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**Abstract**

In this paper we present an analytical model for computing the othercell interference distribution in a third generation UMTS network. Our proposed model is based on an iterative calculation of a fixed point equation which describes the interdependency of the interference levels at neighboring base stations. Furthermore, we developed an efficient algorithm based on Lognormal approximations to compute the mean and standard deviation of the othercell interference. We will show that our model is accurate and fast enough to be used in UMTS network planning tools, e.g. T-Mobile's *Pegasos*.


## 1 Introduction

The *Universal Mobile Telecommunication System* (UMTS) is the proposal for third generation wireless networks in Europe. Contrary to conventional second generation systems, like GSM, which focus primarily on voice and short message services, UMTS will provide a vast range of data services operating with bit rates of up to 2Mbps and varying quality of service requirements. This will be achieved by operating with *Wideband Code Division Multiple Access* (WCDMA) over the air interface.

The use of WCDMA, however, requires also new paradigms in wireless network planning. While in GSM capacity is a fixed term, it is influenced in WCDMA by the interference caused by all mobile stations (MS) on the uplink, as well as the transmitting powers of the base stations (BS) or NodeB on the downlink. Due to the power control mechanisms in both link directions, the signals are transmitted with such powers that they are received with nearly equal strength. Therefore, the distribution of the user locations must be taken into account in order to perform a thorough network planning.

A detailed examination of the interference on the uplink, however, is not a very straightforward task. Due to the universal frequency reuse in UMTS, all users both in the considered cell and in the neighboring cells will contribute to the total interference, thus influencing the link quality in terms of received bit-energy-to-noise ratio ($E_b/N_0$). Apart from the previously mentioned direct influence, there is also an indirect effect in the system. Since an increase in interference results in a higher required transmission power of the MS, there is a feedback behavior on the other cells as well. It is obvious that in order to model interference adequately it is necessary to capture this feedback behavior by performing an iterative computation.

Most studies on interference found in the literature do not fully take these interactions between cells into account. Among the first papers in this field, [1] and later [2] introduced a relative othercell interference factor $f$ as the ratio between othercell interference to the interference due to users in the same cell. A closed form expression of the $f$-factor can be found in [3], when both BS and MS are assumed to be distributed according to a spatial Poisson process. Similar simple approximations with a fixed interference factor can be found in [4] and [5]. A more sophisticated model is given in [6] and later extended in [7]. Contrary to the prior studies, these models derive distributions for othercell interference which are used to calculate capacity bounds.

In this paper we present an analytical model for the computation of the interference which uses iterative fixed-point equations to determine the distribution of the othercell interference. This iterative approach allows us to include the interdependency between the interferences of neighboring cells in our model which is not fully considered in previous work. By using Lognormal approximations, this method proves to be superior in computation speed compared to the exact computation, which requires multiple convolutional operations. Furthermore, we investigate the influence of different service mixes on the othercell interference.

The paper is organized as follows. Section 2 describes the basic model and the derivation of interference and transmission power in a multi-cell and multi-user scenario. This is extended in Section 3 to an iterative model using fixed-point equations which is solved efficiently using Lognormal approximations. The accuracy of the model is validated in Section 4. The paper is concluded in Section 5 with a short outlook on future work.

## 2 Basic model using point patterns

The capacity of a UMTS system is limited on the uplink by the interference at the BS. This interference level corresponds to the sum of the powers received from all MS within a certain distance to this BS. In the following, the interference level at BS $\ell$ is denoted by $\hat{I}_\ell$, $\hat{S}_k$ and $\nu_k$ define the transmission power and the activity of MS $k$, and the path loss from MS $k$ to BS $\ell$ is given by $\hat{d}_{k,\ell}$. The interference level is computed as

$$\hat{I}_\ell = \frac{1}{W} \sum_{k=1}^{K} \hat{S}_k \hat{d}_{k,\ell} \nu_k. \tag{1}$$

The variables $\hat{\alpha}$ written with a hat are always linear and the corresponding values $\alpha$ are in decibels with $\hat{\alpha} = 10^{\alpha/10}$. $K$ denotes the number of considered MS and $W$ is the frequency bandwidth. The transmission power of each user is defined by the power control equation, see e.g. [4],

$$\hat{\epsilon}_k^* = \frac{\frac{\hat{S}_k \hat{d}_{k,\ell}}{R_k}}{\hat{N}_0 + \sum_{i \neq k} \frac{\hat{S}_i \hat{d}_{i,\ell} \nu_i}{W}} \tag{2}$$

with the target $E_b/N_0$ $\hat{\epsilon}_k^*$, the bit rate $R_k$, and the activity $\nu_k$ specifying the service of user $k$. Note that $\ell$ is the BS with least attenuation which controls the power of MS $k$. These $K$ power control equations are equivalent to the following $K$ equations together with Eqn. (1) for each of the $L$ considered BS.

