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Modeling of Resource Allocation in OFDMA systems with Multiple Handover Stations

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Abstract

In the orthogonal frequency division multiple access (OFDMA) systems, one of the efficient and low complex methods to allocate radio resources among multiple users is chunk based resource allocation, which groups a number of adjacent sub carriers into a chunk and allocates resources chunk by chunk. In this paper we address the problem of radio resources allocation in the Downlink (Dl)of cellular systems with Handover Stations(HS), based on OFDMA systems .In this there is a need for resource allocations for efficient algorithms to the exploit potential capacity and coverage area increased by using Handover Stations. We propose several algorithms for different options such as frequency and time division. One algorithms offers an overall improvement of throughput and coverage, compared to a system without relays. At the same time the advantage of our algorithms is that their complexity and amount of information overhead are much reduced compared to an optimal algorithm.

INTRODUCTION

Because of the advantage of transforming a frequency selective fading into multiple frequency nonselective fading or flat fading channels, which is inherited from orthogonal frequency division multiplexing (OFDM) orthogonal frequency division multiple access (OFDMA) has become very attractive and been widely adopted in high data rate wireless communication systems, such as long-term evolution(LTE) or LTE-advanced .[8]

In order to achieve high data rate wireless transmission must be invented and developed in OFDMA systems .One of these techniques to allocate radio resources (e.g. Sub channels, power and bits) to the multiple users [9] .The maximum system throughput or minimum transmit power can achieved high through optimally allocating resources subcarrier by subcarrier, which is called sub carrier based resource allocation. However, the implementation of subcarrier based resource allocation technique is very complicated when the numbers of subcarriers in OFDM is large For example, the number of subcarriers in the LTE-Advanced can be as large as thousands. In order to reduce the complexity of subcarrier based resource allocation, chunk-based resource allocation was proposed, which groups contiguous subcarriers into a chunk and allocates resources chunk by chunk. The basis of the chunk resource allocation technique is the channel correlation among adjacent subcarriers in the broadband wireless channel. The chunk based resource allocation can significantly simplify the complexity of OFDMA resource allocation, when the number of subcarriers for chunk is small.

While coming to 4th Generation (4G) wireless system, it is highly expected that high data rates will be accessible over large areas. By deploying Handover Stations (RS) in a cellular system, it becomes possible to forward high data rates in remote areas of the cell while keeping a low cost of infrastructure. To exploit this potential gain in capacity and coverage, an adequate and practical radio resource allocation strategy should be designed. Hence, the problem of resource allocation and scheduling for relay-aided cellular systems has been a flourishing topic for investigation and has produced a number of work such as[1] [2] [3]. However, in these works an OFDM physical layer is not considered. By combining HS resource allocation with OFDMA, even higher capacity and cell coverage can be expected. Some works on resource allocation for OFDMA Handover systems (Relay systems) can be found in the literature [4] [5], but to the best of the author's knowledge, there has been little work in the literature on specific resource allocation schemes for multiple access in a HS-aided cellular system based on OFDMA technology. Thus, our goal is to provide efficient allocation algorithms for that system to enable a high capacity and high coverage. Also, one of the key points is that the algorithms are designed in such a way that reduces the algorithm complexity and required amount of Channel State Information (CSI)

