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Performance Analysis of Dynamic Radio Resource Allocation for Self-organising Cellular Mobile Radio Networks

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Abstract

Scarcity of the spectrum suited for mobile radio application and the increase of the capacity requirements of mobile customers require high efficiency in the use of the spectrum available for mobile radio networks. Furthermore, mobile network operators face increasing costs since as technology evolves, network complexity increases and several networks of different technologies have to be operated simultaneously. A promising approach to meet both challenges is the implementation of self-organising technologies in cellular mobile radio networks. Such technologies are capable of automating certain tasks of operation and maintenance of cellular mobile radio networks and are able to constantly operate the network at an optimum configuration while saving costs due to their autonomous nature. One important aspect in this context is the self-organising optimisation of the radio resource assignment of a cellular mobile radio network. This paper presents an approach for the self-organising allocation of cell bandwidth and transmit power to the cells of a cellular mobile radio network. In order to efficiently enable self-organising operation, distributed implementations of the presented approach are proposed. The approach is evaluated in different key scenarios and its performance shown. The performance results show the suitability of the presented approach for self-organising dynamic resource allocation and point out the individual strengths of dynamic cell bandwidth allocation and dynamic transmit power allocation. [1] [2]

1 Introduction

As mobile radio technology evolves and new services are introduced in mobile radio networks, the capacity demand on the networks increases. The spectrum suited for mobile radio application, however, is limited, making a more efficient exploitation of the available spectrum necessary in order to be able to fulfil the increasing capacity demand.

At the same time, network operators expect an increase in operational expenditures since due to the evolution of mobile radio technology, several mobile radio technologies will coexist and the network complexity will increase. As a consequence, operators seek for ways to optimise and automate operation and maintenance of their mobile radio networks.

In cellular mobile radio networks, the capacity demand on the network constantly changes over time and space due to user mobility, changing user behaviour and changes in the environment. As a consequence, the efficient operation of cellular mobile radio networks from the point of view of spectral efficiency as wells as economic aspects requires the dynamic adaptation of the network according to the changing capacity demand. This adaptation can efficiently be carried out by assigning radio resources dynamically to the cells of the network. In modern cellular mobile radio networks applying adaptive transmission [1], both, bandwidth and transmit power can be considered as radio resources and can thus be used to dynamically adapt a cellular mobile radio network to varying capacity demands.

Several approaches concerning the adjustment of the bandwidth allocation in order to adapt a network to changing capacity demands exist. General approaches that allocate frequencies or chunks of bandwidth based on the topology of the network have been presented in [2-4]. Concerning modern packet switched networks applying adaptive transmission techniques, approaches that allocate bandwidth based on signal quality measurements have been investigated in [5-7].

In this paper, a new approach for the dynamic assignment of resources is proposed. The approach estimates the resource demand of each cell based on the bit rate requirements of its users

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and their distribution over the cell area. The estimation is used to carry out a resource allocation, which consists of either a cell bandwidth allocation or a transmit power allocation. The established resource allocations are according to the capacity demand and maximise the capacity of the cellular mobile radio network. Convex formulations of the resource assignment problems are given such that their solutions can be determined efficiently. Also, a method for the distributed implementation of the presented approach is presented since the distributed implementation is of great interest for practical application. Finally, the performance of the presented resource allocation approach is analysed in different key scenarios and under different conditions. The results are then used to show the capabilities and individual performance characteristics of cell bandwidth allocation and transmit power allocation.

The paper is organised as follows. The system model is presented in Section 2. Section 3 introduces approaches for the demand oriented allocation of cell bandwidth and transmit power. Section 4 derives a method for the distributed implementation of the presented approaches and Section 5 presents the results of the performance analysis. Section 6 concludes the paper.

2 System Model

The downlink of a cellular mobile radio network with N_{C} cells of radius R is considered. The available spectrum can be reused by the cells, which causes inter-cell interference between cells that use same parts of the spectrum. In order to assure a certain signal quality, inter-cell interference is controlled by assigning the available spectrum such that within a certain distance D, called reuse distance, no part of the spectrum can be used by more than a single cell. The reuse distance is related to the cell radius R by $D = \sqrt{3r} \cdot R$, where the reuse factor r is a rhombic number [8].