$$\hat{\epsilon}_k^* = \frac{\frac{\hat{S}_k \hat{d}_{k,\ell}}{R_k}}{\hat{N}_0 + \hat{I}_\ell - \frac{\hat{S}_k \hat{d}_{k,\ell} \nu_k}{W}} \tag{3}$$

Solving each of these equations for $\hat{S}_k$ yields

$$\hat{S}_k = \frac{W}{\hat{d}_{k,\ell}} \left( \hat{N}_0 + \hat{I}_\ell \right) \frac{\beta_k}{W + \beta_k \nu_k}, \tag{4}$$

where $\beta_k = \hat{\epsilon}_k^* R_k$ is an abbreviation for the "bit rate"×"target $E_b/N_0$"-product of MS $k$. These $K$ equations are merged into a single matrix equation to compute the transmission power vector $\hat{S}$ which comprises the transmission powers $\hat{S}_k$ of all users.

$$\begin{aligned} \hat{S} &= W \left( \hat{N}_0 + \hat{I} \right) Q \qquad (5) \\ Q_{k,\ell} &= \begin{cases} \frac{\beta_k}{(W+\beta_k \nu_k)\hat{d}_{k,BS(k)}} & \text{if} \quad \ell = BS(k) \\ 0 & \text{otherwise} \end{cases}, \end{aligned}$$

where $BS(k)$ is the BS which controls the power of MS $k$. Note that $\hat{N}_0$ in matrix equations denotes an $L$-vector with identical entries. This equation contains the variable $\hat{I}$ which denotes a vector of the interference levels at the BS defined in Eqn. (1). These $L$ equations are also written as matrix equation

$$\hat{I} = \frac{1}{W}\hat{S}\tilde{\nu}\hat{d}, \tag{6}$$

where $\tilde{\nu}$ is a $K \times K$ diagonal matrix with $\tilde{\nu}_{k,k} = \nu_k$ and $\hat{d}$ is a $K \times L$-matrix containing the attenuations. Now substituting the vector $\hat{S}$ in Eqn. (6) by Eqn. (5) and solving for $\hat{I}$ yields after some transformations

$$\begin{aligned} \hat{I} &= \hat{N}_0 A \left(E - A\right)^{-1}, \\ A &= Q\tilde{\nu}\hat{d}. \end{aligned} \tag{7}$$

The matrix $E$ is the $L \times L$ identity matrix. Similar to the $A_{out}$ case defined in [4] when the pole capacity of a single cell is exceeded, the capacity in the multi-BS case is sufficient only if the inverse of matrix $(E - A)$ is positive. Finally, the transmission power $\hat{S}_k$ of MS $k$ can be calculated using Eqn. (5). A more detailed description of the model can be found in [8] and is extended to include soft handover and transmission power limitations [9], as well.

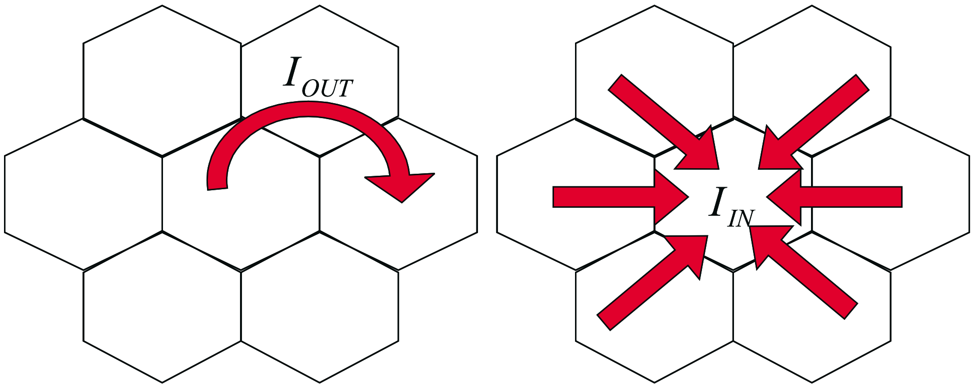
Distributions of the total, incell, and othercell interference for a specific BS layout are obtained from this model by generating a large number of point patterns. These define the positions where users with a specified service are located according to a spatial arrival process, e.g. the spatial Poisson process. For all these point patterns the interference is computed separately and all results yield the interference distribution. This method is very flexible regarding different propagation models, spatial MS distributions, and BS layouts. However, the computation of interference distributions is time consuming, thus a fast approximation of interference distributions is desired for planning large UMTS networks. In the following section such an approximation using fixed-point equations will be proposed; the computation relying on point patterns will be used to verify the approximated results.

