International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 5 Issue: 5
ISSN: 2321-8169
666 – 672

Performance Analysis of Resource Allocation with Successive group in Dense Femtocell Networks

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Abstract: To mitigate the uplink co-tier interference in heterogeneous networks, advanced receivers are used by Femtocell Base Stations. Orthogonal frequency allocation in interfering cells leads to inefficient spectrum usage. The users can opportunistically access the resources of nearby cells by exploiting the advantage of successive group decoder. Multi cell uplink spectrum allocation with SGD is formulated as a joint channel, rate and decoding group allocation problem. A greedy algorithm is proposed to maximize the weighted sum rates of variable bit rate users while meeting the rate requirements of guaranteed bit rate users. This greedy algorithm allows opportunistic transmission on nearby cell channels by GBR users and utilise interference free channels for high-rate transmission of VBR users. It also focuses on reducing the complexity of decoder design and improving the throughput gain over the conventional orthogonal spectrum allocation.

Keywords*: Successive group decoder, Guaranteed bit rate, Spectrum resources, Variable bit rate, femto base Station.*

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1. INTRODUCTION

A cellular network or mobile network is a communication network where the last link is wireless. The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell site or base station. This base station provides the cell with the network coverage which can be used for transmission of voice, data and others. A cell might use a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell. These cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission.There are several types of cells. Typically the range of a standard base station may be up to 35 kilometers (22 mi), a microcell is less than two kilometers wide, a picocell is 200 meters or less, and a femtocell is in the order of 10 meters. Femtocell Base Stations are low-power nodes to provide high throughput and customized services. Interference management becomes more challenging due to the dense and unplanned deployment .

A typical solution is allocating orthogonal channels to interfering femtocell while it leads to the inefficient spectrum utility. Conflict detection and resolution based approach is proposed in to improve the spectrum utility. Interfering links are identified through exchanging channel allocation and interference messages over the air interface and the transmit power is regulated to mitigate the interference. The over-the-air coordination occupies extra spectrum, which is unattractive in practice especially in dense scenarios.

In this paper successive group decoder that achieves the near-ML performance with low complexity is used. The interfering signals are partitioned into several optimized ordered groups. The SGD jointly decodes a group of users in each stage. The SGD encompasses both the SIC and ML receivers as special cases, and by limiting the group size the computational complexity can be controlled.

The interference management problem with the SGD is formulated as a joint channel, rate and decoding group allocation problem. The objective is to maximize the weighted sum rates of VBR users with the rate requirement constraints of GBR users, the orthogonal frequency-division multiple access constraints (users in the same cell cannot share a channel), and the SGD-related constraints. The SGD-related constraints are used to guarantee the entitled share of each cell.

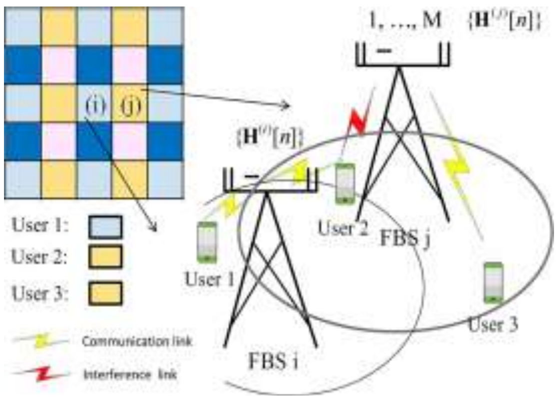

Figure 1.1 Illustration of Uplink Co-tier Femtocell networks

 ISSN: 2321-8169
666 – 672

Successive interference cancelation (SIC) decodes only one user at time This will leads to less rate gain. This SIC is explained in Uplink scheduling in wireless networks with successive interference cancellation [5]. A femtocell resource management scheme called FERMI is utilized for Orthogonal Frequency Division Multiple Access to reduce the Interference in the femtocells [4].In Chapter 2, an overview of femtocells, its various access modes and interference issues including interference types and various interference scenarios are discussed. In Chapter 3,the problem formulation considering the Resource guarantee, Successive Group Decoding (SGD) related constraints, Orthogonal Frequency Division Multiple Access constraints are discussed.In Chapter 4, Algorithms and Pseudo codes for Single Cell Allocation and Joint Channel Group and Decoding (CRG) problem with an illustration is provided in detail. In Chapter 5 ,the allocation of channel to Guaranteed Bit Rate and Variable Bit Rate is done and the Throughput and Signal to Interference Ratio is calculated. In Chapter 6, emphasizes the concluded from the simulated results.

