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Spectrum Allocation for Non- Orthogonal Multiple Access In Heterogeneous Networks

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Abstract: *To meet the emanate traffic requirement, 5G system should be capable of supporting high data rates with very low latency. Since the resources are limited, it will be a tough task. In order to solve the crisis, two techniques are studied in Non Orthogonal Multiple Access. The first one is, many to one matching where small cell base station is matched to resource block which results in a low complexity algorithm. The small cell base stations (SBSs) are capable of communicating with multiple small cell users. The spectrum allocation issue is modeled as a many-to-one matching game. The Second one is, a hybrid system which is a combination of both orthogonal and non-orthogonal multiple access. It can enhance capacity. The sum rate for a large number of users can be optimized. Hybrid multiple access which is a combination of NOMA and OFDMA utilize the transmission schemes for varying channel conditions. Non-orthogonal multiple accesssuperior in spectral efficiency and will improve the capacity of future networks against orthogonal multiple access. By these two techniques, resources are split into chunks and assigned to users or group of users.*

Keywords: *Heterogeneous network, Non orthogonal multiple access (NOMA), orthogonal multiple access (OMA), Spectrum allocation, Spectral efficiency*

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I. Introduction

Orthogonal frequency-division multiple access (OFDMA) is an orthogonal multiple access technology. OFDM is a multi-user version of the popular orthogonal frequency-division multiplexing (OFDM) digital modulation scheme. Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users. This allows simultaneous low-data-rate transmission from several users. The resources are limited and multiple users have to be allocated in this particular limit. It is a serious issue. Here two techniques are introduced in order to maximize sum rate and to improve spectral effeciency. First one is a low complexity algorithm based on the swap operations enables SBSs and RBs to effectively interact with each other. The small cell base stations (SBSs) are capable of communicating with multiple small cell users. The spectrum allocation issue is modeled as a many-to-one matching game with peer effects. The SBSs and resource blocks interact to decide their desired allocation. The concept of exploration into the matching game for further improved the SCUs' sum rate. The exploration will further enhance the performance of the matching algorithm and the NOMA-enhanced HetNets will achieve a higher SCUs' sum rate compared to that of conventional OMA-based HetNets.Second one is vertical pairing concept. The sum rate for a large number of users can be optimized. Hybrid multiple access which is a combination of NOMA and OFDMA, will utilize the transmission schemes for varying channel conditions. Non-orthogonal multiple access (NOMA) superior in spectral efficiency and will improve the capacity of future networks against orthogonal multiple access. The sum rate will be maximized based on the total power and rate constraints.

A novel resource allocation design is introduced for non-orthogonal multiple access (NOMA) enhanced heterogeneous networks (HetNets) [1]. Here small cell base stations (SBSs) are capable of communicating with multiple small cell users (SCUs). With the aim of maximizing the sum rate of SCUs, issue of spectrum allocation and power control is formulated. Here the spectrum allocation problem is modeled as a many-to-one matching game with peer effects. This has a novel algorithm where the SBSs and resource blocks interact to decide their desired allocation. This algorithm is proved to converge to be a stable matching. The concept of exploration into the matching game for further improving the SCUs' sum rate is adapted. The proposed algorithm closely approaches the optimal solution within a limited number of iterations. The exploration action is capable of further enhancing the performance of the matching algorithm and the NOMA-enhanced HetNets achieve a higher SCUs' sum rate compared to that of conventional OMA-based HetNets.

Non-orthogonal multiple access (NOMA) is superior in spectral efficiency and could play a vital role in improving the capacity of future networks against orthogonal multiple access[2]. Here a resource allocation scheme is developed for a downlink multi-user NOMA system. An optimization issue is formulated to maximize the sum rate based on the total power and rate constraints. Due to the complexity of computing the best solution, a low complexity sub-optimal solution for two-user scenario is developed and then extended to the multi-user case by user-pairing approach as well as a number of power allocation techniques. In addition, hybrid multiple access technique which combines the properties of NOMA and the orthogonal frequency division multiple access (OFDMA) is implemented.

