]}}\right) \quad (7)$$

The prices of information transfer at different data rates can be computed proportionally. Two hypothesis have been considered: $R_{144[€/min]}$=0.02 and $R_{144[€/min]}$=0.005. As the transfer of 1 MB of information lasts 56s at 144 kb/s, R_{144} corresponds approximately to the price of a 1 MB transfer. Two different assumptions (hypothesis A [10], and B) were also considered for the cost of pico-cell BSs, Table 3.

Parameters	*Values* [€]	
	A	*B*
Initial Costs:		
BS price, C_{BS}	5000	2500
Installation, C_{Inst}	3000	250
License fees, $C_{fi[€/hm]}$	1000	1000
Annual Cost:		
Operation and maintenance, $C_{M\&O}$	1000	250

Table 3: Assumptions for base station costs

One also assumes that the maximum life-time of BS is N_{year}=5 years. Therefore the cost per BS is calculated by

$$C_{fb[€]} = \frac{C_{BS} + C_{Inst}}{N_{year}} + C_{M\&O}. \quad (8)$$

5.2 Optimisation and Profit

Having hypothesis A into account, Table 3, the cost and the revenue per unit length per year are given by

$$C_{0[€/hm]} = 1000_{[€/hm]} + [(5000_{[€]} + 3000_{[€]})/5 + 1000_{[€]}] \cdot N_{c/hm}, \quad (9)$$

$$R_{v[€/hm]} = thr_{[kb/s]} \cdot R_{144[€/min]} \cdot 6 \cdot 60 \cdot 240 \cdot (l_{[hm]} - R)/[(L_{simul} - R) \cdot 144_{[kb/s]}], \quad (10)$$

where $l_{[hm]}$=1 and L_{simul}=1.40$_{[hm]}$. Note that $thr_{BS} = thr/N_c$, where N_c is the number of BS.

Figure 6 presents results for the overall cost per unit length per year, $C_{0\ [€/hm]}$, and the revenue per unit length per year, $R_{v[€/hm]}$, for the cases $R_{144[€/min]}$=0.02 and 0.005.

One can conclude that for the lowest values of revenues, $R_{144[€/min]}$= 0.005, the costs are higher than revenues, while for $R_{144[€/min]}$=0.02 the revenues clearly overcome the costs.

Another important result that can be obtained from (9) e (10) is the profit, P_{ft}, in percentage, Figure 7,

$$P_{ft[€/hm]} = (R_{v[€/hm]} - C_{0\ [€/hm]})/(C_{0\ [€/hm]}). \quad (11)$$

By analysing these curves, optimum/maximum values for the profit (in percentage) are only found for hypothesis B, the case of lower costs.

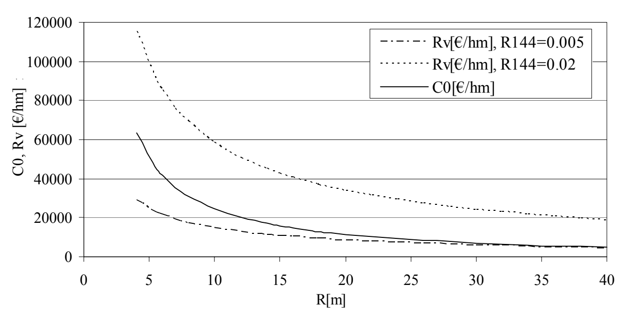

Figure 6: Network revenue and cost per unit length per year as a function of R (hypothesis A).

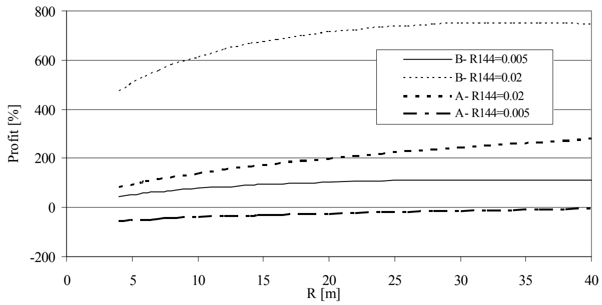

Figure 7: Profit per unit length per year, in percentage, for different hypothesis (A and B) and different $R_{144[€/min]}$.

In this case, the optimum value for the cell radius is around 34-35 m. By varying $R_{144[€/min]}$ from 0.005 to 0.02 there is no significant variation on the optimum coverage distance but the profit increases more than six times, from 112 to 750%. In hypothesis A, i.e., higher costs, no optimum coverage distance was found in the range of the simulations. Furthermore, profit is negative when $R_{144[€/min]}$= 0.005.
Although in hypothesis A the reduction of cells size is not profitable (even if there is a need to support a given system capacity), results from case B shows that a higher number of pico-cells with a given optimum cell radius can be installed in the future when costs of deploying and maintaining the network will decrease, allowing for supporting higher capacity. In this case (hypothesis B) because revenues will increase considerably prices will not need to be so high.

6 Conclusions

One of the most important challenges faced by the wireless industry today is providing seamless coverage for universal mobile and wireless communications, including improved coverage to indoor environments. In this paper, we show that E-UMTS pico-cells will be an affordable solution for providing the required network quality and to reduce infrastructure investments and running costs. We start by proposing a model for costs/revenues, which allows for the determination of the revenue and cost per hectometre, per year. Revenues are proportional to the supported throughput, which was obtained through simulation by using the SEACORN SLS. From these results, the profit (in percentage) was obtained, and the optimum (most profitable) cell radius was found. We can conclude that the profit is highly dependent on costs. Although in the case of higher costs the reduction of cells size is not profitable (even if there is a need of extra system capacity), results for lower costs shows that a higher number of pico-cells (with a cell radius around 34 m) will be a profitable solution for the optimisation of network planning. This will also allow for increasing system capacity and reducing prices.

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