2. FEMTO CELL

A femtocell is a small, low-power cellular base station, typically designed for use in a home or small business . It connects to the service provider's network via broadband (such as DSL or cable). In 3GPP terminology, a Home Node B (HNB) is a 3G femtocell. A Home eNode B (HeNB) is an LTE femtocell. Typically the range of a standard base station may be up to 35 kilometres (22 mi), a microcell is less than two kilometers wide, a picocell is 200 meters or less, and a femtocell is in the order of 10 meters.femtocell networks.*Cross-Tier Interference* - Interference that occurs between a macrocell and a femtocells is called the cross-tier interference.*Co-Tier Interference* - Interference that occurs among the femtocell is called the co-tier interference.Most existing works address the cross-tier interference problems to provide the possibility for the coexistence of macrocell and femtocell. However, the co-tier uplink interference problem has few solutions.

3. PROBLEM FORMULATION

The weighted sum rate of VBR users are maximized and is subjected to meet the GBR user rate requirement through joint channel, rate and decoding group allocation. Let the variables be

x_k [n] indicates whether user k is allocated to channel n (1 if it is, 0 otherwise) where

$x_k[n] \in \{0,1\}$ $k \in K, n \in N$ (3.1)

$r_k[n]$ represents the allocated rate of user k on channel n, where

$r_k[n] \geq 0,$ $k \in K, n \in N$ (3.2)

$r_k[n] \geq \epsilon\, x_k[n]$ $k \in K, n \in N$ (3.3)

Inequality is used to guarantee that if $x_k[n] = 1$, then $r_k[n]$ should be no less than the minimum decoding rate ϵ, if $r_k[n] = 0$, then $x_k[n]$ should be 0.

The SGD variables are $\{G^k[n]\}$ determining the optimal partition of users on channel n,when user k transmits on channel n. Since only the interference from neighbor cells is considered, the possible interference set of user k is $I = k \cup K^B_{Ne}$. Note that $G^k[n]$ is empty if $x_k[n] = 0$.

The objective function is the weighted sum rate of VBR users,

$$\sum_{k \in V} w_k r_k \quad (3.4)$$

where $r_k = \sum_{n \in N} r_k[n]$ and the weight w_k is assumed to be given. Different weights reflect different utility goals; e.g., $w_k = 1$ is used to maximize the aggregate throughput and w_k is set inversely proportional to the allocated rates to account for fairness.

The constraints in maximizing the weighted sum rate include:

a) Resource Guarantee

Each cell i should be allocated at least $N_{en}^{(i)}$

$$\sum_{n \in N_{en}^{(i)}, k \in K^{(i)}} x_k[n] \geq |N_{en}^{(i)}| \qquad i \in B \qquad (3.5)$$

If the VBR user k is allocated the entitled channel n € N_{en}, then it should achieve the single-user capacity on channel n,

$$r_k[n] = c_k[n]\, x_k[n], \quad \forall k \in V,\ n \in N_{en}^{(i)} \qquad (3.6)$$

Constraint (3.5) and (3.6) guarantee that channel reuse would not affect the entitled share of each cell.

The allocated rates for GBR users should be equal to their requirements, that is

$$\sum_{n \in \mathcal{N}} r_k[n] = \hat{r}_k, \qquad \forall k \in \mathcal{F}. \qquad (3.7)$$

b) The SGD Related Constraints

If more than one users share the same channel, no outage should occur; otherwise theyare only allowed to use their entitled channels. More specifically, if user k is allocated channel n $\in N_{en}^{(i)}$, co-channel users should be successfully decoded by their respective FBSs. The outage occurs for the condition

$$\mathcal{E}(\mathbf{H}_{\mathcal{I}}, \underline{\mathcal{G}}, \mathbf{r}_{\mathcal{I}}) < 0 \qquad (3.8)$$

Based on that, to guarantee no outage to happen , the SGD related constraints are formulated as

as $\forall k \in \mathcal{K}, n \in N_{en}^{(B_k)}$ and $\mathcal{I} = k \cup \mathcal{K}_{Ne}^{(B_k)}$

$$\mathcal{E}\left(\mathbf{H}_{\mathcal{I}}^{(B_l)}[n], \underline{\mathcal{G}}^k[n], \mathbf{r}_{\mathcal{I}}\right) x_k[n] \geq 0, \qquad \forall l \in \mathcal{I}. \qquad (3.10)$$

c) OFDMA Constraint

The OFDMA constraint requires that the users associated to the same FBS cannot share the same channel, that is

$$\sum_{\forall k \in \mathcal{K}^{(i)}} x_k[n] \le 1, \qquad \forall i \in \mathcal{B},\ n \in \mathcal{N}. \tag{3.11}$$

