

# Enhanced UMTS Micro-Celular Multi-Service Planning Optimisation in Business City Centres

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**Abstract** — Optimisation of the cellular planning process for multi-service Enhanced UMTS in business city centre environments is addressed by using results for system capacity as an input for a cost/revenue function. Based in a definition of simulations scenarios, traffic behaviour, and Quality of Service aspects, a System Level Simulator is used for obtaining system capacity results in the business city centre scenario when overload conditions are considered. Optimum values of the cell coverage distance that maximise the profit per unit length were found. For prices of 5 and 7 Euro cents/MB, optimum values of 80 and 150 % occur around 240m, respectively.

**Keywords** — Enhanced UMTS, business city centre, simulation, micro-celular planning, optimisation

## I. INTRODUCTION

NOWADAYS, while 3<sup>rd</sup> Generation, 3G, systems are giving the first steps in its commercial affirmation, mobile communication networks are evolving to B3G, beyond 3<sup>rd</sup> Generation, 3G systems. This paper focuses the possible enhancements to 3G 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, which encompass radio interface, access network, and core network [1]. Enhancements will allow supporting data rates up to 8-10 Mb/s in both directions (up- and downlink), and include, among others, advanced modulation and radio transmission techniques, improved strategies for IP routing and Quality of Service assurance at the radio access and core networks.

The effect of these enhancements is evaluated by means of simulation. For that purpose a set of services are used, in order to create a complete and realistic simulation framework, impacting directly on traffic generation models. Services are accessed from a variety of operation environments each with its distinctive set of service preferences, usage patterns, and associated mobility profiles.

A communication application can be defined as a task that requires communication of one or more information streams between two or more geographically separated participants, characterised by traffic, communication and service parameters. A service is defined as a generic set of applications with similar characteristics, or as a single application if it is significant by itself.

Although it is possible to define several types of applications/services classifications for UMTS, this paper focuses the 3G QoS, Quality of Service, in the perspective of the UMTS Forum and 3GPP, which considers the following classes: conversational, streaming, interactive and background, Table I, distinguished by their delivery requirements and intrinsic time dependency.

TABLE I  
FUNDAMENTAL CHARACTERISTICS OF TRAFFIC CLASSES.

Traffic Class	Fundamental Characteristics	Examples
CONVERSATIONAL (Real Time)	Preserves the temporal relation between the flow and traffic information entities. Requires low delay.	Voice
STREAMING (Real Time)	Preserves the temporal relation between the flow and traffic information entities.	Video Streaming
INTERACTIVE (Real Time)	Request-response pattern. The user information content is preserved..	Web Browsing
BACKGROUND (Non Real Time)	The end user does not expect the data during a certain period of time. The user information content is preserved.	E-mail

Terminal mobility has a great influence in most UMTS communication aspects involving either performance or traffic generation as a result of handover. Issues such as radio resource management, location management and QoS, as well as traffic handling capacity, are directly affected by mobility. The purpose of mobility models is to describe typical terminal movement for performance analysis purposes. Many link level simulations require the knowledge of detailed terminal position so that the effectiveness of studied techniques such as link adaptation (adaptive coding and modulation) transmission diversity, and beam forming may be evaluated.

The purpose of this work is to optimise the cellular planning process for multi-service E-UMTS in BCC, business city centre, 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.

In Section II the BCC scenario is described. Application characterisation parameters are presented, and the activity behaviour of applications is described. Section III describes the simulation methodology and parameters that allow to obtaining system capacity. The simulation topology is described, and results for the supported throughput are presented. Then, Section IV presents the cost/revenue optimisation model used in this work, and discusses results for profit. Finally, conclusions are drawn in Section V.

## II. E-UMTS SCENARIOS

Scenarios, representing real environments, were defined in terms of mobility, traffic and propagation environment. These can be divided into indoors scenarios (office scenario), formed by picocells, and outdoors scenarios, the object of study of this paper. The latter can be divided into low mobility, with low power base stations in microcells (business city centre scenario, BCC), and high mobility ones, with macrocells and higher power base stations (urban scenario).

In BCC the mobile units move along the streets and can change direction in crossroads following a certain probability. The position actualisation needs to be performed with some frequency, since pedestrian velocities are considered in this environment, an actualisation at each 5 meters is reasonable. At each position actualisation, a velocity variation may occur according to a certain probability. A Manhattan topology is often used to represent BCC scenarios, Fig 1.

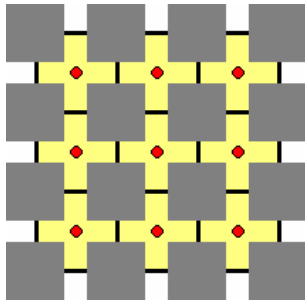


Fig. 1. Manhattan topology model.

This model consists in a rectangular grid composed of intersecting streets, characterised by homogeneous square buildings with 200 meters length, and streets with 30 meters width. It is also characterised by small areas with skyscrapers and a large density of users with pedestrian mobility [2]. The Radio Propagation model is the Walfisch propagation one [3], and omnidirectional antennas are used.