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SYSTEM MODEL

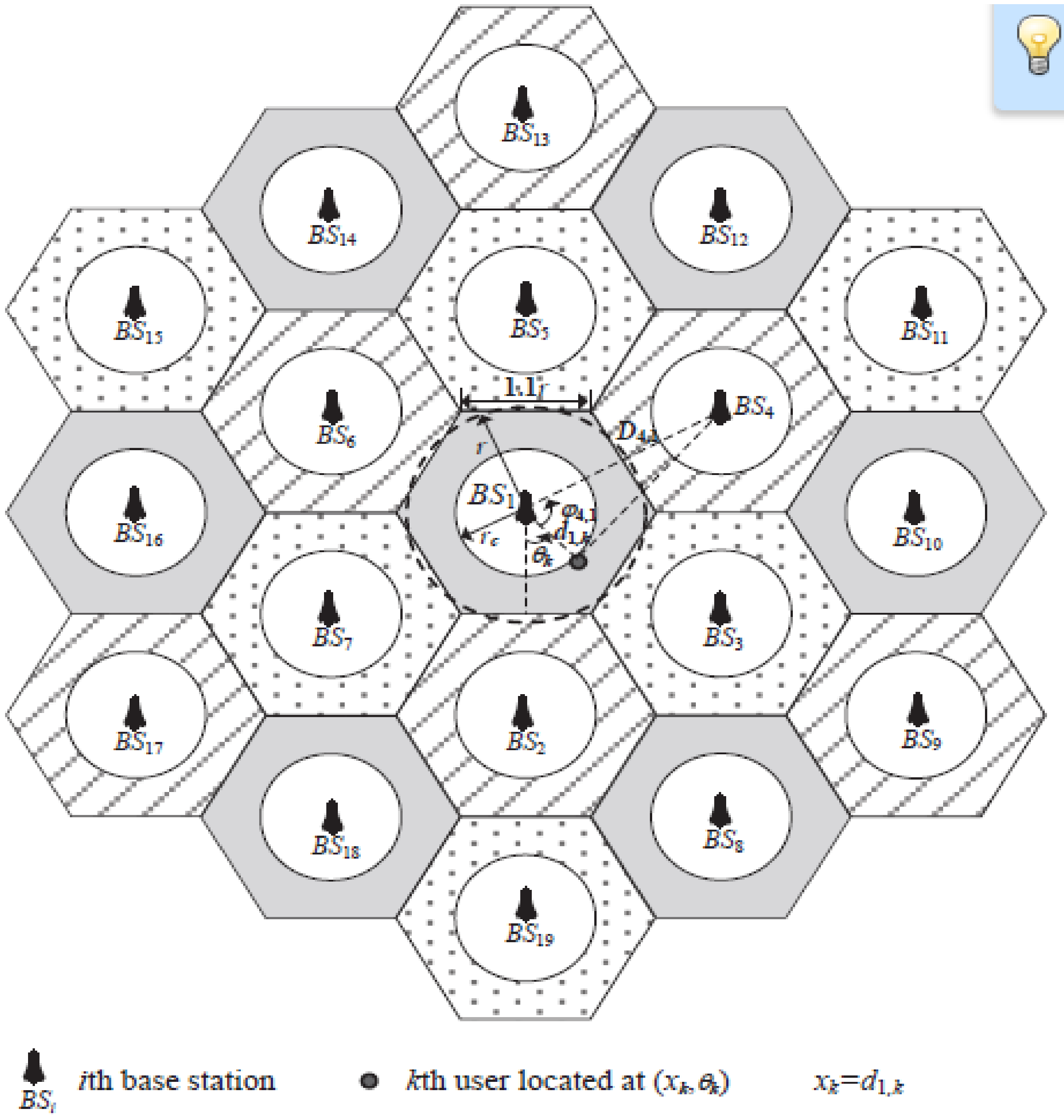

Figure 1: Cellular model with fractional frequency reuse

Fig. 1 shows the two-layer cellular model with FFR and 19 cells in total.In the two layer cellular model, each cell is divided into two areas :the central area and edge area and the same frequency can be reduced among the areas with in the same pattern of shadow. As shown in the figure, the frequency with in the central area of cell is reused in all other cells, while the frequency within the edge area of one cell is reused every three cells, but not reused among adjacent cells. Therefore the frequency reuse factor in the central area of the one cell is re used in the edge area is 1/3. For *i* th cell, where ,where *i*=1,2,………19, there is one base station(BS),defined asBS_i, located in the center cell. The first time, i.e,*i*=1, is the assumed reference cell, and BS_1 is the reference .The number of active users in the first cell is assumed to be K. The user shown by the black point in the first cell, all other eighteen BSs outside the first cell, all other eighteen BSs outside the first cell may cause co-channel interface to the interference to the reference user through downlink transmission due to frequency reuse factor of one.

However, when the reference is located in the edge area of the first cell, only six BSs (i.e.BS_8,BS_{10},, BS_{14}, BS_{16} $and BS_{18}$) having the same grey shadowing edge area cause co-channel interface to the reference user. In order to simplify the analysis, each hexagonal cell is approximated as a circular cell with the equal area as explained in. By denoting radius of the equivalent circular cell as *r*, the edge length of the hexagonal cell is equal to 1.1*r*, as shown in fig 1.the radius of the central area of the cell is denoted as *rc*. Further, by denoting the distance, $d_{1,k}$, between BS_1 and the reference user (i.e. the *k*th user) as x_k, i.e. $d_{1,k} = x_k$ and Θ_k as the angle of the user between the line from BS_1 vertical to the lower horizontal edge of the first cell and the line from BS_1 to the user, the distances $\{d_{i,k}\}$ *i*=2,…..,19, between BS_i and the reference user can be expressed as

$$d_{i,k}=\sqrt{[x_k \sin(\varphi_{i,1} - \theta_k)]^2 + [D_{i,1} - x_k \cos(\varphi_{i,1} - \theta_k)]^2}$$

$$= \sqrt{x_k^2 - 2x_k D_{i,1} \cos(\varphi_{i,1} - \theta_k) + D_{i,1}^2} \quad (1)$$

Where $D_{i,1}$ is the distance between BS_i and BS_1,e.g.$D_{4,1}$ Shown in Fig .1, and $\varphi_{i,1}$ is the angle between the line from BS_1 to BS_i and line from BS_1 vertically to the lower horizontal edge of the first cell, e.g. $\varphi_{4,1}$ in Fig.1. Therefore the location of the *kth* user is represented by (x_k,θ_k) in Fig.1.