## 3 Iterative model using Fixed-Point equations

The aim of this approximation is to model analytically the stochastic variables defined by the spatial arrival process used to generate point patterns. These stochastic elements consist of the number of users in the system, the location of the users, and their service. In the analytic model we focus on a user distribution according to a homogeneous spatial Poisson process, a regular hexagonal BS layout, and the propagation model of the vehicular test environment in [10]

$$d_{k,\ell} = -128.1 - 37.6 \log_{10}(dist_{k,\ell}), \tag{8}$$

where $dist_{k,\ell}$ denotes the distance between an MS $k$ and a BS $\ell$ in km.




(a) Interference induced to the neighbor BS

(b) Othercell interference induced from neighbor BS

Figure 1: Illustration of the iterative model

The idea behind the approximation is to calculate the othercell interference distribution iteratively by solving fixed-point equations. The iterative model is illustrated in Fig. 1. Assuming a homogeneous user distribution with equal densities in all cells, the r.v. (random variable) $\hat{I}_{OUT}$ describing the interference induced by the MS of an arbitrary cell at a neighbor BS is identically distributed. The distribution of $\hat{I}_{OUT}$, however, depends both on the users in the cell as well as on the interference $\hat{I}_{IN}$ produced by users of the surrounding cells. Thus, a fixed-point equation can be formulated describing $\hat{I}_{OUT}$ depending on $\hat{I}_{IN}$, illustrated in Fig. 1(a), and $\hat{I}_{IN}$ depending on $\hat{I}_{OUT}$, shown in Fig. 1(b). The solution of these two equations yields the distribution of the othercell interference.

### 3.1 Fixed-Point Equation

Let the central BS of Fig. 1 be BS $i$ with $K$ MS and $j$ denotes an arbitrary neighbor BS. Then, assuming that the distribution of the othercell interference $\hat{I}_{IN,i}$ is known we can compute the induced interference $\hat{I}_{OUT,j}$ at BS $j$ by

$$\hat{I}_{OUT,j} = \sum_{k=1}^{K} \frac{(\hat{N}_0 + \hat{I}_{IN,i})}{1-A} \alpha_k \frac{\hat{d}_{k,j}}{\hat{d}_{k,i}}, \tag{9}$$

with $\alpha_k = \beta_k (W + \beta_k \nu_k)^{-1}$. The variable $A$ is a $1 \times 1$-matrix as defined in Eqn. (7). Note that the location of a user $k$ in the cell of BS $i$ is described completely by the ratio of the attenuations to BS $j$ and BS $i$. This ratio is a r.v. denoted by $\Delta$ and its distribution is derived empirically by generating a number of locations according to a spatial Poisson process. The distribution of $\Delta$ is shown in Fig. 2. With the r.v. $\Delta$ Eqn. (9) becomes

$$\hat{I}_{OUT,j} = (\hat{N}_0 + \hat{I}_{IN,i}) \sum_{k=1}^{K} \frac{1}{1-A} \alpha_k \Delta. \tag{10}$$

The other stochastic variables in the equation are the number of MS attached to BS $i$ and their services. A new r.v. $F$ is introduced which comprises all stochastic influences of the spatial Poisson process. Thus, Eqn. (10) is simplified to

$$\hat{I}_{OUT,j} = (\hat{N}_0 + \hat{I}_{IN,i}) F. \tag{11}$$

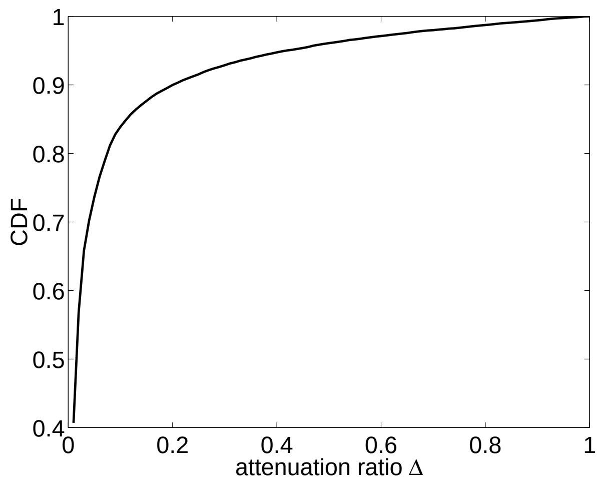



Figure 2: CDF of the attenuation ratio

In the following we will derive the distribution of $F$. The users are generated according to a $T$-dimensional Poisson process with $T$ the number of offered services where a service $t$ is taken with probability $q_t$. The number of users in a cell are then given by a $T$-tuple $\bar{n} = (n_1, ..., n_T)$ with $n_t$ the number of users with service $t$. The probability $p(\bar{n})$ that $\bar{n}$ MS are in a cell is calculated by the product form solution

