

# Enhanced UMTS Simulation-based Planning in Office Scenarios

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**Abstract** - Enhanced UMTS traffic characterisation parameters have been addressed for the offices scenario. By using a system level simulator, results concerning QoS measures as packet delay, blocking and handover failure probabilities have been obtained. If the cell radius decreases and the number of BSs increases the blocking probability decreases with a linear trend. One concludes that the supported traffic and the corresponding throughput significantly increase when the cell radius decreases. However, increasing system capacity by decreasing the cell radius causes an increase in the intensity of handovers and a decrease in the throughput per BS. Hence, optimum values for the coverage distance will correspond to higher cell radius. Delay and delay variation are not a limitation.

## 1. Introduction

Enhanced UMTS (E-UMTS) is a UMTS evolution step, which provides bit rates higher than 2 Mbit/s both in the uplink and downlink directions, over a 5 MHz frequency carrier. It enables the provision of new wideband services and a significant reduction of the price per bit, running over flexible QoS enabled IP based access and core networks, and making possible an effective end-to-end packet based transmission. Unlike High Speed Downlink Packet Access (HSDPA), which will mostly extend UMTS maximum achieved data rates for the downlink, E-UMTS will allow for expansion in both down- and uplink directions, e.g., by using higher order modulations, and advanced coding schemes. Hence, it will support wideband real-time/time-based mobile applications with a very high system capacity, and will set the ground for an initial introduction of actual broadband mobile applications, an important step towards 4G. IST-SEACORN [1] proposed scenarios that include expected population density, deployment and mobility characteristics, and usage of service mix for each environment. To meet the technical demands of the simulation tools a reduced set of services and environments were selected, distributed among different service classes (Sound, High Interactive Multimedia, Narrow-, Wide-, and Broadband, depending on data rates). As a result three operation environments

(offices, business city centre, and vehicular) were defined, with four or five services each [2]. In this work only the offices scenario and classes of service up to wideband are taken into account.

The IST-SEACORN project developed a System Level Simulator (SLS) that captures the dynamic end-to-end behaviour of the whole 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. By using the SLS, in this work, one obtains results for the quality of service, i.e., blocking and handover failure probabilities, and delay as well. From these results, conclusions can be extracted to the behaviour of system capacity, in terms of the supported throughput for a given GoS, Grade of Service, and optimum coverage distances can be sought.

Section 2 presents the simulations scenarios and parameters, e.g., propagation parameters, mobility models, and offices topology. Section 3 describes the SEACORN System Level Simulator, and the involved algorithms are briefly presented. Section 4 presents quality of service results at call and packet levels. At the call level, the parameters are blocking and handover failure probability, while at the packet level one considers delay and delay variation. By using these results, a model for the fraction of active users as function of the cell radius is found in Section 5, and the corresponding supported throughput is obtained as well. The resulting throughput per base station allows for extracting conclusion on system capacity. Finally, conclusions are drawn in Section 6.

## 2. Scenarios and Parameters

A traffic generation model is used to allow for quantification and description of traffic offered to the E-UMTS in an office environment. This 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. For each service an activity model was chosen and the ON and OFF states were characterised by appropriate statistical distributions. Table 1 presents the characteristics of the office scenario, namely the usage of applications, their average duration, the activity/inactivity distribution and their average

durations. Slightly different assumptions are considered relatively to the IST-SEACORN scenarios [2]. The data rate,  $R_b$ , and average duration,  $\tau$ , are also defined in this Table. Session activity parameters describe the detailed aspects of traffic within a call. 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. Table 2 presents the service characteristics of the corresponding applications, intrinsic time dependency, delivery requirements, directionality, symmetry/asymmetry [3]. Examples of sound, high interactive multimedia (HIM), narrowband (NB) and wideband (WB) applications are VOI (Voice), VTE (Video-telephony), MWB (Multimedia Web Browsing) and IMM (Instant Messaging for Multimedia).

Services	$R_b$ [kbit/s]	Usage [%]	$\tau$ [min]	Distribution of activity/inact.	Activity duration ON[s] OFF[s]
Sound-VOI	12.2	58.0	3	Exponential	1.4 1.7
HIM-VTE	144	22.3	3	-	$\tau$ 0
NB-MWB	384	8.0	15	Pareto	5 13
WD-IMM	768	11.7	15	Weibull/Pareto	5 90

Table 1: Characteristics of the offices scenario.