We focus on Downlink (DL) transmissions from base station (BS) to mobile stations or Handover Stations(HS) in a single cell 1,where users feed back to the BS their Channel State Information (CSI) on every sub channel, defined as a group of adjacent subcarriers .Discrete Adaptive Modulation and Coding(AMC model from table 1 is applied per sub channel, for each user. The BS is surrounded by multiple HS, as depicted in Fig1. The HS are placed at a distance of 0.8km from BS, where the cell radius is 1km. Two categories of frame structure are considered:

- Time division between BS and each HS transmissions with $T_{BS}$the time allocated to the BS-subframe where transmissions from the BS occur,T_{HS} allocated to each HS-sub frame where transmissions from the HS occur.
- Time division is widely consider in the 802.16-based relay systems [6].Since the interface between opposite HS can be assumed low they are allocated the same sub frame in a parallel manner, as shown in Fig.3.there are 3 groups of opposite HS: airs(HS_1, HS_4), (HS_2, HS_5) and (HS_3, HS_6).
- Frequency division: each HS is served a certain frequency region. With the frequency reuse mentioned above, the structure shown in Fig. 3. Moreover, the following assumptions are taken.
- Inside the BS-subframe, BS-MS or direct transmissions and BS-HS or feeder transmissions, are divided in frequency, where each sub channel can be allocated to either link. To the best of our knowledge, this is the new type of structure as usually, the frequency regions for BS-MS and for BS-HS are fixed and separated
- T_{BS} and T_{HS} can be adapted from frame to frame. The algorithms are optimized for the two-hop scenario. With this frame structure, the packets of a relayed user queued at the BS will require at least two frames to arrive to destination: with the first frame, packets are sent from BS to HS in the second frame, from HS to MS.

Table 1: Discrete AMC Model

Modulation	BPSK	4-QAM	16-QAM	64-QAM	256-QAM
Rate[b/symbol]	1	2	4	6	8
SNR[dB]	-5	13.6	20.6	26.8	32.9