For cells being separated by more than the reuse distance D, random spectrum allocation is assumed. With this assumption, the amount of interference between two cells depends on the allocated bandwidth of both cells. The interference factor $\beta_{l,m}$ considers that the transmitting cell m transmits only on a part of the spectrum while the receiving cell l receives only on a part of the spectrum. It describes the average ratio of overlap of the spectrum allocated randomly to cells l and m and is defined by

$$\beta_{l,m} = \frac{B_{\mathrm{cell},l}}{B_{\mathrm{sys}}} \cdot \frac{B_{\mathrm{cell},m}}{B_{\mathrm{sys}}} \tag{1}$$

with $B_{\mathrm{cell},i}$, $i = 1 \ldots N_{\mathrm{C}}$, the allocated bandwidth of cell i and B_{sys} the total system bandwidth.

A Neighbourhood Group is a group of exactly r cells that are all mutually located within the reuse distance D [9]. With $\{i_1, \ldots, i_r\}$ a set of r cells, where $\{i_1, \ldots, i_r\} \subseteq \{1, \ldots, N_{\mathrm{C}}\}$, the set of all Neighbourhood Groups is defined by

$$\mathbb{G} := \{\{i_1, \ldots, i_r\} \,|d(i_l, i_m) < D\} \ , \quad l, m = 1 \ldots r \, , \tag{2}$$

where $d(i_l, i_m)$ is the distance between the centres of cell i_l and cell i_m. Considering (2), no frequency can be reused within a Neighbourhood Group and

$$\sum_{n \in \{i_1, \ldots, i_r\}} B_{\mathrm{cell},n} \leq B_{\mathrm{sys}} \quad \forall \ \{i_1, \ldots, i_r\} \in \mathbb{G} \tag{3}$$

holds [10].

In order to relate transmit power to the transmit powers of other cells, the power ratio Γ_i of cell i is defined by

$$\Gamma_i = \frac{P_{\mathrm{tx},i}}{\bar{P}_{\mathrm{I},i} + P_{\mathrm{N}}} \tag{4}$$

where $P_{\mathrm{tx},i}$ is the transmit power of cell i and P_N the receiver noise power. $\bar{P}_{\mathrm{I},i}$ is the average interference power received by the N_i users requesting service from cell i and is given by

$$\bar{P}_{\mathrm{I},i} = \frac{1}{N_i} \sum_{k=1}^{N_i} \sum_{\substack{j=0,\\ j\neq i}}^{N_\mathrm{C}} \frac{P_{\mathrm{tx},j}}{a_j^{(i,k)}} \, \beta_{i,j} \,, \tag{5}$$

with $a_j^{(i,k)}$ the attenuation between the position of user k of cell i and BS j. Considering (5) and resolving (4) for $P_{\mathrm{tx},i}$ yields [11]

$$\mathbf{P}_\mathrm{tx} = \left(\mathbf{I} - \mathrm{diag}\left(\mathbf{\Gamma}\right) \cdot \mathbf{G}\right)^{-1} \cdot \mathrm{diag}\left(\mathbf{\Gamma}\right) \cdot \mathbf{P}_\mathrm{N}, \tag{6}$$

with $\mathbf{P}_\mathrm{tx} = [P_{\mathrm{tx},1} \,, \, \ldots \,, \, P_{\mathrm{tx},N_\mathrm{C}}]^\mathrm{T}$, $\mathbf{\Gamma} = [\Gamma_1 \,, \, \ldots \,, \, \Gamma_{N_\mathrm{C}}]^\mathrm{T}$, $\mathrm{diag}\left(\mathbf{\Gamma}\right)$ a $N_\mathrm{C} \times N_\mathrm{C}$ matrix with the elements of vector $\mathbf{\Gamma}$ on the diagonal and zeros elsewhere, $\mathbf{G}$ a $N_\mathrm{C} \times N_\mathrm{C}$ matrix with elements

$$g_{lm} = \begin{cases} 0 & \text{if } \ l = m \\ \frac{1}{N_i} \sum\limits_{k=1}^{N_i} \frac{1}{a_m^{(l,k)}} \, \beta_{l,m} & \text{else} \end{cases} \tag{7}$$

and $\mathbf{P}_\mathrm{N}$ a vector of size N_C containing the receiver noise power.