Non-orthogonal multiple access (NOMA) has spurted as a key technology for boosting the capacity of 5G networks[3]. Since, NOMA is expected to be heterogeneous networks (HetNets), its performance on 5G HetNets is highly anticipated. 5G HetNet with hybrid multiple access where NOMA and orthogonal multiple access coexist. Here a dynamic power allocation is used and four generic pairing methods for NOMA are explained: Hungarian, Gale-Shapley, random, and exhaustive. Through the results, the close-to-optimal pairing methods offer the highest capacity gain whenever the network cells are equally loaded. If the load is unequal and load balancing techniques are used, simpler pairing methods offer higher gains. Thus a flexible choice of the pairing method to be used for NOMA depending on the network load, thus achieving a balance between the network capacity gain and the complexity of the pairing method.

Resource allocation and user association are two key problems in the heterogeneous wireless cellular networks [4]. The joint optimization on these two problems is difficult to achieve thus the exact solution cannot be obtained effectively. Here a novel shareable resource allocation and user association scheme is introduced with frequency reusing taken into consideration. The optimization issue on the whole networks is divided in two stages: resource allocation for each base station and user association. In stage one, an adaptive allocation algorithm is provided, which can increase the frequency reuse performance is introduced based on the priori traffic spatial distribution. In stage two, by a relaxed convex optimization each user is associated with a BS then assign some physical resource blocks.

II. Spectrum Allocation in NOMA

Spectrum allocation argument is casted as many to one matching game. In spite of meeting the flowing demands for wireless services, deployment of Het Nets is required. Thus spectral efficiency can be achieved. The sharing of spectrum among multiple users can cause co-tier and cross-tier obstruction, so dynamic spectrum allocation technique should be implemented.

2.1 System Description

A K-tier Heterogeneous networks, with first and large tier as macro cell and the rest as low powered small cells. The small cells here considered are femto cells and pico cells. Femto cells can support a handful of users and simultaneous calls per time. Its has less radius of coverage. For pico cell, it can handle about 100 users and the radius of coverage is much more than that of femto cells. The network capacity can be enhanced by the deployment of these small cells. Small cell base stations can be substituted as SBS = {1, . . . , B}. The Macro cell base station serves macro cell control units, i.e., MCU = {1, . . . , M}.

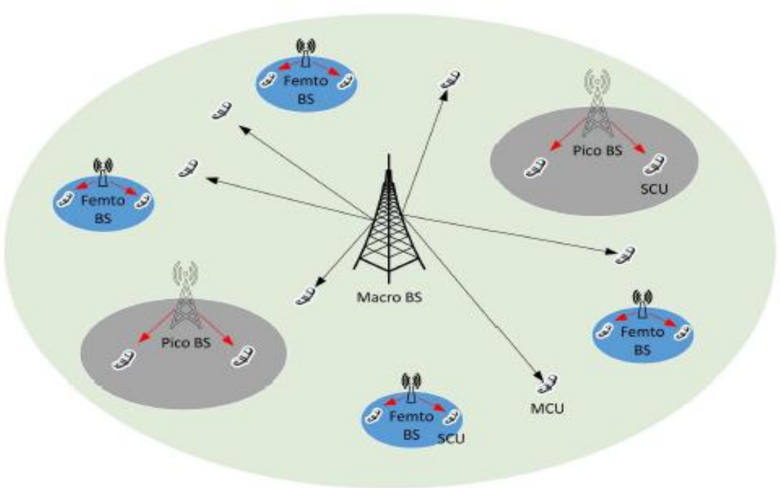

Fig 1: NOMA enhanced HetNets [1]

2.2 Channel Model

In power domain NOMA, at the transmitter multiplexed signals are superimposed and at receiver, successive interference cancellation is done to reduce interference. Interference can be allowed to a limit. Consider thevector a_b=[$a_{b,k}$, $a_{b,j}$] where a_b is the power allocation coefficients for the control units of small cells. The small cell base station can send message to small cell control units k and j which can be represented as:

$a_{b,k} * x_{b,k} + a_{b,j} * x_{b,j}$ (1)

where the term x denotes to the messages for the respective control units. The received signal can have the following output:

$y_{b,k}$ = desired signal + interference from NOMA users + noise + cross-tier interference + co-tier interference (2)

In the case of orthogonal multiple access, interference can be limited due to orthogonality. While in NOMA, intentionally interference is added at the transmitter. The strongest signal can be decoded first and then the process continues with the rest of signals.