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

TB-time-based; NTB-non-TB; RT- real-time; NRT-Non-RT.

Table 2: Enhanced UMTS service characteristics.

From the IST-SEACORN scenarios [2], an offices scenario with omni directional pico-BS, and a maximum power of 3 dBW was chosen. Additional parameters used in this scenario are described in Table 3. 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<sup>2</sup> [3]).

Handover Threshold	3 dB
Active set number	3
Downlink orthogonality	0.9
PC range	65dB
Power control step size	1dB
BS Noise figure	8 dB
MS noise figure	5 dB
Noise rise over thermal noise	3dB
Log-normal shadowing "slow fading"	10 dB
Fast fading margin (means PC headroom)	4 dB
Max BS Tx power	33dBm
UE transmit power class	+33, 27, 24, 21(default) dBm
Average transmitter power per traffic channel (downlink)	10 dBm Pico
Average transmitter power per traffic channel (uplink)	4 dBm
Duration of Simulations	200s
Number of runs	5

Table 3: Parameters for the offices scenario.

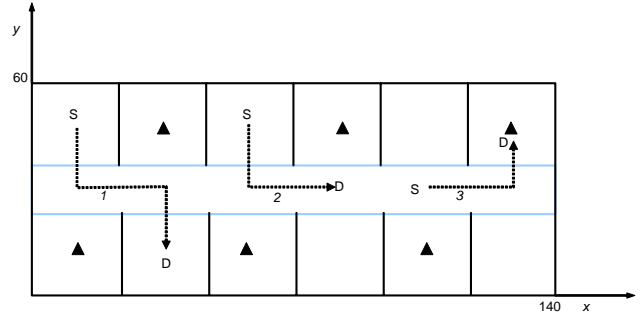


Figure 1. Offices topology (triangles represent BSs).

The mobility model used for the Office Environment scenario is the Random-Waypoint mobility model. The model defines a pattern of movements for each user individually. This pattern is confined within the predefined grid area and consists of a sequence of movements in the  $x$  or  $y$  direction due to the environment, Figure 1. Each node in the model is randomly assigned a pause time between 0 and the maximum pause time (200s). Every node waits for the pause time, but some of them have not a pause time in the 200s of simulation. Then, it chooses a random location on the map, and moves towards that location with a fixed speed of 3km/h (0.83m/s), a typical pedestrian speed. The average ratio of room to corridor mobile terminals is 85%. More details on the mobility model are presented in [4].

The propagation model implemented in the simulator for offices is the Indoor Offices path loss one. It exhibits a low increase of path loss versus distance, which is a worst case from the interference point of view and is defined as follows

$$L = L_{FS} + L_c + \sum k_{wi} \cdot L_{wi} + n^{((n+2)/(n+1)-b)} \cdot L_f, \quad (1)$$

where  $L_{FS}$  is the free space path loss between transmitter and receiver,  $L_c$  is the constant loss,  $K_{wi}$  is the number of penetrated walls of type  $i$ ,  $n$  is the number of penetrated floors,  $L_{wi}$  is the loss of the wall of type  $i$ ,  $L_f$  is the loss between adjacent floors, and  $b$  is the empirical parameter. The average number of floors considered in office environment is usually 4. For capacity calculations in moderately pessimistic environments, the model can be modified to  $n=3$ . Another simplification is the use of weighted averages for certain loss categories. For example, the path loss for typical floor structures can be averaged to 18.3 dB, to 3.4 dB for light internal walls, and to 6.9 dB for internal walls. Under such simplifying assumptions, the indoor path loss model has the following form when  $L_c=0$  dB,  $k_{wi}=1$  and the frequency is 2GHz

$$L = 44 + 30 \cdot \log_{10}(R) + 18.3 \cdot n^{((n+2)/(n+1)-0.46)}, \quad (2)$$

where  $R$  is the transmitter receiver separation given in metres, and  $n$  is the number of floors in the path.  $L$  shall in no circumstance be less than the free space loss. According to [5] a log normal shadow fading standard deviation of 12dB can be expected.