For each cell, a Power-Bandwidth Characteristic is determined. The Power-Bandwidth Characteristic is a stochastic model of the bandwidth required by a cell to support all its users with their bit rate requirements. The model is based on measurements of the signal to interference and noise ratio (SINR) of the users and it thus reflects the environment, the cell layout and the distribution of the users over the cell area [12]. Using (4), the Power-Bandwidth Characteristic can be used to relate the resource allocation in terms of cell bandwidth $B_{\mathrm{cell},i}$ and power ratio Γ_i to outage probability according to [11]

$$p_{\mathrm{cell},i}\left(B_{\mathrm{cell},i}, \Gamma_i\right) = 1 - \Phi\left(\frac{B_{\mathrm{cell},i} - \mu_{\mathrm{cell},i}(\Gamma_i)}{\sigma_{\mathrm{cell},i}(\Gamma_i)}\right), \tag{8}$$

where $\Phi(\cdot)$ is the cumulative distribution function (cdf) of a Normal distributed random variable with zero mean and a variance of one and $\mu_{\mathrm{cell},i}(\Gamma_i)$ and $\sigma_{\mathrm{cell},i}(\Gamma_i)$ mean and standard deviation of the bandwidth required by cell i to support all its users with their required bit rates. Probability $p_{\mathrm{cell},i}$ of (8) is called cell outage probability and gives the probability that the resource assignment of cell i in terms of $B_{\mathrm{cell},i}$ and Γ_i is not sufficient to support all users of the cell with their required bit rates [11].

The capacity demand distribution is expressed by factors λ_i, which give the percentage of the total number N_tot of users in the scenario that request service from cell i. The number of users that request service from cell i can thus be expressed by

$$N_i = N_\mathrm{tot} \cdot \lambda_i, \tag{9}$$

with $\sum\limits_i \lambda_i = 1$, such that $N_\mathrm{tot} = \sum\limits_i N_i$ holds. Note that mean $\mu_{\mathrm{cell},i}(\Gamma_i)$ and standard deviation $\sigma_{\mathrm{cell},i}(\Gamma_i)$ of the bandwidth required by cell i depend on the number N_i of users that request service from the cell and their bit rate requirements. As a consequence, the Power-Bandwidth Characteristic as formulated by (8) changes depending on the capacity demand distribution.

3 Demand Oriented Radio Resource Allocation

In this section, radio resource allocation approaches for capacity maximisation of cellular mobile radio networks are presented. The approaches allocate more resources to areas of higher capacity demand. The network is thus adapted to the capacity demand distribution and the presented approaches are suited for dynamic resource allocation.

The allocation of resources to the cells of a cellular mobile radio network is a complex task, since several interdependencies exist between the cells due to inter-cell interference, as it can be seen from (5). A promising approach to solve resource allocation problems is therefore mathematical optimisation, since it is able to handle large numbers of variables and interdependencies among them. The resource allocation approaches of this section are thus stated as optimisation problems. The optimisation goal is the maximisation of the network capacity. Cell bandwidth, transmit power and cell outage probability are related via the Power-Bandwidth Characteristic as formulated in (8). It is assumed that a certain capacity demand distribution is given, which, as stated before, determines the Power-Bandwidth Characteristics of the individual cells.

3.1 Bandwidth Allocation

Adjusting the bandwidth allocation of a cell is a straight forward way of adapting the capacity of a cell since capacity increases directly with allocated bandwidth [13]. In this section, the capacity demand oriented allocation of bandwidth to the cells of a cellular mobile radio network is presented.

The principal bandwidth allocation problem for maximum capacity is given by

$$\begin{aligned} \max_{N_{\mathrm{tot}},B_{\mathrm{cell},i}} \quad & N_{\mathrm{tot}} \\ \text{s. t.} \quad & p_{\mathrm{cell},i}\left(B_{\mathrm{cell},i},\Gamma_i\right) \le p_{\mathrm{cell,max}} \\ & B_{\mathrm{min},i} \le B_{\mathrm{cell},i} \le B_{\mathrm{sys}} \\ & \sum_{n\in\{i_1,\ldots,i_r\}} B_{\mathrm{cell},n} \le B_{\mathrm{sys}} \quad \forall\ \{i_1,\ldots,i_r\} \in \mathbb{G} \end{aligned} \tag{10}$$

This optimisation problem maximises the number of users in the scenario under the conditions that the maximum allowed cell outage probability $p_{\mathrm{cell,max}}$ is observed, that a certain minimum bandwidth $B_{\mathrm{min},i}$ is allocated to each cell and that the total available bandwidth is not exceeded by the bandwidth allocations. The observation of the reuse distance is assured since (3) is considered in the last constraint.