2.3 Many-To-One Matching For Spectrum Allocation

A matching function Φ is chosen from the set RB ∪SBS into the set of all subsets of RB ∪SBS such that

1) |Φ(b)| = 1, ∀b ∈ SBS, each SBS matched to only one RB

2) |Φ(m)| ≤ qmax , ∀m ∈ RB, number of SBSs matched to each RB limited to qmax

3) Φ(b) = m if and only if b ∈Φ(m), if and only if SBS b is matched with RB m, then RB m latter will also be matched with SBS b

Before matching, both SBSs and RBs should set up a preference lists. It should be in descending order. Formed by interest of each. Each SBS b compare RB m and m' based on data rate and each m compares SBS b and b'. Choose the preferred RB and SBS respectively. Thus the preference list may change as the matching game proceeds.

2.4 Initialization Algorithm

An initialization algorithm (IA) is proposed based on the traditional Gale Shapely algorithm to obtain the initial matching state. After the initialization, swap operations among SBSs is done to better handle interdependencies between preference of players. This is to further improve the performance.

In the initialization algorithm, SBSs and RBs first initialize their own preference lists. The list of all the SBSs that are not matched with any RB is denoted by UNMATCH. In the matching process, each SBS proposes to its most preferred RB, then each RB accepts the most preferred SBS and rejects the others. This process continues until the set UNMATCH goes empty.

Algorithm 1: Initialization Algorithm (IA)
1. Initialize preference list of SBS and RB.
2. Construct a set of unmatched SBS with RB.
3. **while**Unmatch is not empty
4. **for**∀b ∈Unmatch**do**
5. SBS proposes RB
6. **end for**
7. **for**∀m ∈ RB **do**
8. **if**|Φ(m)| ≤ qmax**then**
9. RB m keep all proposed SBS
10. Remove matched SBS from the set Unmatched
11. **else**
12. RB m keeps most preferred qmax SBS and reject others
13. Continue step 10
14. **end if**
15. Remove m from preference list of SBS that have sent requests
16. **end for**
17. **end while**

2.5 Swap Operations Enabled Matching Algorithm

After the initialization, swap operations among SBSs are enabled to further enhance the performance of the resource allocation algorithm. Swap Operations Enabled Matching Algorithm is composed of three steps. First, initializes the matching state based on the algorithm IA. Second, focuses on the swap operations between

SBSs. Every SBS keeps on searching all the other SBSs if they form a swap-blocking pair. The swap-matching process continues till there will be no swap blocking pair. And finally end of the algorithm.
To prevent cyclic swapping between SBS b and b', the flag is set to record the time that b and b' swap their allocated RBs. Each SBS b can at most swap with another SBS b' twice, which prevents flip flop and ensures convergence.

Algorithm 2: Swap Operations Enabled Matching Algorithm

Step 1: Initialization
Initialize matching state and flag
Initialize no: of swapping proposals from b to b' as 0
Step 2: Swap matching process
Each SBS b search for another SBS b' to evaluate if a swap blocking pair exist
if (b,b') exists, update current matching state
Increment flag by 1
else
Keep current matching state
end if
Repeat step 2 till no swap blocking pair exists
Step 3: End of algorithm

III. Spectrum Allocation In Hybrid Multiple Access With Rate Constraint

In 4G networks, orthogonal multiple access is used as the air interface technique. The effectiveness against multi-path fading and achieving high system throughput does not make full use of the spectral resource because it restricts each user to use only a limited part of the spectrum. This limits enhancement of spectral efficiency and the capacity of future networks. Non-orthogonal multiple access (NOMA) is as a promising radio access scheme for further capacity enhancement