$$\begin{aligned} \tilde{p}(\bar{n}) &= \prod_{t=1}^{T} \frac{(m_t)^{n_t}}{n_t!} \text{ and} \\ p(\bar{n}) &= \frac{\tilde{p}(\bar{n})}{\sum_{\bar{n}':A(\bar{n}')<1} \tilde{p}(\bar{n}')}, \end{aligned} \tag{12}$$

where $m_t$ is the mean number of MS with service $t$ in the cell. For a traffic density of $\lambda$ users per cell $m_t$ is given as $m_t = \lambda \cdot q_t$. The variable $A(\bar{n})$ is defined as

$$A(\bar{n}) = \sum_{t=1}^{T} n_t \alpha_t = \bar{n} \cdot \bar{\alpha}^T \tag{13}$$

Now, the r.v. $F$ is calculated according to the theorem of total probability

$$F = \sum_{\bar{n}:A(\bar{n})<1} p(\bar{n}) \frac{1}{1 - A(\bar{n})} \sum_{t=1}^{T} \alpha_t \sum_{i=1}^{n_t} \Delta. \tag{14}$$

With Eqn. (11) and Eqn. (14) one of the two formulae required to define the fixed-point equation is formulated, i.e. $\hat{I}_{OUT}$ can be calculated depending on $\hat{I}_{IN}$. The other equation derives the r.v. $\hat{I}_{IN}$ under the condition that $\hat{I}_{OUT}$ is known. Assuming that the r.v. $\hat{I}_{OUT}$ are iid for all 6 neighboring cells and also independent of $\hat{I}_{IN}$ the othercell interference is given as the sixfold sum of $\hat{I}_{OUT}$

$$\hat{I}_{IN} = \sum_{i=1}^{6} \hat{I}_{OUT} \tag{15}$$

Now the fixed-point equations consisting of Eqn. (11) and Eqn. (15) are formulated and can be solved iteratively by starting with $\hat{I}_{IN} = 0$ and subsequently substituting $\hat{I}_{OUT}$ and $\hat{I}_{IN}$ until convergence is reached. However, the solution requires many convolutions and discretizations of distributions and is therefore numerically intractable. Therefore, in the next section some approximations are shown to reduce the complexity.

### 3.2 Approximation by Lognormal Distributions

In Figure 3 the distribution of the logarithm of the r.v. $F$ is shown for service mix 1 consisting of 75% 12.2kbps users, 20% 64kbps users, and 5% 144kbps users. The target $E_b/N_0$ values

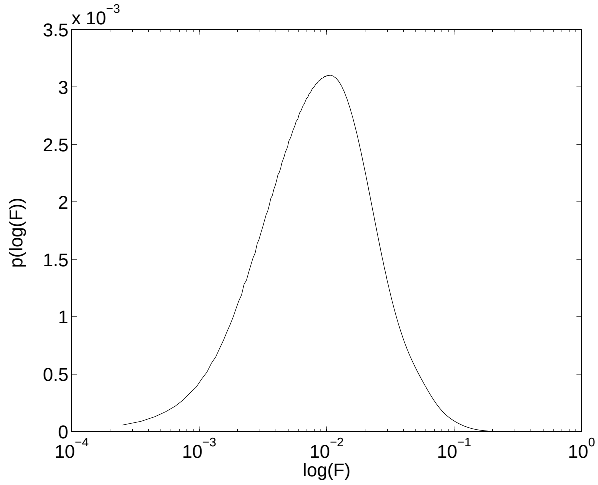
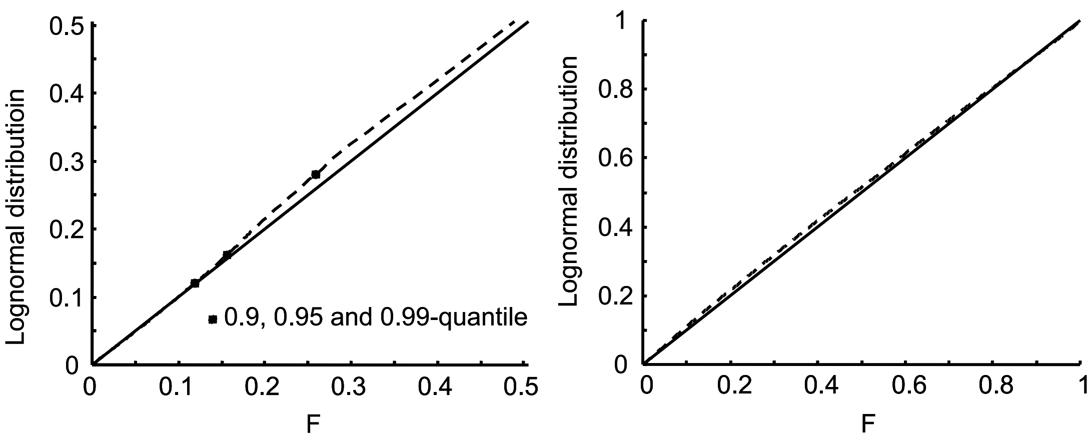



Figure 3: Distribution of the logarithm of the r.v. F

are set to 5.5dB, 4.0dB, and 3.5dB, respectively. The activity factors of all services are equally set to 1 and the user density is 20 MS per BS. At first glance the r.v. $F$ seems to follow a Lognormal distribution. This is further confirmed by the Q-Q plot and the P-P plot, see [11], given in Fig. 4.