Note that the optimisation problem of (10) is a continuous valued optimisation problem. Consequently, it does not determine an assignment of discrete subcarriers to the cells. Instead, the optimum assignment of bandwidth to the cells is determined. Based on the solution of (10), the assignment of certain frequencies or chunks of bandwidth, e. g. subcarriers or subsets of subcarriers, can be carried out using efficient heuristics, as proposed in [10], for example.

In order to solve (10) in an efficient way, it is reformulated to a convex optimisation problem. In a convex optimisation problem, objective function as well as constraints have to be convex functions of the optimisation variables, according to [14]. For this purpose, the utility function

$$\psi\left(x\right) = -\log\left(1-x\right) \tag{11}$$

is introduced. Since the Normal cdf is a log-concave function [14], $\psi\left(p_{\mathrm{cell},i}\left(B_{\mathrm{cell},i},\Gamma_i\right)\right)$ is convex.

Using the utility function in the first constraint of (10) yields

$$\begin{array}{rl} \max\limits_{N_{\text{tot}}, B_{\text{cell},i}} & N_{\text{tot}} \\ \text{s. t.} & \psi\left(p_{\text{cell},i}\left(B_{\text{cell},i}, \Gamma_i\right)\right) \leq \psi\left(p_{\text{cell},\max}\right) \\ & B_{\min,i} \leq B_{\text{cell},i} \leq B_{\text{sys}} \\ & \sum\limits_{n \in \{i_1,\ldots,i_r\}} B_{\text{cell},n} \leq B_{\text{sys}} \quad \forall \, \{i_1, \ldots, i_r\} \in \mathbb{G} \end{array} \tag{12}$$

which is a convex equivalent of the optimisation problem of (10).

3.2 Power Allocation

In systems applying adaptive transmission, the capacity of a radio link depends on the SINR at the receiver [13]. As a consequence, if a certain cell increases the transmit power, the SINR and thus the capacity of this cell increase. At the same time, the SINR and thus the capacity of all cells using same parts of the spectrum decrease since interference rises in these cells.

The described effect is used in this section for the allocation of transmit power to the cells of a cellular mobile radio network in order to adapt the network to the capacity demand. It is assumed that the cell borders and cell sizes stay constant, independent of the transmit power.

For the approach, the allocation of power ratios Γ_i instead of transmit powers $P_{\text{tx},i}$ is pursued, which allows the convex formulation of the optimisation problem. After carrying out the optimisation, the optimum transmit power values have to be calculated from the optimum power ratio values using (6).

The principal power ratio allocation problem for maximum capacity is given by

$$\begin{array}{rl} \max\limits_{N_{\text{tot}}, \Gamma_i} & N_{\text{tot}} \\ \text{s. t.} & p_{\text{cell},i}\left(B_{\text{cell},i}, \Gamma_i\right) \leq p_{\text{cell},\max} \\ & P_{\min,i} \leq P_{\text{tx},i} \leq P_{\max,i} \\ & \rho\left(\operatorname{diag}\left(\mathbf{\Gamma}\right) \cdot \mathbf{G}\right) < 1 \end{array} \tag{13}$$

with $\rho\left(\mathbf{X}\right)$ the spectral radius of matrix $\mathbf{X}$, which is equal to the largest magnitude of the eigenvalues of $\mathbf{X}$ [15]. Similar to the case of bandwidth allocation, (13) maximises the number of users in the scenario under the condition that the maximum cell outage probability is not exceeded and minimum as well as maximum transmit power limits are observed. The third constraint assures that only feasible power ratio allocations are considered, i.e. that (6) always has a non negative solution [15].