### 3. System Level Simulator

One adopted the SEACORN system level simulator. It is a System Level Simulator (SLS) that captures the dynamic end-to-end behaviour of the whole network, including the dynamic user behaviour (e.g., mobility and

variable traffic demands), radio interface, radio access network, and core network. In order to fulfil the needs of a system level simulation three different simulators were joined together, i.e., the link level (radio link) one, the network and transport level one, and the system level simulator itself [6]. Since UMTS provides a variety of services with variable data rate, a wide range of QoS (Quality of Service) mechanisms are needed. Radio Resource Management mechanisms handle the QoS provisioning over the wireless interface and control the cell capacity (and interference as well), in order to optimise the use of the wireless interface resources. E-UMTS system level simulator Radio Resource Management mechanisms include functions such as power control, handover, call admission control, load control, and packet scheduling [7].

As the simulator is built in a modular manner, the modules may be categorized, according to their functionality, into three main categories: Control Mechanisms, Mobile Environment, and Performance Evaluation. The system level simulator structure is presented in Figure 2.

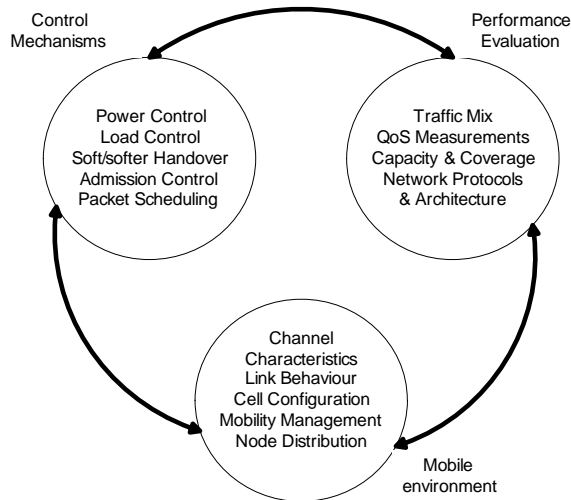


Figure 2. Modular View of the System Level Simulator.

This separation is made according to their functionality. Control mechanisms involve power control (PC), call admission control (CAC), handover control, load control, and packet scheduling. PC consists of open-loop PC and inner-loop PC, outer-loop PC in both uplink (UL) and downlink (DL) directions, and slow PC applied to the DL common channels. When a new call is required, the CAC checks if there is an Orthogonal Variable Spreading Factor (OVSF) code, and if there is enough power, PC. Hard handover is the only one supported by the simulator.

The mobile environment category contains the methods of generating a topology for a scenario as well as the initialization or redefinition of node properties. Node-Bs and UEs are distributed in a predefined grid that represents the simulation area [8].

Performance evaluation will consider the network traffic model, the network protocols and architecture from the network and transport level simulations, and scenarios for traffic services and applications. Network performance must enable the evaluation of coverage, capacity, RRM mechanisms, protocols, architectures, and QoS (using

metrics such as call blocking, call/packet dropping, and end-to-end packet delay).

Several factors influence the performance including the coverage and capacity, i.e., mobility, QoS demands, radio environment, plus radio and core network control mechanisms. For example, the distance between the UE and the Node-B, the path loss, and the power control mechanisms affect the coverage. Capacity is affected by traffic and handover mechanisms. Interference affects both coverage and capacity. QoS is affected by the different network architectures, protocols, and Radio Resource Management (RRM) mechanisms. These factors will be addressed by network and transport level simulations. The basic algorithm for system level simulations is

1. Generate network elements – network topology
2. Distribute users on the simulation space
3. Start traffic generators
4. Calculate which of the users are active
5. Update users' location (simulation triggers)
6. Update Handovers
7. Estimate the interference for each specific cell
8. Determine the Signal-to-interference Ratio (SIR), and compare it against the target SIR
9. If calculated SIR < target SIR, then BLOCK
10. If it is a Real Time Service (RTS) then activate Admission Control (AC)
  - a. If there are radio resources available then ADMIT
  - b. Else, AC send request for resources to Packet Scheduling (PS)
    - i. If PS could free resources from Non Real Time (NRT) then NRTs reconfiguration, RTS are admitted
    - ii. Else BLOCK
11. If it is a non Real Time Service (non-RTS) then PS
  - a. If there are radio resources available then ADMIT
  - b. Else, BLOCK
12. Perform Power Control
13. Update counters for statistics
14. If time > simulation time then Stop Simulation
15. Else, process next event.

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 [9].

#### 4. System Performance

When the cell radius,  $R$ , decreases more BSs are needed to cover the same area, Table 4.

$R$	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 4: Cell radius versus number of cells,  $N_c$ .

