Optimisation of Indoor Mobile B3G Systems Based in Economic Aspects

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System capacity results are obtained by using a system level simulator which considers traffic characterisation parameters and services usage, among other, in an offices scenario. Results for the most profitable cell radius are obtained via an optimisation procedure based in economic aspects. A higher number of pico cells (with a smaller radius, around 30-32 m) can be installed in the future when costs of deploying and maintaining the network decreases, allowing for supporting higher system capacity, and reducing prices. The impact of call blocking, handover failure, end-to-end delay, and delay variation are taken into account.

Introduction

As IEEE 802.11 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, 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 Enhanced UMTS (E-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]. In indoor hotspots a solution to overcome limitations coming from interference and the inter-dependence between capacity and coverage can be to deploy a large number of pico cell, which will guarantee higher system capacity.

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 starts by presenting the scenarios and the parameters to be used in simulations. Then, after presenting the main characteristics of the System Level Simulator, results on QoS (Quality of Service) measures are obtained at call level and at packet level, e.g., the supported fraction of active users, and the throughput. After presenting the cost/revenue model, the optimisation of E-UMTS coverage distances is achieved in offices scenario based in economic aspects. Finally, conclusions are drawn.

Scenarios and Parameters

From the IST-SEACORN scenarios [6], 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.

Table 1: Proposal for services usage in the offices scenario.

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		

Furthermore, the traffic model is based on population and service penetration values in order to determine call generation rates for the constituent services within the scenario.

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. From the IST-SEACORN scenarios [6], an offices scenario with omni directional pico-BSs (base stations) with a maximum power of 3 dBW was chosen. Additional parameters used in this scenario are described in [11]. A floor with 140 m x 60 m, is considered as shown in Figure 1, and 1260 users (corresponding to a density factor of 0.15 user/m^2 taken from Table 1). Details on the mobility model are presented in [5].

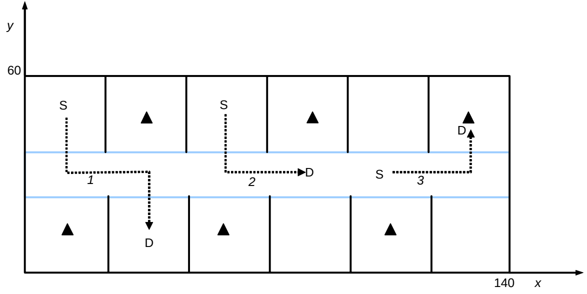

Figure 1: Offices topology (triangles represent BSs).

Capacity estimation

The SEACORN simulator is a System Level Simulator (SLS) [2], [3], [4] 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. Hard handover is the only one supported by the simulator. 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, Table 2.

Table 2: Cell radius versus number of cell, N_c.

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

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. These QoS measures are analysed in two different approaches: the "total" and the "detailed" services ones. The first one does not discriminate which kind of service is being blocked or accepted but only considers the mixture of services as a whole for the determination of "total" call blocking and handover failure probabilities. The other discriminates which kind of service is being blocked or accepted, and a distinction is made between four different call blocking probabilities, one for each real-time/time-based service, i.e., sound and multimedia.

Regarding GoS (Grade of Service), the maximum acceptable values for delay is 150ms, the maximum acceptable P_b is 2%, while the maximum value for P_{hf}, P_{hfmax}, was obtained by using the model described in [8], and by considering a maximum call dropping probability of 1%. From the results, one concluded that handover failure problems 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.

Taking the results for P_b and P_{hf} into account, and by considering the GoS thresholds, by an inversion procedure, the most suitable f for each value of R was found, Figure 2. By using a curve fit approach, a curve for the supported f can be found for both approaches:

- "Total" services: $f = 0.1448R^{-0.7524}$;
- "Detailed" services: $f = 0.112R^{-0.6992}$.

The curve for the supported f using "total" services presents lower values than the one with "detailed" services. By using these curves for $f(R)$ the total throughput, $thr_{[\text{Mb/s}]}$ can also be extracted from the simulation results. Once more, by using a curve fit approach, curves for the supported throughput were found, i.e., $thr=44.109R^{-0.752}$, and $thr=32.368R^{-0.759}$ for the "total" and "detailed" services approaches, respectively. As for the curves for the fraction of active users, the resulting throughput presents lower values in the "total" services approach relatively to the "detailed" services one.