The hardness is inferred from two facts

- Even without the SGD related constraints, the problem is NP-hard in that it is an integer linear program.
- Given the results of the entitled channel allocation to the users (i.e., given $x_k[n]$, $r_k[n]$, $\forall$ k ϵ K, n ϵ $N_{en}^{(i)}$), finding the neighboring users who can satisfy the SGD related constraints and maximize the weighted sum rate is computationally infeasible

For user k and channel n, all possible partitions in $Q^k_I[n]$ should be searched, which grows exponentially in the number of interfering users . Even though the NP-hardness is determined by the existence of VBR users.

Theorem 1: No matter F is empty or not, the CRG problem is NP-hard as long as $V \neq 0$.

4. CHANNEL ALLOCATION AND DECODING

4.1 SINGLE-CELL ALLOCATION

Each FBS individually performs single-cell allocation on its entitled channels. Specifically, it first assigns the entitled channels to GBR users until their rate requirements are satisfied and then allocates the remaining channels to VBR users based on their channel conditions. Each entitled channel is paired with a user and rate.To guarantee the entitled resource for each cell, neighbour users can access a certain cell's entitled channels unless their interference signals cannot affect the current allocated rates. For instance, in cell i user k is allocated channel n, n ∈ $N^{(i)}_{en}$ and rate $r_k[n]$. User l from a neighbour cell is allowed to access channel n only if the decoding rate for user k is no less than $r_k[n]$, if the SGD is applied to decode user k by FBS i. The GBR users transmit on neighbour cells channels (if possible) at low transmission rates and release their initially allocated entitled (interference-free) channels to VBR users. In this way, GBR users utilize neighbour cells entitled channels for low-rate transmission and VBR users can occupy more interference-free channels for high-rate transmission.

4.2 CRG PROBLEM- GREEDY ALGORITHM

First implements Single cell allocation to complete the entitled channel allocation, followed by exploiting channel reuse. The OSGD, which is expressed as OSGD (d, I, r) with inputs of the deserted user d, interferer set I and their rate vector r is used. To reduce the complexity, the neighboring GBR users are sorted and in sequence check whether the user at the current position can coexist with the users who have already been allocated channel n. The order is determined based on the maximum potential throughput gains (PGs) of GBR users allocated channels of their associated cells.The PG of an entitled channel m of cell j is the maximum single-user capacity among all VBR users designated to cell j, provided that channel m is not shared by neighboring users; otherwise it is equal to 0.Given sorted GBR users, checking the coexistence is implementing a series of OSGDs. The interfering set (S) contains the GBR user in current index of the sorted GBR users and the users who have already been allocated channel n (user k and some neighboring GBR users before the current index). Each user d in S implements the OSGD in its respective FBS (B_d), taking d as the desired signal and S \ d as the interferers. If the check succeeds then there is no outage declared and these GBR users can coexist on channel n.Once the check is true, the GBR user can use channel n and the corresponding VBR user use the released channel. As long as a channel is shared by multiple users, the PG relating this channel is set to 0 and this channel is no longer released for other VBR users .The potential gain (PG) and the metrices ($\Delta \mathbf{r}_{\mathbf{k}}$) are updated.

4.3 ILLUSTRATION

Four interferring femtocells are considered . Each cell consists of 2 users. Totally, K={1,2,3,…..8}

Let B be the set of femtocell base stations

B={1,2,3,4} ; i ε B

Let the set of Guaranteed Bit Rate users be (F)={1,3,5,7}

Let the set of Variable Bit Rate users (U)={2,4,6,8}

The Channel set N = F ⋃ V

N = {1,2,3,4,…8}

Entitled channel N_{en} = {2i-1,2i} for i = {1,2,3,4}

Table. 1. Four grid area

1	2
3	4

Table. 2. User and Channel Assumption

FBS	ENTITLED CHANNELS	(USER,TYPE)
1	1,2	(1,GBR)(2,VBR)
2	3,4	(3,GBR)(4,VBR)
3	5,6	(5,GBR)(6,VBR)
4	7,8	(7,GBR)(8,VBR)

CELL 1

CHANNEL 1

Order the GBR users (3,5,7) based on their metrics r3, r5 and r7; assuming $c_4[3] > c_6[5] > c_8[7]$ the order is then (3,5,7). The algorithm first checks user 3, where S = {3, 1}.