In the offices scenario, the topology considered for the base stations presents two levels,  $y=20m$  and  $y=40m$ . In Figure 1 an example of a topology is presented for  $R=20m$ . To reduce the coverage radius, pairs of base stations are added horizontally, one for  $y=20m$  and other for  $y=40m$ , repositioning the whole group in a way that there is equal

horizontal spacing among base stations, Figure 1. Table 4 presents the set of cell radiuses used in simulations. The following equation is used to obtain the cell radius as a function of the number of BSs

$$R = \frac{x_{\max}[\text{m}]}{n + 1} \quad (3)$$

where  $n$  is the number of base stations and  $R$  is the covering radius. It was considered  $x_{\max}[\text{m}] = 140\text{m}$ .

In order to find the maximum capacity of the network, a certain GoS needs to be guaranteed. One considers call level and packet level groups of QoS parameters.

#### 4.1 Call Level

In the context of an all IP Network the most common way to treat users is to queue them instead of blocking. However, for services with stringent QoS requirements, e.g., real-time services, an admission control algorithm has to be implemented. The admission control is necessary to maintain desired QoS, specially to the real time services. At call level, the parameters considered to analyse system capacity are blocking and handover failure probabilities. The call blocking probability,  $P_b$ , is defined as the ratio between the number of blocked calls and the total number of call attempts, while the handover failure probability,  $P_{hf}$ , is the ratio between the number of handover failures and number of handover attempts.

In the SLS, call blocking and handover failure occur in the context of the implementation of two mechanisms: CAC and PC. This two mechanisms test if there are OVSF codes available to support the required data rate and thresholds of power. Hence, the offices scenario involves several classes of services. As only one carrier is considered, the bandwidth is shared among classes. In such situation, due to different characteristics of each class of service, the QoS performance needs to be analysed separately of each one, Table 2. Blocking probability is only being considered for real time/time based applications.

The first set of results includes the blocking probability as a function of the cell radius, for different values of the fraction of active users,  $f$ , Figure 3.

By considering a GoS of  $P_b=2\%$ , for  $f=4.1\%$ ,  $P_b=2\%$  is never overcome, while, for  $f=8.2\%$ , the acceptable radius that corresponds to  $(P_b)_{\max}=2\%$ ,  $R_a$ , is 15.7 m; for  $f=12.4\%$ , it is 7.5m, and for  $f=16.5\%$   $R_a$  is 5.6m. These results for the acceptable radius according to blocking probability restrictions will be used to extract conclusion about system capacity.

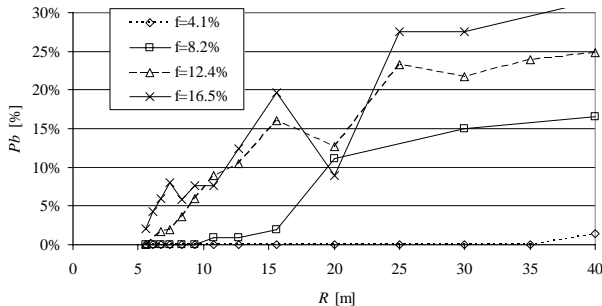


Figure 3.  $P_b$  for different fraction of active users  $f=4.1, 8.2, 12.4$  and  $16.5\%$ .

HO (Handover) is one of the major characteristics of mobile systems. Its influence in QoS is proportional to its intensity/rate. The smaller is the cell radius and higher is the mobility of users the highest is the handover intensity/rate, Figure 4.

The SLS only considers hard handover. Besides, it considers three base stations in the active set; a user is dropped only after six unsuccessful attempts to make handover. In order to find the maximum acceptable  $P_{hf}$ ,  $P_{hf\max}$ , one considers the model described in [10].

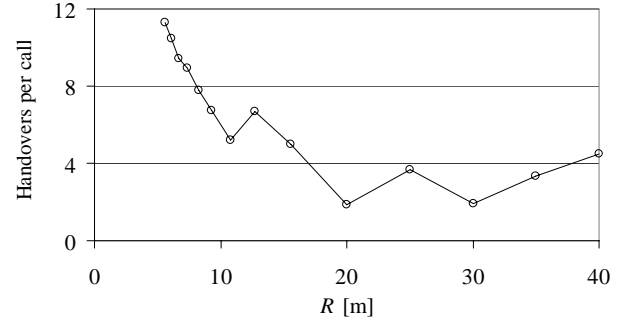


Figure 4. Number of Handovers per call.