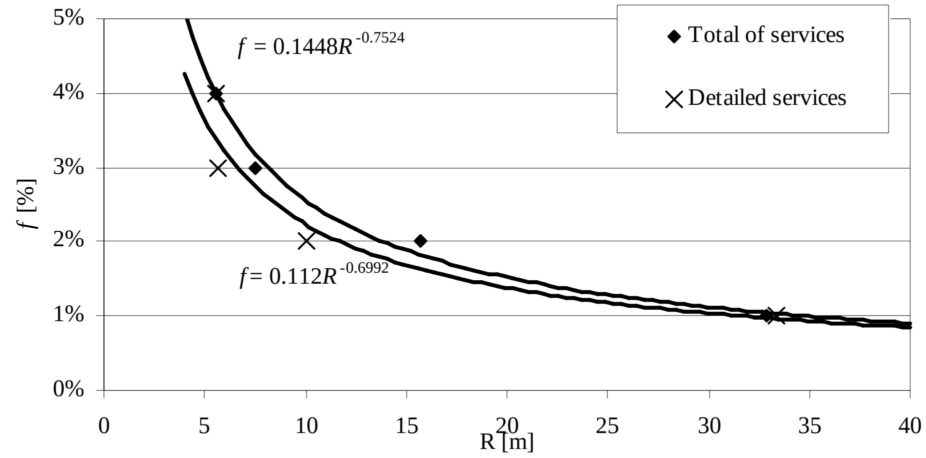

Figure 2: Fraction of active users as function of cell radius.

Cost/Revenue Model

Typically, the final cost of a mobile network has a fixed part, C_{fi} (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, C_{fb}. The cost of a RNC is proportional to the number of BS although the number of RNC can also depend on the throughput.

The costs and revenues will be taken in an annual basis, although the project duration is five years [10]. The offices scenario has a linear geometry with two rows of offices (located side by side) along a central corridor. As BSs are alternately located inside offices at each side of the corridor, Figure 1; the number of cell per hectometre is

$$N_{c/\mathrm{hm}} = l_{[\mathrm{hm}]} / R_{[\mathrm{hm}]} - 1\,, \tag{1}$$

where $l_{[\mathrm{hm}]}=1$. So, the overall network cost per unit length per year is [7], [12]

$$C_{0\,[€/\mathrm{hm}]} = C_{fi[€/\mathrm{hm}]} + C_{fb\,[€]}\, N_{c/hm}. \tag{2}$$

From point of view of revenues, one considers a methodology which depends on the amount of traffic, i.e., the supported throughput. However, it is faced in a compound way, also considering the call/session duration. The price per minute of a connection 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 (corresponding to information truly transferred, i.e., obtained by discounting the off periods of the traffic). The revenue per cell per year, $(R_v)_{cell}$ can then be obtained as a function of the throughput per BS, $thr_{\mathrm{BS}\,[\mathrm{kb/s}]}$, and the revenue of a channel with a data rate $R_{b[\mathrm{kb/s}]}$, $R_{Rb[€/\mathrm{min}]}$,

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

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

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

The net revenue, R_n, in €/hm/year is obtained by the difference between the revenues and costs per year, and results from (2) and (4). If R_n is positive there is profit.

Economic impact

Taking costs and revenues on an annual basis, and by considering six busy hours per day, 240 busy days per year [12], and the revenue/price of a 144 kb/s "channel" per minute, $R_{144[€/\mathrm{min}]}$, the revenue per hectometre can be obtained as

$$R_{\mathrm{v}[€/\mathrm{hm}]} = \left(l_{[\mathrm{hm}]} / R_{[\mathrm{hm}]} - 1 \right) . \left(thr_{BS[\mathrm{kb/s}]} \cdot 60 \cdot 6 \cdot 240 \cdot R_{144[€/\mathrm{min}]} \big/ 144_{[\mathrm{kb/s}]} \right). \tag{5}$$

The prices of information transfer at different data rates can be computed proportionally. Two hypothesis have been considered: $R_{144[€/\mathrm{min}]}=0.02$ and $R_{144[€/\mathrm{min}]}=0.005$. 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 [9], and B) were also considered for the cost of pico cell BSs, Table 3. One also assumes that the maximum life-time of BS is $N_{year}=5$ years. Therefore the cost per BS is calculated by

$$C_{fb[€]} = \left(C_{BS} + C_{Inst} \right) / N_{year} + \mathrm{C}_{M\&O}, \tag{6}$$

with $C_{fi[€/\mathrm{hm}]}=1000$, and $C_{fb[€/\mathrm{hm}]}=(5000+3000)/5+1000=2600$ in case A.