For the efficient solution of the optimisation problem, a convex formulation is aimed for. Concerning the first constraint, the utility function of (11) is used. A convex formulation of the third constraint is according to [15] achieved by introducing the transformation

$$\tilde{\Gamma}_i = \ln(\Gamma_i). \tag{14}$$

The problem of (13) can now be rewritten as

$$\begin{array}{rl} \max\limits_{N_{\text{tot}}, \tilde{\Gamma}_i} & N_{\text{tot}} \\ \text{s. t.} & \psi\left(p_{\text{cell},i}\left(B_{\text{cell},i}, e^{\tilde{\Gamma}_i}\right)\right) \leq \psi\left(p_{\text{cell},\max}\right) \\ & P_{\min,i} \leq P_{\text{tx},i} \leq P_{\max,i} \\ & \rho\left(\operatorname{diag}\left(e^{\tilde{\mathbf{\Gamma}}}\right) \cdot \mathbf{G}\right) < 1 \end{array} \tag{15}$$

which is a convex optimisation problem.

4 Distributed Implementation for Practical Application

In Section 3, resource allocation problems for capacity maximisation have been introduced and convex formulation have been given. The convex formulation allows to obtain a solution to the problem in an efficient way by a global algorithm. For practical application, however, distributed algorithms are of great importance since they provide advantages in robustness and implementation effort. In this section, the optimisation problems introduced in Section 3 will be used to derive approaches for the distributed implementation.

The approaches presented in this section are meant for the on-line application of running cellular mobile radio networks in order to adapt the network to changing capacity demands. It is assumed that the number N_{tot} of users in the scenario and the distribution of the users is given. The presented approaches are supposed to be capable of establishing a resource allocation that allows to maintain the maximum cell outage probability $p_{\text{cell,max}}$ up to the maximum number N^*_{tot} of users which is the solution of (10) and (13).

For the derivation of a distributed approach, first the cell outage probability will be considered. Noting that mean and variance of the cell bandwidth increase with the number of users in the cell, it can be seen from (10) and (13) that at the point of maximum network capacity

$$p_{\text{cell},i}\left(B_{\text{cell},i}, \Gamma_i\right) = p_{\text{cell,max}} \tag{16}$$

has to be fulfilled for both, cell bandwidth allocation as well as transmit power allocation. As a consequence, each cell will have to claim as much bandwidth or transmit power until (16) is fulfilled. At the same time, each cell has to observe that the remaining constraints of (10) and (13) are fulfilled. In the case of bandwidth allocation, it may require inter-cell communication in order to fulfil the last constraint. In the case of transmit power allocation, the last constraint is implicitly observed by yielding to the maximum power constraint. If any of the second or third constraints of the cell bandwidth allocation or transmit power allocation problems can not be fulfilled, the system is overloaded and the maximum cell outage probability $p_{\text{cell,max}}$ can no longer be guaranteed.

5 Performance Analysis

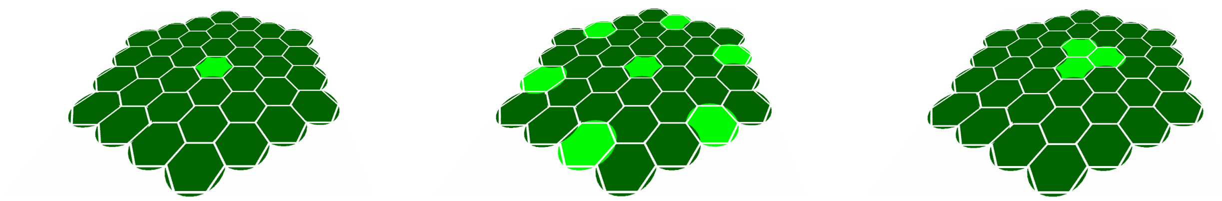
For performance evaluation, inhomogeneous scenarios are applied. Some of the cells, called hotspot cells, support a number N_{hs} of users each. The remaining cells support a number N_0 of users each. This way, hotspots of different strength can be created by adjusting the number N_{hs} of users in the hotspot cells.

The scenarios differ in number and distribution of the hotspots. In the single hotspot scenario, only one hotspot cell is present, the multiple hotspot scenario considers several hotspot cells distributed over the coverage area and in the cluster hotspot scenario, several neighboured hotspot cells form one large hotspot. Two tiers of interferers are considered in all scenarios. Figure 1 illustrates the different scenarios.