A maximum dropping probability,  $P_{d\max}$ , equal to 1%, was considered, and  $P_{hf\max}$  is computed by using

$$P_{hf\max} = \frac{P_{d\max}}{Nb\_HO_j}, \quad (4)$$

where  $Nb\_HO_j$  is the number of handovers per application  $j$  call/session.

Figure 5 presents results for  $P_{hf}$  as a function of the cell radius, for  $f=4.1, 8.2, 12.4$  and  $16.5\%$ . The curve of  $P_{hf\max}$ , as a function of the coverage distance, is also presented.

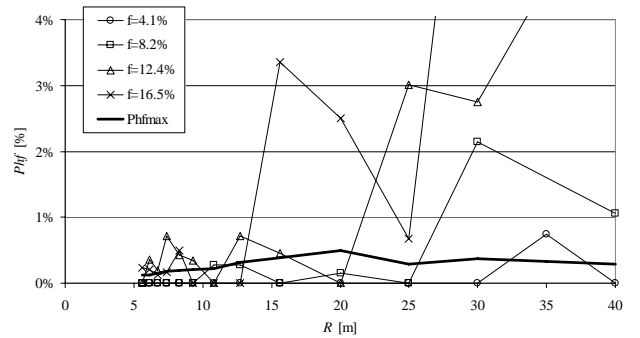


Figure 5.  $P_{hf}$  for VOI, VTE, MWB and IMM.

By adding BSs to the topology, although the network capacity increases, the number of handovers per call also increases, Figure 4. Then, small radius might not be the solution that better satisfy the QoS handover requirements, particularly in applications that are RT/TB calls. The reason is related with the fact that a call being dropped causes extreme dissatisfaction to the users.

Hence, when analysing graphs from Figure 5, for  $f=4.1\%$ , the most appropriate cell radius accounting for handover failure probability constraints,  $R_{ap}$ , is 32.9 m, while for  $f=8.2, 12.4,$  and  $16.5\%$ , the most limitative restriction is blocking probability. Hence, the acceptable cell radiuses for the blocking probability threshold,  $R_a$ , are 15.7, 7.5, and 5.6 m, for the respective  $f$ s, Table 5.

$f_{[%]}$	$R_{a[m]}$	$R_{ap[m]}$
4.1%	40.0	32.9
8.2%	15.7	25.7
12.4%	7.5	20.8
16.5%	5.6	12.8

Table 5: Acceptable cell radius for several values of  $f$ .

## 4.2 Packet Level

The communications between different entities of an all IP Network result from sending/receiving IP packets. In E-UMTS, Packet Data Protocol (PDP) contexts are defined to make this packet exchange possible. Each PDP context exists either during the packet transmission/reception states, or in standby state [11]. The packet level parameters that are being considered to evaluate system capacity are packet delay, and delay variation.

Figure 6 presents simulation results for end-to-end delay (latency). Regarding GoS, the maximum acceptable values for latency (end-to-end delay) is 150ms. From the simulation results, one can conclude that the maximum values for latency do not overcome the threshold. Regarding delay variation, jitter, values never overcome 1ms, being also within the acceptable limits.

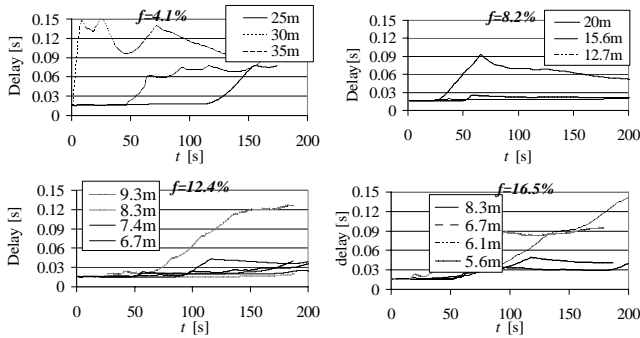


Figure 6. Delay for  $f=4.1, 8.2, 12.4$  and  $16.5\%$  and several cell radiuses.

## 5. System Capacity

Using the cell radiuses from Table IV, the ones effectively simulated, taking a worst case situation between the GoS constraints for  $P_b$ ,  $P_{hf}$ , delay, and delay variation into account (which corresponds in practice to the worst case between  $P_b$  and  $P_{hf}$ , Table 5), by using an inversion procedure, the most suitable  $f$  for each value of  $R$  was found, Figure 7. By using a curve fit approach, a curve for the supported  $f$  was found,  $f_{[%]}=0.6025R^{-0.7569}$ .