Figure 3 presents results for the overall cost per unit length per year, $C_{0[€/\mathrm{hm}]}$, and the revenue per unit length per year, $R_{\mathrm{v}[€/\mathrm{hm}]}$, for the cases $R_{144[€/\mathrm{min}]}=0.02$ and 0.005.

Table 3: Assumptions for base station costs.

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

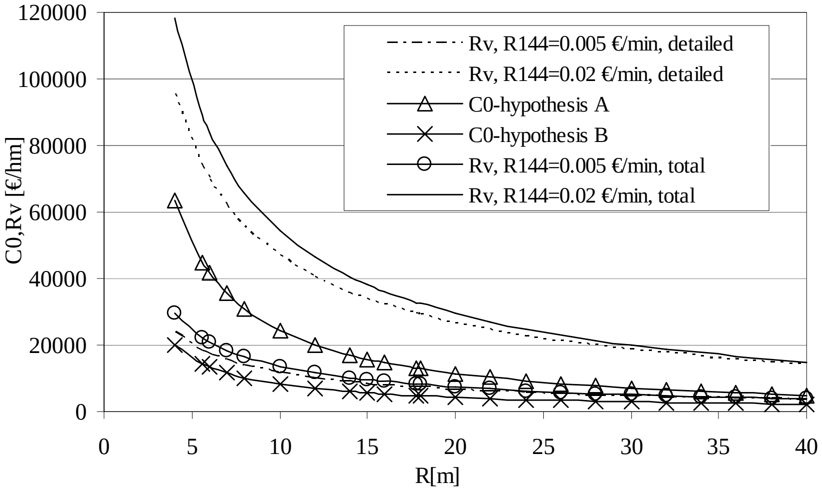

Figure 3: Network revenue and cost per unit length per year as a function of *R*.

By comparing revenues in hypothesis *A* (for the costs), one concludes 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 revenues clearly overcome costs. By using hypothesis *B*, the revenue is always higher than the cost. Since the revenues depend on the throughput, as the curve of throughput takes higher values when considering the "total" services approach (than in the "detailed" services one), the revenues are also higher.

Another important result is the profit, P_{ft}, in percentage. Figure 4 presents an example for the "detailed" services approach. Maximum values for the profit are only found for hypothesis B, the case of lower costs. The optimum value for the cell radius is around 30-32m. 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 about eight times, from 63% to 552%. In hypothesis A, profit is negative when $R_{144[€/min]}$= 0.005.

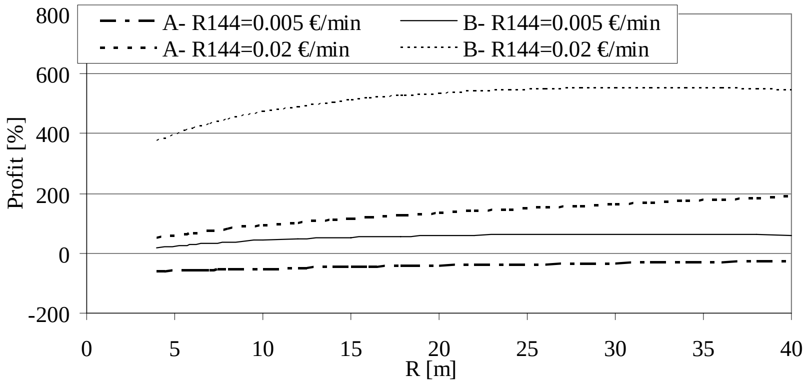

Figure 4: Profit per unit length per year, in percentage, for hypothesis A and B and different $R_{144[€/min]}$.

Conclusions

Mobile and wireless networks must provide improved coverage to indoor environments, including buildings, commercial centres, airports, and tunnels. In this paper, we propose a model for costs/revenues per hectometre per year in offices scenarios. Revenues are proportional to the supported throughput, which was obtained through simulation by using the IST-SEACORN System Level Simulator. As the "detailed" services approach represents a worst case situation it is more appropriate than the "total" services one.

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 show that a higher number of pico cells (with a radius around 30-32 m) can be installed in the future when costs of deploying and maintaining the network decreases, allowing for supporting higher system capacity. This will also allow for reducing prices.

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