(a) Q-Q Plot

(b) P-P Plot

Figure 4: Comparison of the r.v. $F$ with the corresponding Lognormal distribution

Since the Lognormal distribution is entirely described by the mean and the variance only the first two moments of $F$ have to be calculated. The mean of $F$ is given by the following equation

$$\begin{aligned} E[F] &= \sum_{\bar{n}:A(\bar{n})<1} p(\bar{n}) E\left[F(\bar{n})\right] \\ &= \sum_{\bar{n}:A(\bar{n})<1} p(\bar{n}) E\left[\frac{\sum_{t=1}^{T} \alpha_t \sum_{i=1}^{n_t} \Delta}{1-A(\bar{n})}\right] \\ &= \sum_{\bar{n}:A(\bar{n})<1} p(\bar{n}) \frac{\sum_{t=1}^{T} \alpha_t \cdot n_t E\left[\Delta\right]}{1-A(\bar{n})} \end{aligned} \tag{16}$$

The second moment of $F$ is also calculated using the theorem of total probability

$$E[F^2] = \sum_{\bar{n}:A(\bar{n})<1} p(\bar{n}) E\left[F(\bar{n})^2\right] \tag{17}$$

and the second moment of $F(\bar{n})$ is

$$E\left[F(\bar{n})^2\right] = \sum_{\bar{n}:A(\bar{n})<1} p(\bar{n}) \left(VAR\left[F(\bar{n})\right] + E\left[F(\bar{n})\right]^2\right).$$

The mean of $F(\bar{n})$ is already given in Eqn. (16) and the variance is specified by

$$\begin{aligned} VAR[F(\bar{n})] &= VAR\left[\left(\frac{\sum_{t=1}^{T} \alpha_t \sum_{i=1}^{n_t} \Delta}{1-A(\bar{n})}\right)\right] \\ &= \sum_{t=1}^{T} \sum_{i=1}^{n_t} VAR\left[\left(\frac{\alpha_t \Delta}{1-A(\bar{n})}\right)\right] \\ &= \sum_{t=1}^{T} n_t \left(\frac{\alpha_t}{1-A(\bar{n})}\right)^2 VAR\left[\Delta\right]. \end{aligned} \tag{18}$$

Finally, the variance of $F$ is given by

$$VAR\left[F\right] = E\left[F^2\right] - E\left[F\right]^2. \tag{19}$$

With the mean and the variance of $F$ the parameters required for the iteration are known. The solution of the fixed point equation is simplified by approximating $F$ by a Lognormal distribution, as well. In Eqn. (11) two r.v. $(\hat{N}_0 + \hat{I}_{IN})$ and $F$ have to be multiplied. With an initial value of $\hat{I}_{IN} = 0$ the first value of $\hat{I}_{OUT}$ is obtained by multiplying $F$ with the constant $\hat{N}_0$ and so $\hat{I}_{OUT}$ is Lognormal distributed, as well. According to Eqn. (15) $\hat{I}_{IN}$ is the sixfold sum of $\hat{I}_{OUT}$ such that $E[\hat{I}_{IN}] = 6 \cdot E[\hat{I}_{OUT}]$ and $VAR[\hat{I}_{IN}] = 6 \cdot VAR[\hat{I}_{OUT}]$. Assuming that the sum of few Lognormal distributions is again Lognormal distributed in the next iteration step two Lognormal distributed r.v. $(\hat{N}_0 + \hat{I}_{IN})$ and $F$ have to be multiplied and the result $\hat{I}_{OUT}$

is in turn Lognormal distributed. The multiplication is performed by adding the parameters of $(\hat{N}_0 + \hat{I}_{IN})$ and $F$

$$\mu_{I_{OUT}} = \mu_{(\hat{N}_0+\hat{I}_{IN})} + \mu_F \qquad \text{and} \tag{20}$$

$$\sigma^2_{I_{OUT}} = \sigma^2_{(\hat{N}_0+\hat{I}_{IN})} + \sigma^2_F. \tag{21}$$