FBS 2 : OSGD ({3},{1},[r^3,r^1]) → g^3 [1]

FBS 1 : OSGD ({1},{3},[r^1,r^3]) → outage

User 3's check fails, and then check user 5, where *S* = {5, 1}.

FBS 3 : OSGD ({5},{1},[r^5,r^1]) → g^5 [1]

FBS 1 : OSGD ({1},{5},[r^1,r^5]) → g^1 [1]

$x_5[1]=1, x_5[5]=0, x_6[5]=1$

$r_5[1]=r\hat{}_5, r_5[5]=0, r_6[5]=c_6[5]$

$PG_1(1)=0, \Delta r1=0, \Delta r5=0.$

User 5's check succeeds, and then check user 7, where *S* ={7, 5, 1}.

FBS 4 : OSGD ({7}, {1,5}, [r^1,r^1, r^5]) → g^7 [1]

FBS 3 : OSGD ({5}, {1,7}, [r^5, r^1,r^7]) → outage

Since outage is declared when implementing the OSGD at FBS 3, we do not need to check user 1 at FBS 1, taking user 5 and 7 as interferers.

User 5 occupies channel 1 transmitting at r^5 and user 6 occupies both channel 6 and 5 transmitting at $c_6[6] + c_6[5]$. The PG of channel 1 becomes 0 as it has been shared by multiple users, resulting in r1 = 0,r5 = 0 also becomes 0 as there is no entitled channel allocated to the GBR user 5.

CHANNEL 2

Order the GBR users (3,7) based on their metrics r3 and r7; assuming c4[3] > c8[7] the order is then (3,7).The algorithm first checks user 3, where S = {3, 2}.

FBS 2 : OSGD ({3},{2},[r^3,r^2]) → outage

User 3's check fails and then check user 7, where S={7,2}

FBS 4 : OSGD ({5},{2},[r^7,r^2]) → outage

CELL 2

CHANNEL 3

Only GBR user 7 is considered, where S={7,3}

FBS 4 : OSGD ({7},{3},[r^7,r^3]) → outage

CHANNEL 4

Only GBR user 7 is considered, where S={7,4}

FBS 4 : OSGD ({7},{4},[r^7,c4[4]]) → g^7 [4]

FBS 2 : OSGD ({4},{7},[c4[4],r^7]) → g^4 [4]

$x_7[4]=1, x_7[7]=0, x_8[7]=1$

$r_5[1]=r\hat{}_7, r_7[7]=0, r_8[7]=c_8[7]$

$PG_4(2)=0, \Delta r7=0.$

After cell 2 and channel 4, User 7 occupies channel 4 transmitting at r^7 and user 8 occupies both channel 7 and 8 transmitting at $c_8[7] + c_8[8]$. There still exists a user (user 3) whose metric is greater than 0 hence the algorithm is continued

CELL 3

CHANNEL 5

Only user 3 is considered, where S={3,6}

FBS 2 : OSGD ({3},{6},[r^3,c6[5]]) → outage

CHANNEL 6

Only user 3 is considered, where S={3,6}

FBS 2 : OSGD ({3},{6},[r^3,c6[6]]) → outage

CELL 4:

CHANNEL 7

Only user 3 is considered, where S={3,8}

FBS 2 : OSGD ({3},{8},[r^3,c8[7]]) → outage

CHANNEL 8

Only user 3 is considered, where S={3,8}

FBS 2 : OSGD ({3},{8},[r^3,c8[8]]) → outage

5.SIMULATION AND RESULTS

5.1 SINGLE CELL ALLOCATION

The simulation results shows the assignment of GBR and VBR users , the entitled channel calculation, the channel matrix and channel allocation to the GBR and VBR users.

Figure 5.1 Entitled channels calculation

In figure 5.1, the entitled channels of all the femtocells are calculated.

Figure 5.2 Channel matrix Formation

 ISSN: 2321-8169
666 – 672

In Figure 5.2, the channel matrix with the elements as the channel capacities are calculated.