3.1 Hybrid System

It is the mixture of OFDMA and NOMA in the sense of orthogonality between users. Thus it could enhance the capacity. In a hybrid multiple access scheme, part of the spectrum are reserved for orthogonal access (dedicated) and the rest (shared) are for all users by NOMA is shown in Fig 2. An illustration of this hybrid scheme in a two user case is depicted in Fig 2. In this example the first RB is dedicated for user 1 and the s-th RB is dedicated for user 2 respectively. Both users share the second RB. Hence the merit of the hybrid method is that it is less susceptible to interference and requires less SIC process than NOMA. Some users could share more spectrum as compared to the purely orthogonal case thus hybrid system has more spectral efficiency than OFDMA. RB allocation is performed by assuming equal power allocation.

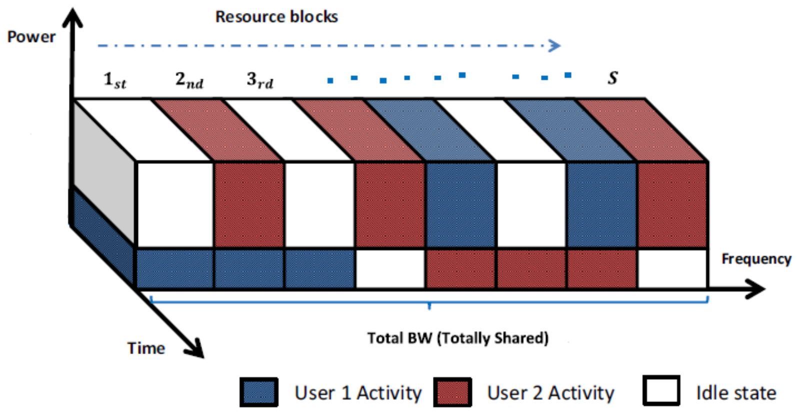

Fig 2: Structure of the hybrid scheme [2]

3.2 Multi-User Noma With Vertical Pairing Concept

A vertical pairing concept is shown in Fig 3, allocate the users in pairs. The total number of pairs are denoted by Z, and the pairs are arranged based on their channel powers from the weakest to the Z-th pair i.e, the strongest. Starting from the bottom pair which has both weak and strong user, the weakest user among them in the first pair will not perform SIC while the better one in this pair will perform SIC only to its partner in this pair. As moving on to top, the weaker user of the Z-th pair or the strongest pair will perform SIC to all of the previous pairs, but the strongest user at this pair will perform SIC to all of the previous pairs along with its companion.

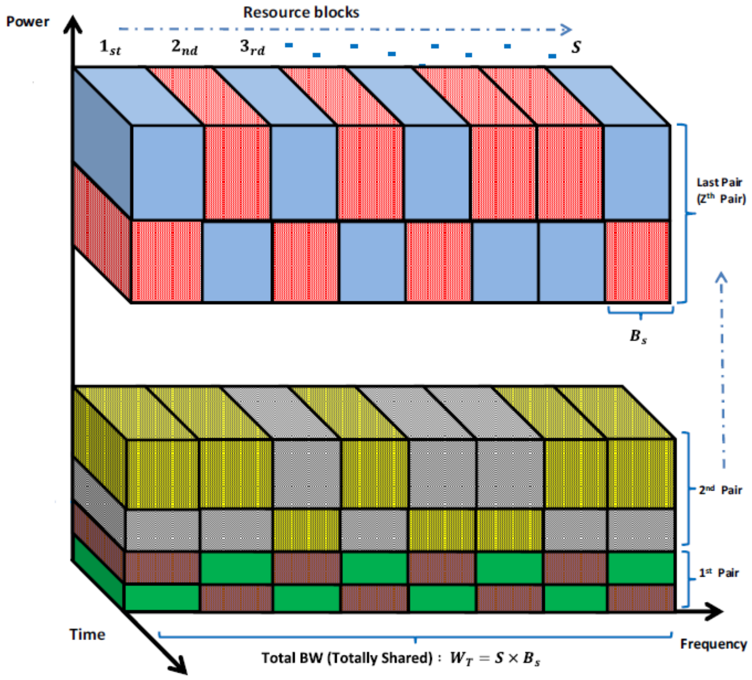

Fig 3 : NOMA structure with vertical pairing concept [2]