For bandwidth allocation, a fixed uniform transmit power $\tilde{P}_{\text{tx}}$ of 30 dBm is assumed for each cell. The minimum allocated cell bandwidth is $B_{\text{min},i} = 0$ Hz.

For transmit power allocation, a fixed uniform bandwidth allocation of $\tilde{B}_{\text{cell}} = \frac{B_{\text{sys}}}{r}$ to each cell is assumed. No limitations on minimum and maximum allocated power are given. For both, bandwidth allocation and transmit power allocation, the reuse distance D is observed. The common performance evaluation parameters are summarised in Table 1.

For the simulations, different values for N_0 are chosen. The optimisation of the network capacity by adjusting the bandwidth allocation is then carried out using the optimisation problem of (12).



(a) Single hotspot scenario. (b) Multi hotspot scenario. (c) Cluster hotspot scenario.

Figure 1: Performance evaluation scenarios.

For network capacity optimisation by adjusting the transmit power allocation, the optimisation problem of (15) is solved. In either case, the number N_0 of users in the not-hotspot cells is kept constant, such that the maximisation of the number of users in the scenario leads to the maximisation of the number N_{hs} of users in the hotspot cells.

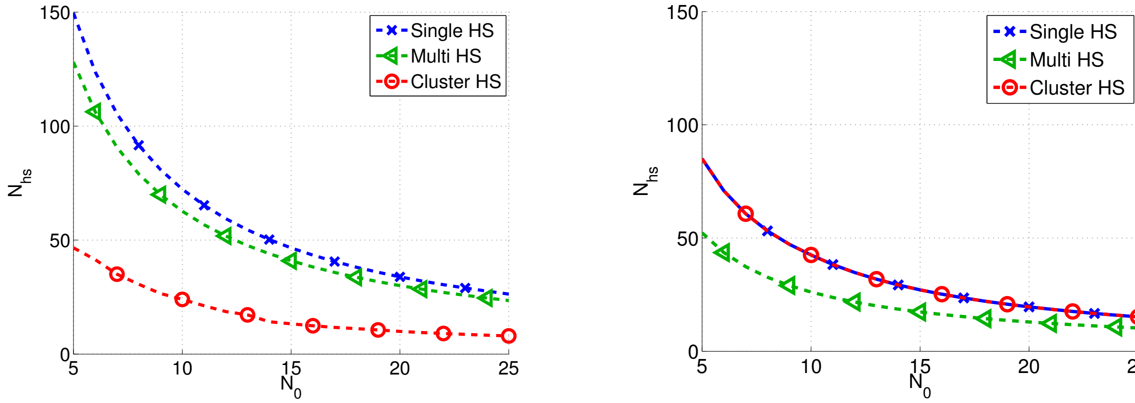
The results of the network capacity optimisation achieved by adjusting the bandwidth allocation are shown for all three scenarios in Fig. 2(a) in terms of the maximum number N_{hs} of users in a hotspot cell as a function of the number N_0 of users in the cells surrounding a hotspot. The figure shows that the presented bandwidth allocation approach is capable of allocating resources, and thus capacity, to areas of increased capacity demand in the network. In the case of the single hotspot scenario, stronger hotspots can be supported than in the scenarios where several hotspot cells are present.

The reason for the decrease in the maximum hotspot strength, i.e. the maximum number N_{hs} of users per hotspot cell, is different in the multi hotspot scenario and the cluster hotspot scenario. Since in the case of bandwidth allocation, hotspot cells take away bandwidth from their neighbours located within the reuse distance D, the hotspots in the multi hotspot scenario are practically independent of each other. Some interdependence, however, exists since inter-cell interference increases in the scenario according to (5) and (1) due to the increased bandwidth requirements of the hotspot cells. The increase in inter-cell interference leads to a decrease in the maximum hotspot strength compared to the single hotspot scenario.

The situation is different in the case of the cluster hotspot scenario since the hotspot cells now compete with each other for the available bandwidth. As a consequence, the sum of the users of the hotspot cells is relevant for the maximum possible hotspot strength in the cluster hotspot scenario

Table 1: Common performance analysis parameters.