By considering these experimental values of  $R$ , the total system throughput,  $thr_{[Mbit/s]}$ , can be extracted from the simulation results, Figure 8.

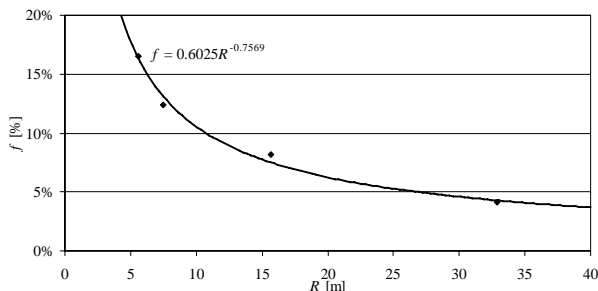


Figure 7. Supported fraction of active users as function of cell radius.

Once more, by using a curve fit approach, the curve for the supported throughput, in the downlink, can be found,  $thr_{[Mbit/s]}=44.1098R^{-0.8289}$ , which presents a decreasing behaviour. It means that, as the cell radius increases, system capacity decreases.

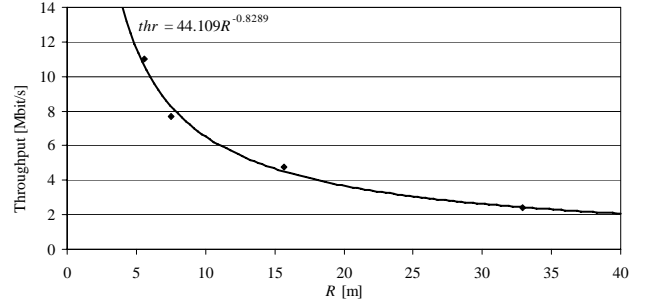


Figure 8. Total system throughput as function of  $R$ .

Another result is the throughput per BS, Figure 9. It can be seen that the throughput per BS increases as the radius increases.

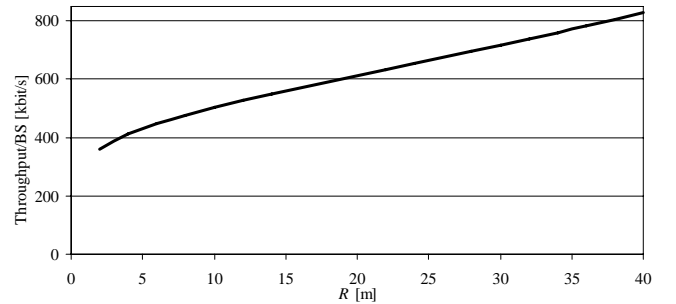


Figure 9. Throughput per BS as function of  $R$ .

This is due to the interference between BSs. When the distance between BSs is lower, the interference is higher, what jeopardises the system, and consequently reduces BS capacity. Though, decreasing BS distance reduces the throughput per BS, it increases system capacity, Figure 9.

However, by analysing Figure 9, the throughput per BS, obtained for a given GoS, increases when the cell radiuses increases. This decrease of the throughput occurs because of the interference from other BSs. One also concludes that the BS throughput will achieve values around 800 kbit/s for cell radius around 40 m.

It is a worth noting that these results can be fed into a merit function which takes both costs and revenues into account. The optimisation that results from the application of this function will provide a means of joining together several contributions from the cellular planning process.

## 6. Conclusions

A traffic generation model was used to allow quantification and description of traffic offered to the E-UMTS in an office environment. This 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. For each service an activity model was chosen and the ON and OFF states were characterised by appropriate statistical distributions.

Results regarding QoS measures such as packet delay, blocking probability and handover failure probability were obtained. By using these results, a model for the fraction of active users as a function of the cell radius was obtained,  $f=0.6025 \cdot R^{-0.7569}$ . A model for the supported throughput was found as well,  $thr=44.109 \cdot R^{-0.8289}$ .

One concludes that, when the cell radius decreases, the supported traffic and the corresponding throughput increase but at the cost of a significant increase in the number of BSs. Hence, when  $R$  varies up to 40 m the throughput per BS increases when the cell radius increases, and the trend is to obtain higher optimum values of  $R$ . This behaviour of the throughput occurs because of the increase in interference, caused by other BSs, while the cell radius decreases.

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