3.3 Hierarchical Pairing Power Allocation (HPPA)

After the application of multi-user NOMA with vertical pairing,power will be allocated to the vertically paired users, in stratified manner based on their channel powers. Divide the users into two groups and blend their channel powers. Based on the concept of NOMA, the stronger half of the users form one group, and the weaker half the other. After the power for the two groups are determined, the procedure is repeated to each group as a second stage. Thus two subgroups are formed in each group of the previous stage. The multiple stage approach is continued until the subgroups become pairs of users.

3.4 RB Allocation and Classification

The achievable rates of RB are first evaluated and then choose the best one to segregate RB for orthogonal or non-orthogonal transmission. For the orthogonal case, the achievable rate of each user over the s-thRB is evaluated using:

$$R_{orth,s} = B_s \log_2 \left(1 + \frac{P_{RB} |h_s^{(u)}|^2}{B_s N_0} \right) \tag{3}$$

The non-orthogonal sum rate of all users over the s-th RB is given by:

$$R_{non,s} = B_s \log_2 \left(1 + \frac{\beta_{\tilde{u},s} P_{RB} |h_s^{(\tilde{u})}|^2}{B_s N_0} \right) + B_s \sum_{u=1, u \neq \tilde{u}}^{U} \log_2 \left(1 + \frac{\beta_{u,s} P_{RB} |h_s^{(u)}|^2}{B_s N_0 + \sum_{m=u+1}^{U} \beta_{m,s} P_{RB} |h_s^{(u)}|^2} \right) \tag{4}$$

After the above process, the RB classification process will be done by comparing the achievable rates $R_{orth,s}$ by each user (the individual user rate of all users over the s-th RB) with the $R_{non,s}$(the sum rate of all users over the same s-th RB). If $R_{non,s} \geq R_{orth,s}$ then the respective RB will be shared using NOMA. Else the RB will be classified as an orthogonal RB.

3.5 Power Allocation For The Hybrid System

According to the classification process, all users will have non-orthogonal RBs but only some will also have the orthogonal ones.

Algorithm 3: Power Allocation for the Hybrid System

1. Initialize S_{noma} and S_{orth}
2. Compute achievable rates
3. Compare $R_{orth,s}$ against $R_{non,s}$
4. **if**$R_{non,s} > R_{orth,s}$
5. RB shared using NOMA
6. Increment S_{noma}
7. **else**
8. RB classified as OMA
9. Increment S_{orth}
10. **end if**

The amount of power allocated to the dedicated part is:

$$P_{orth} = \frac{P_t * S_{orth}}{S} \quad (5)$$

that of shared is:

$$P_{non} = \frac{P_t * S_{non}}{S} \quad (6)$$

where S_{non} and S_{orth} are the corresponding number of RBs allocated to each part. For the shared part, since being a NOMA transmission, the proposed HPPA method for power allocation is used. The power allocation for the orthogonal part will be applied using an optimal water-filling based approach.

IV. Conclusion

The formulation of spectrum allocation problem as a many-to-one matching game, a low complexityalgorithm stand on the swap operations was considered to enable small cell base stations(SBS) and resources blocks(RB) to effectively cooperate with each other.SBSs are up to broadcast with multiple small cell users. The spectrum allocation problem is modeled as many-to-one matching game. This has a novel algorithm where the SBSs and RBs interact to decide their desired allocation. The proposed algorithm closely approached the best solution within a limited number of iterations and the NOMA-enhanced HetNets achieved a higher SCUs sum rate compared to that of conventional OMA-based HetNets. Hybrid multiple access which is anamalgamof NOMA and OFDMA, employ the hauling schemes for fluctuating channel conditions.By the vertical pairing concept the sum rate for a large number of users is enhanced.Non-orthogonal multiple access superior in spectral efficiency and the capacity of future networks against orthogonal multiple access is alsoimproved. The sum rate is maximized stand on the total power and rate constraints.

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