The parameters of a Lognormal distributed r.v. $Z$ are calculated from the mean and variance by

$$\sigma_z^2 = log\left(\frac{VAR[Z]}{E[Z]} + 1\right) \qquad \text{and}$$

$$\mu_z = log\left(E[Z]\right) - \frac{\sigma_z}{2}. \tag{22}$$

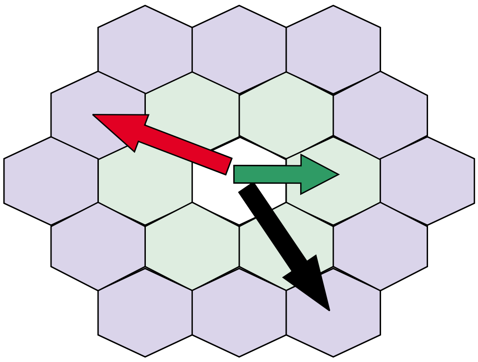
In the next iteration step the mean and variance of $\hat{I}_{OUT}$ are required again to determine the mean and variance of $\hat{I}_{IN}$. They are calculated by solving Eqn. (22) for the moments. Thus, the iteration is performed by subsequently calculating the mean and variance of $\hat{I}_{OUT}$ and $\hat{I}_{IN}$ and it finally converges if the moments do not change any more.

### 3.3 Extension to Two Cell Rings

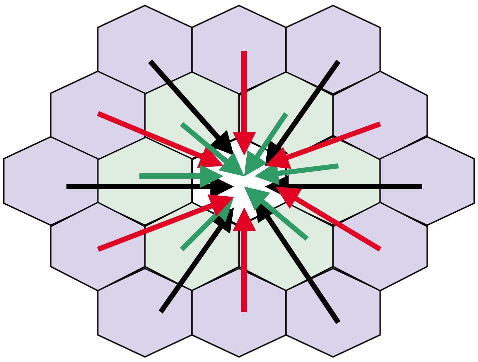
In the last section an iterative model was described to calculate the othercell interference efficiently. However, results shown later in Fig. 6 indicate that the mean of the othercell interference is underestimated while the variance matches well the results obtained by the point pattern model in Section 2. Therefore, the iterative model is changed to consider the othercell interference of two surrounding cell rings. The extended model is illustrated in Fig. 5. Now three different r.v. for $\hat{I}_{OUT}$ exist depending on the distance between the BS. In a regular hexagonal BS layout the distance to the BS in the first ring is denoted by $d$, the distance to the BS in the second ring is either $2d$ or $\sqrt{3}d$. Therefore, the new r.v. are denoted by $\hat{I}_{OUT,\sqrt{3}d}$, $I_{OUT,2d}$, and $\hat{I}_{OUT,d}$ which corresponds to the previous $\hat{I}_{OUT}$. The calculation of these r.v. $\hat{I}_{OUT,x}$ is similar to Eqn. (11) however with different r.v. $F_x$

$$\hat{I}_{OUT,x} = (\hat{N}_0 + \hat{I}_{IN})F_x. \tag{23}$$

The formula to determine the moments of $F_x$ is also similar to the one for $F$ described in Eqn. (16) to Eqn. (19). Only, the mean and variance of the attenuation ratios $\Delta_x$ varies depending on the BS distance. The computational effort only hardly increases as the moments of all r.v. $F_x$ can be determined in parallel, i.e. the algorithm has to run through the states $\bar{n}$ only once and therefore a single calculation of the state probabilities $\tilde{p}(\bar{n})$ is required.



(a) Interference at the BS of the first and second ring



(b) Othercell interference induced by the MS of the first and second ring

Figure 5: Illustration of the extended iterative model

Furthermore, the calculation of mean and variance of $\hat{I}_{IN}$ has to be modified. In the previous model the mean and variance of $\hat{I}_{OUT}$ are simply multiplied by 6. When considering the second cell ring, as well, the means and variances of the r.v. $\hat{I}_{OUT,x}$ have to be added and the sum is multiplied by 6 since there are six cells in the first ring and of the twelve cells in the second ring six have a distance of $2d$ and the other six have a distance of $\sqrt{3}d$. So, the mean and variance of $\hat{I}_{IN}$ is

$$\begin{aligned} E\left[\hat{I}_{IN}\right] &= 6 \cdot \sum_{x\in\left\{d,2d,\sqrt{3}d\right\}} E\left[\hat{I}_{OUT,x}\right], \text{ and} \\ VAR\left[\hat{I}_{IN}\right] &= 6 \cdot \sum_{x\in\left\{d,2d,\sqrt{3}d\right\}} VAR\left[\hat{I}_{OUT,x}\right]. \end{aligned} \tag{24}$$

## 4 Verification of the iterative model

The proposed iterative model to calculate othercell interference distributions using fixed-point equations includes the following assumptions which are verified in this section. First, it is assumed that the r.v. $F_x$ follow a Lognormal distribution which was already shown in Fig. 4 by a Q-Q and a P-P plot. The second assumption is that the sum of the Lognormal distributed r.v. $\hat{I}_{OUT,x}$ is again approximately Lognormal distributed. Finally, the r.v. describing interferences are considered to be independent. In particular, we presume the independence of the othercell interferences of all surrounding cells among each other as well as the independence of the othercell interference from a neighboring cell and the incell interference which is directly related to $F_x$. Evidently, all these values are correlated, however, we will show that due to the iteration the effects of the correlations diminish.