In Table II,  $R_b$  represents the data rate for each considered application while the usage represents the percentage of E-UMTS applications users for URB and BCC scenarios [4]. Examples of applications in each class are VOI-voice, VTE-Video-telephony, MWB-Multimedia Web Browsing, and ATR-Assistance in Travel. Table III presents the service characteristics of these applications (TB-time based, NTB-non TB, RT-real time, NRT-non real time, Bid-bidirectional).

The model for traffic mix defined for these environments generates traffic according to the predefined usage percentages, and assigns an application to each user accordingly. Each user has a probability to be active. This is determined by the Busy Hour Call Attempts (BHCA).

TABLE II  
E-UMTS APPLICATIONS DATA RATE AND USAGE IN BCC.

Services and Applications	$R_b$ [kb/s]	$\tau$ [min]	Usage [%]
Sound (e.g., VOI)	12	3	27.0
Multimedia (e.g., VTE)	144	3	16.0
Narrowband (e.g., MWB)	384	15	26.0
Wideband (e.g., ATR)	768	20	31.0

TABLE III  
ENHANCED UMTS SERVICE CHARACTERISTICS [5].

Applications	Intrinsic time dependency	Delivery requirements	Directionality	Symmetry / Asymmetry
VOI	TB	RT	Bid	Sym
VTE	TB	RT	Bid	Sym
MWB	TB	RT	Bid	Asy
ATR	TB	RT/NRT	Bid	Asy

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.

The activity within a call is modelled by defining an average duration of each active/inactive period, together with an adequate statistical distribution. The basic model for application data normally uses a Web session as a paradigm, although the model may be used for all types of data. A session is composed of a set of active periods made of packet sequences (packet calls) separated by inactivity periods. A packet call is a sequence or burst of packets, corresponding, e.g., to a Web page or other data item. Inactivity periods between packet call arrivals are often called reading or inactivity time. Table IV describes average active versus inactive durations, and presents the statistical distributions of the active and inactive durations.

TABLE IV  
APPLICATION ACTIVITY PARAMETERS.

Applications	Active state (ON)		Inactive state (OFF)	
	Avg.[s]	Distrib.	Avg.[s]	Distrib.
Sound	1.4s	Expon.	1.7 s	Expon.
HIMM	10	Expon.	10	Expon.
Narrowband	10	Pareto	13	Pareto
Wideband	10	Expon.	10	Expon.

## III. SIMULATION

Due to the involved complexity, it is only possible to analyse the 3G/3.5G networks behaviour case by case, e.g., by using a simulation approach. Hence, the system level simulator, SLS, developed within the IST-SEACORN (Information Society Technologies - Simulation of Enhanced UMTS Access and Core Network) was used for the simulations, which allowed for obtaining system capacity results such as blocking probability, handover failure the BCC scenario. Table V presents the main parameters for the BCC scenario.

The BCC scenario represents the system behaviour in a Manhattan geometry outdoor environment with microcells and omnidirectional antennas. Nine base stations were assumed. In the performed simulations, some parameters varied in order to study its influence on the system performance. These parameters include the number of user,  $M$ , and the distance between base stations (n.b., the dimensions of the covered area depends on the distance being therefore, variable).

TABLE V  
SIMULATION PARAMETERS FOR THE BCC SCENARIO.

Parameters	Values
Average user velocity	3km/h
Minimum velocity	0km/h
Direction update	5m
Probability to change velocity in position update	0.2
Probability to turn in a crossroad	0.5
Number of base stations	9
Distance between base stations	[50, 1000]m
Cell coverage distance	[25, 500]m
BS Antenna	Omnidirectional
Maximum BS Tx power	13dBW
Antenna gain	0 dBi
Number of users	[500, 1000]
Interval between successive calls	0.005s
Simulation time	180s

A situation in which all active users initiate a session during a small initial period is simulated. The users remain active until the end of the simulation time, unless call losses occur, e.g., due to handover failure. Values were obtained for the QoS parameters by varying the number of users,  $M \in [500, 1000]$ , for each cell coverage distance,  $R \in [25, 500]$ m. To perform this analysis, one determines the values of  $R$  and  $f$  (the fraction of active users) where the thresholds are reached, i.e., 150 ms for latency, 2% for the blocking probability, and  $(P_{Hf})_{\max}$  for the handover failure probability which corresponds to a maximum call loss probability of 0.5%.

A reference geometry of 900x900 meters was considered, with cells of  $R = 150$  m. A normalisation/transposition from simulation results obtained with geometries of different dimensions, corresponding to different cell coverage distance,  $R$ , to this reference geometry was performed. This is justified because, as cells are tessellated in between blocks of buildings, for each  $R$ , in the usual approach for BCC scenarios, there are different dimensions for the block of buildings because the length of the blocks of buildings is  $2R-l$ , where  $l$  is the street width.

By analysing the results, one concludes that, in geometries with an area equal to the one of the reference geometry, for cell radiuses below 100 m, although throughput is higher, Fig. 2, latency and handover failure probability are limitative. Therefore, in this kind of geometry, to enable the use of microcells with radiuses below 100 m, mechanisms to decrease the effect the excess in these parameters must be developed, e.g., appropriate scheduling algorithms.