Cell radius R	250 m
Number N_{C} of cells	39
Height of the BSs/users	32 m/1.5 m
User distribution over cell area	uniform
Carrier frequency	1.9 GHz
Propagation model	3GPP Urban Macro
Shadow fading variance σ_{sh}^2	8 dB
Reuse factor r	3
System bandwidth B_{sys}	10 MHz
User bit rate requirement	100 $\frac{\text{kbit}}{\text{s}}$
Noise power density P_{N}	-167 $\frac{\text{dBm}}{\text{Hz}}$
Max. cell outage prob. $p_{\text{cell,max}}$	0.05



(a) Cell bandwidth allocation.

(b) Transmit power allocation.

Figure 2: Maximum number N_{hs} of users in a hotspot cell in dependence of the number N_0 of users in the remaining cells for 5 % cell outage probability.

and the number N_{hs} of users in each hotspot cell is significantly lower than in the single hotspot case. This can also be seen from From Fig. 2(a) which shows that in the single hotspot scenario, the number of users a hotspot cell can support is approximately three times as high as in the cluster hotspot scenario, which corresponds to the size of the Neighbourhood Groups, which is equal to r.

The nonlinear, convex shape of the curves of Fig. 2(a) are due to the effect that inter-cell interference increases with the allocated bandwidth according to (5) and (1). Due to this effect, less inter-cell interference is experienced by the hotspot cells if the surrounding cells support few users and occupy little bandwidth.

Fig. 2(b) shows the performance of the network capacity optimisation approach using transmit power allocation for all three scenarios. The results are shown in terms of the number N_{hs} of users in a hotspot cell as a function of the number N_0 of users in the surrounding cells. The figure shows that also this approach is capable of concentrating resources and network capacity at areas of high capacity demand. Comparing Fig. 2(a) with Fig. 2(b), however, shows that the bandwidth allocation approach and the transmit power allocation approach show significantly different performance. While the transmit power allocation approach outperforms the bandwidth allocation approach in the cluster hotspot scenario, the bandwidth allocation approach shows better performance in the single hotspot scenario and the multi hotspot scenario.

One reason for this behaviour is that the increase in capacity gets smaller for larger transmit power, while the relation between capacity and bandwidth is linear, according to [13]. This effect leads to a general performance reduction of the transmit power allocation approach compared to the bandwidth allocation approach. In order to fully explain the results of Fig. 2(b) in comparison to Fig. 2(a), however, it has to be noted that in the transmit power allocation approach, hotspot cells are independent of their neighbours located within the reuse distance D since no inter-cell interference occurs between cells that are located within the reuse distance. In contrast to the bandwidth allocation approach, the hotspot cells of the multi hotspot scenario are thus interdependent while the hotspot cells of the cluster hotspot scenario can be considered independent. This leads to the same performance of the transmit power allocation approach in the single hotspot scenario as in the cluster hotspot scenario, as can be seen in Fig. 2(b). Compared to the bandwidth allocation approach, the transmit power allocation approach thus experiences a performance gain in the cluster hotspot scenario that compensates the losses due to the nonlinear relation between capacity and transmit power. The same way, the performance difference between the single hotspot scenario and the multi hotspot scenario is larger for the case of transmit power allocation, since additionally to the losses due to the nonlinear relation between capacity and transmit power, the hotspot cells of the multi hotspot scenario are dependent for transmit power allocation.

6 Conclusion

In this paper, a new radio resource allocation approach is proposed. The approach estimates the required amount of resources based on the user distribution in the cells and uses this estimation to carry out a resource assignment that maximises the capacity of the network. The resources that are assigned by the proposed approach are cell bandwidth and transmit power. Performance analysis of the presented approach is carried out for different scenarios with different demand distributions and it is shown that the approach is capable of concentrating resources at areas of high capacity demand. It is thus suited to adapt cellular mobile radio networks to changing capacity demands and enables the efficient operation of a cellular mobile radio network from the point of view of spectral efficiency as well as economic considerations. The performance analysis further shows that cell bandwidth allocation and transmit power allocation perform very differently depending on the capacity demand distribution over the network. As a consequence, cell bandwidth and transmit power allocation have to be carried out jointly in order to reliably and efficiently operate a cellular mobile radio network, which will be focused on in future work.

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