The overall validation of the analytic model is performed by the point pattern model described in Section 2. In this model no assumptions about the independence of r.v. are made. The othercell interference distributions are obtained by generating point patterns for 39 BS placed in a hexagonal layout. For each of these point patterns the othercell interferences at all BS are computed according to Eqn. (7). However, to avoid border effects, i.e. the othercell interference at BS with less neighbor cells is smaller, only the value for the central cell contributes to the resulting distribution.

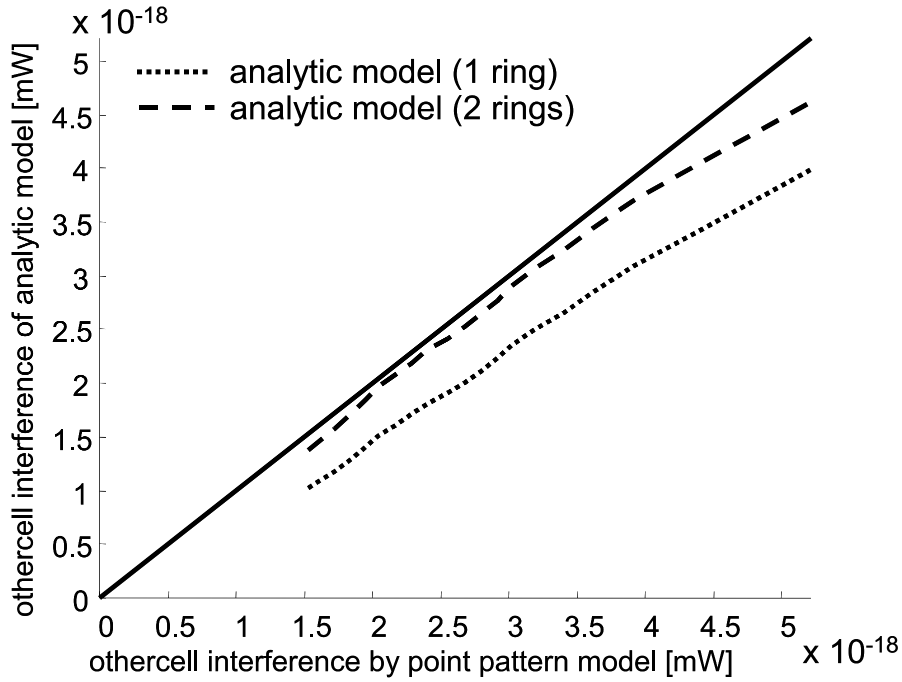
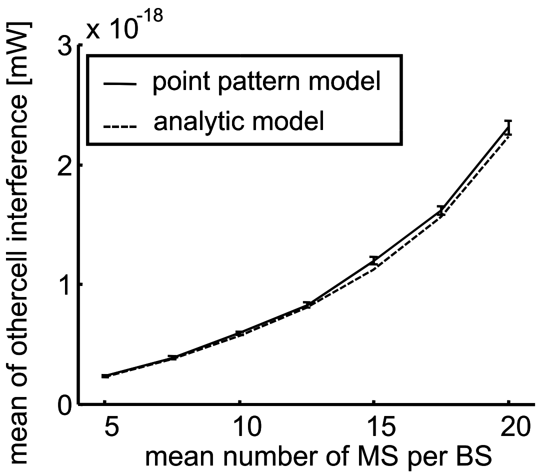


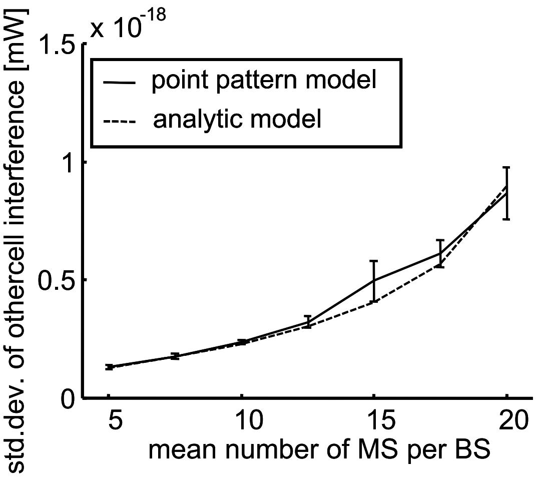

Figure 6: Comparison of the othercell interference distributions resulting from the analytic model and the point pattern model