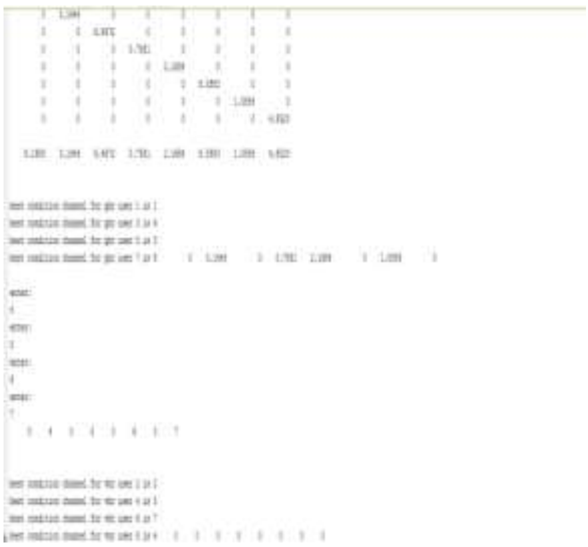

Figure 5.3 Allocating Channel with best condition to GBR and VBR users

5.2 THROUGHPUT ANALYSIS

Figure 5.4 Placing of Femto and macro users in a cell and throughput of a femto user

A single macrocell with 4 users (green dots) and four femtocells with 8 users (blue dots) which are linked with femtocells at different distances are considered (figure 5.4). It shows the throughput , SINR and path loss of a femto user in accordance with the femto cell.

Figure 5.5 Femtocell 1 specifications

The output shows the Bandwith , modulation and power of a femtocell 1 with respect to the macrocell in figure 5.5

Figure 5.6 Femtocell 2 specifications

The output shows the Bandwidth , modulation and power of a femtocell 2 with respect to the macrocell in figure 5.6

 ISSN: 2321-8169
666 – 672

Figure 5.7 Throughput and SINR of Femtouser 2

Since the femtocell 1 and femtocell 2 overlap each other, the interference cause the reduction in signal strength which in turn is shown by reduced SINR as in figure 5.7

Figure 5.8 Femtocell 3 Specifications

The output shows the Bandwith , modulation and power of a femtocell 3 with respect to the macrocell as shown in figure 5.8.

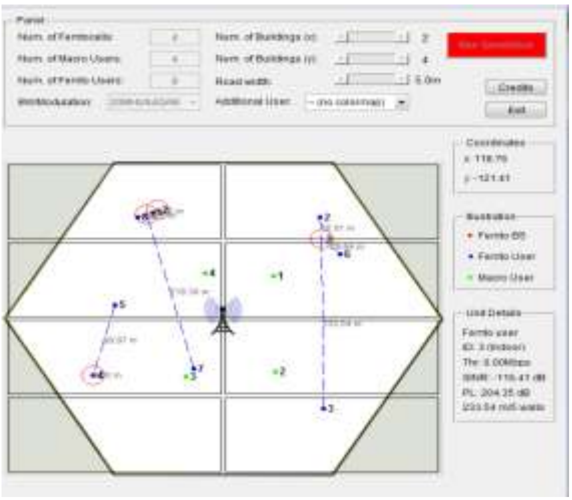

Figure 5.9 Throughput and SINR of femtouser 3

The figure 5.9 shows that as the femtouser 3 is more than 10 m away from its femtocell, it gives a zero throughput and a much low SINR and high path loss

Figure 5.10 Throughput and SINR of femtouser 4

The figure 5.10 shows that as the femtouser 4 is within the corresponding range of the femtocell, it provides a high throughput and high SINR and low pathloss

6. CONCLUSION AND FUTURE WORK

In this paper the resource allocation problem in uplink co-tier femtocell networks when advanced receivers are employed in the femtocell base stations (FBSs) is considered. In particular, the FBS with the successive group decoder (SGD) which represents a family of decoders ranging from successive interference cancelation (SIC) to the optimal maximum-likelihood (ML) decoder by setting different group sizes is employed.The problem is formulated as a joint channel, rate and group allocation problem. Two traffic types are considered, VBR users transmitting at high rates and GBR users with constant bit rate requirements. The weighted sum rates of VBR users under the constraint of GBR users' rate requirement is maximized. Single cell allocation and Greedy algorithms are analysed and the throughput and Signal to Interference Ratios are calculated for the femtousers and the performance is improved.

In future work ,the throughput can be increased and the interference can be reduced by coexisting the GBR users and allocating the freed channel to the VBR users.

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