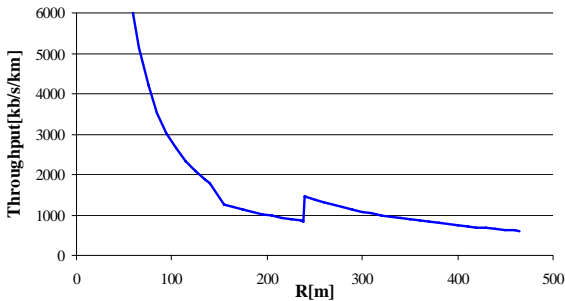


Fig. 2. Throughput per km as a function of  $R$ , for the BCC scenario.

For higher cell coverage distances, an optimum is observed in terms of throughput per kilometre around 240-250 meters, corresponding to a value of the throughput of 1460kb/s/km, Fig. 2. For higher cell radius, the throughput decreases even more. Therefore, the utilisation of cells with radius above 250 meters may not be an advantage.

#### IV. COST/REVENUE OPTIMISATION

In this work, we consider the operator/service provider's point of view [6]. A cost/revenue function was developed for the BCC scenario, 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 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]. By no means is it intended to perform 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).

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, only one carrier is considered, and this is incorporated in  $C_b$ ).

BCC scenario has a regular geometry (Manhattan) which allows for an analysis similar to the linear geometry. Hence, by using a 'linearised' approach which only considers one of the perpendicular streets [7], the total cost per unit of length is given by

$$C_{[\text{€}/\text{km}]} = C_f[\text{€}/\text{km}] + C_b[\text{€}] \frac{1}{2R_{[\text{km}]} - \frac{l_{[\text{km}]}}{2}}, \quad (1)$$

where  $l$  is the street width of the Manhattan geometry. The annual revenue per unit of length is given by

$$R_v[\text{€}/\text{km}] = \frac{p[\text{€}/\text{kb}] \cdot Q_{\text{cell}}[\text{kb}]}{2R_{[\text{km}]} - \frac{l_{[\text{km}]}}{2}}, \quad (2)$$

where  $p$  represents the price per kb of data, and  $Q_{\text{cell}}$  the load supported by a cell during a year, which is obtained by

$$Q_{\text{cell}}[\text{kb}] = \frac{Th_{[\text{kb}/\text{s}]} \cdot t_{\text{BHCA}}[\text{s}]}{N_{\text{cells}}}. \quad (3)$$

Note that  $Q_{[\text{kb}]} = N_{\text{cells}} \cdot Q_{\text{cell}}[\text{kb}]$ , where  $N_{\text{cells}}$  is the number of cells for the 'linearised' geometry.

The annual period corresponding to this busy hour call attempts,  $t_{\text{BHCA}}$ , is obtained by considering 6 equivalent busy hours per day during 250 days per year, i.e., 5400000 seconds per year.

By considering the hypothesis for prices per MB from Table VI, in the range of values for  $R$  to which the latency and the handover failure probability are not limitative, an optimum

was found at  $R \approx 240$ m, where the profit (per cell or per kilometre) presents a maximum, Fig. 3.

However, cell radius up to  $\sim 260$  m can be used without a significant decrease in terms of profit. For these coverage distances, BCC scenarios take clear profitable configurations for Hyps. II and III for prices; profit is approximately 80 and 150 %, respectively.

TABLE VI  
HYPOTHESES FOR THE PRICE PER MB.

Hypotheses	$p$ [€/MB]	$p$ [€/kb]
Hyp. I	0.03	3.66211E-06
Hyp. II	0.05	6.10352E-06
Hyp. III	0.07	8.54492E-06

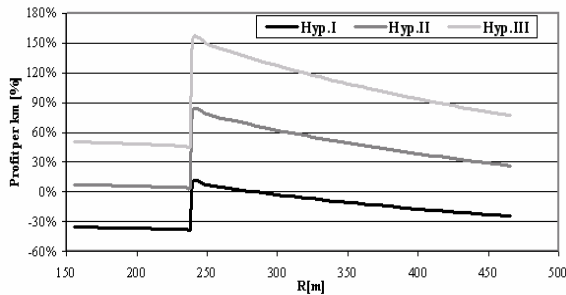


Fig. 3. Total profit per km for BCC, in percentage.

## V. CONCLUSIONS

Based in a definition of Enhanced UMTS simulations scenarios, source traffic characteristics, activity/inactivity behaviour during a call/session, and QoS (Quality of Service) aspects, the SLS (System Level Simulator) developed within IST-SEACORN (Simulation of Enhanced UMTS Access and Core networks) is used for obtaining system capacity results for the business city centre (BCC) scenario.

For the considered hypothesis, revenues exceed the costs for cell radius below 140 m as well as for cell radius higher than 240 meters. By defining the profit as the difference between revenues and costs, optimum values between 240 and 260m were obtained for the coverage distance, the maximum being obtained for  $R \approx 240$ m. Hypothesis II and III are clearly profitable ones.

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