Fig. 6 shows a Q-Q plot which compares the othercell interference obtained by the point pattern model with the results of the analytic model both with one and two cell rings surrounding the central cell. We can see that both the dashed line representing the model with two rings as well as the dotted line showing the results under consideration of one ring run roughly parallel to the main diagonal. This indicates that the variance of the results fits well in both cases. However, the distance from the dotted line to the main diagonal is much larger than for the dashed line which shows that the mean is underestimated if only one ring is considered. The results for the analytic model including two rings match well with the point pattern model.

Up to now we have validated the model for service mix 1, cf. Section 3.2 and a mean of 20 users per BS, only. In the following we will show more results for service mix 1 with different user densities. Furthermore, another service mix 2 with 50% 12.2kbps users, 30% 64kbps users, and 20% 144kbps users is investigated. The target $E_b/N_0$ values and activity factors for this mix are equal to those of mix 1. As we have shown that the othercell interference approximately follows a Lognormal distribution we will focus on the mean and the standard deviation which is sufficient to describe the Lognormal distribution. The results of the point pattern model will be given with 95% confidence intervals.



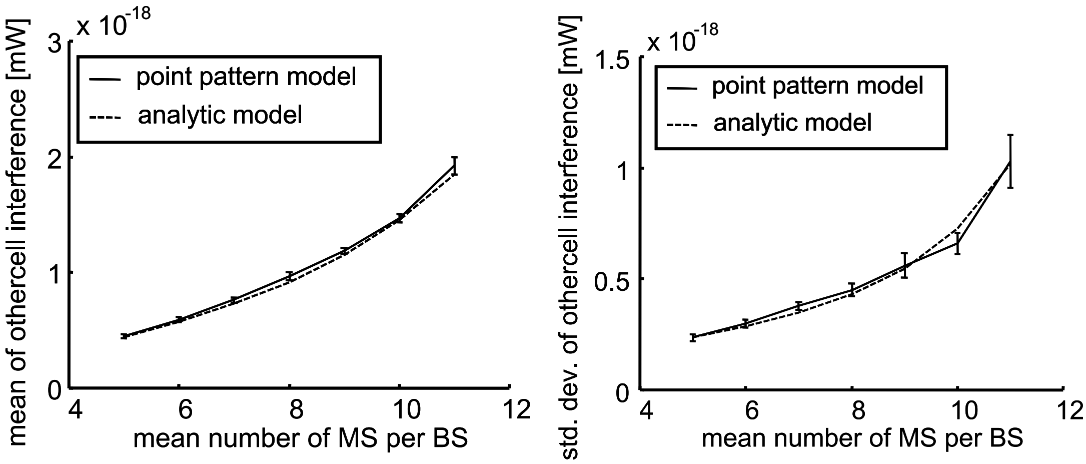

(a) Mean othercell interference




(b) Standard deviation of othercell interference

Figure 7: Comparison of the moments of the othercell interference depending on the mean number of users per BS for traffic mix 1

Fig. 7 shows the results for service mix 1. In the left graphic we can see that the means obtained by both models match very well. The standard deviations plotted in Fig. 7(b) show a larger discrepancy, however they are still within the confidence intervals which are quite large compared to those of the mean. The results in Fig. 8 obtained for service mix 2 show the same behavior. However, comparing the points with highest user density of both service mixes the mean for service mix 1 is larger and the standard deviation of service mix 2 is larger. The reason for this feature is that service mix 2 contains more high data rate users which increases the variance. Finally, we want to mention that it is possible to compute all values for one service mix in parallel such that the algorithm works very efficiently. The means and standard deviations for the two example service mixes with 7 points each have been calculated in less than 10 seconds. Therefore, it is possible to use the algorithm in planning tools for UMTS networks like T-Mobile's *Pegasos*.




(a) Mean othercell interference

(b) Standard deviation of othercell interference

Figure 8: Comparison of the moments of the othercell interference depending on the mean number of users per BS for traffic mix 2

## 5 Conclusion and Outlook

In this paper we presented an analytical model for computing the othercell interference in a UMTS system with multiple services. Our approach is based on solving a fixed-point equation which describes the interdependencies between the interferences at neighboring BS. An efficient algorithm is used to solve these equations using Lognormal approximations such that the model can be implemented in network planning tools for large UMTS networks like T-Mobile's *Pegasos*, see [12]. Our future work consists of an extension of our model to inhomogeneous user distributions and irregular BS layouts. Furthermore, we will include a model for the downlink as well.

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