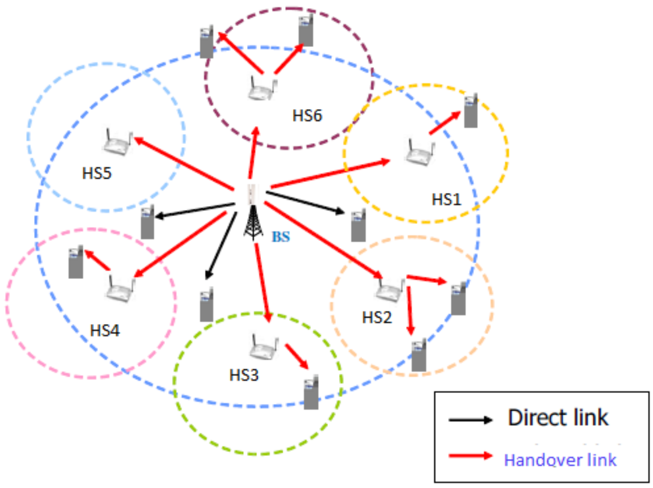

Figure 2: Cellular System with multiple Handover link

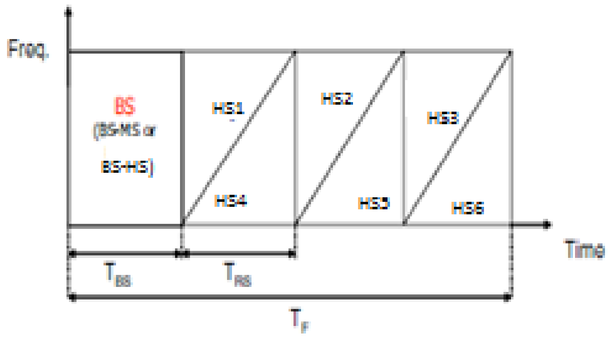

Figure 3: Frame structure with parallel HS transmissions, time division

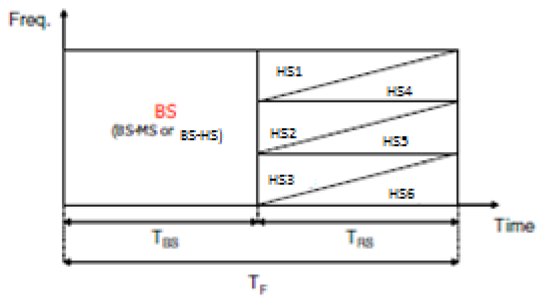

Figure 4: Frame structure with parallel HS transmissions, frequency division

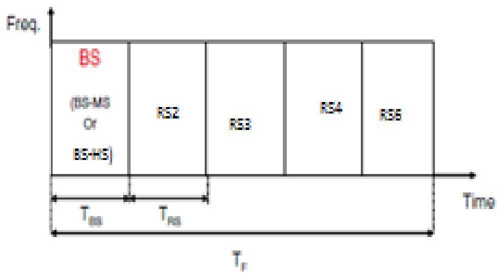

Figure 5: Frame structure with handover structure

We assume here that each MS is attached to one access point at a time, among the BS and the HS. In the optimal allocation, the path selection and the sub channel/time allocation should be made simultaneously in a BS – centralized manner. Since our goal is to provide low complexity algorithms we require only reduced amount of CSI, we consider that the path selection is performed first, based on the long term average user SNR, as done in [2]. The achievable AMC levels corresponding to the long term average SNR of the direct and relayed links are compared for each user, and the path allowing the best achievable rate is chosen. The sub channel/time allocation is made after each user is linked to a path.

RESOURCE ALLOCATION ALGORITHMS

We propose HS-aided centralized algorithm, which goal is to realize a good throughput and outage performance. With the specific design described below, the algorithms minimizes the complexity and required CSI, as opposed to the optimal algorithm. That is, for the optimal algorithm, the BS requires the CSI of all users and all sub channels on all the 7 links, which becomes very large as the numbers grow. However with our HS-aided algorithms, the CSI information for a HS is only required at the HS forward only a minimal information to the BS, such as the required user ID or the CSI of the allocated users, as explained below. The basic steps described below will be used in all the following algorithms.

1) Allocation of each HS-sub frame by each HS: Each sub channel is allocated to the user with the best $\varphi_{k,n}$ensure that the allocated capacity will be used. In the way, the achieved through put can be increased.$\varphi_{k,n}$ is defined as

$$\emptyset_{k,n} = \frac{\tau_{k,n}}{\frac{\beta_k(i-1)}{R}} \qquad (2)$$

Where R is the minimum data rate requirement.$\beta_k(i-1)$is the past average rate allocated to user *k* at the frame *i* over a window of *p* frames and is updated after every allocation(as in proportional Fair scheduling(PFS)

$$\bar{\beta}_k = \frac{p-1}{p} \times \bar{\beta}_k(i-1) + \frac{1}{p} \times \sum_{n=1}^{N} c_{k,n}\tau_{k,n}(i) \qquad (3)$$

Where $c_{k,n}$ is equal to one if subchannel n was allocated to user *k* in the current frame *i*. With the metric φ, users whose achieved throughput is far from the rate requirement are prioritized in order to decrease the outage probability. At the same time, users with the higher instantaneous CSI are prioritized, which increases achieved overall throughput.

2) Requests by each HS sent to BS: during the allocation, each HS_i maintains a list of users URS_i Req for which new packets are requested to the BS. The users in URS_i Req are the ones with a higher values of $\varphi_{k,n}$than the allocated user but who didn't have any packets queued at the HS. For these users, each HS requests the BS to their packets in the BS-sub frame, via the HS-BS link. These packets strategically chosen: since low mobility users are considered, it can be reasonably assumed that a high channel quality for a certain user likely to be kept during the following frame. Therefore, the users with a high $\varphi_{k,n}$ in one frame are likely to be chosen in the next frame.

3) Allocation of BS sub frame by BS based on the requests by each HS: the BS allocates temporarily each sub channel to the direct user with the best $\varphi_{k,n}$. Then these subchannel n_{BR} required to send all the packets in URS_i Req is determined. The crucial assumption here that, we assume that all the BS-HS sub channels have the same average SNR level, since the BS-HS links are in Line-of-Sight (LOS). Thus any sub channel among all N sub channels can be chosen to support BS-HS transmissions. Beginning with sub channel with the worst$\varphi_{k,n}$, we compare the achievable rates for the current user with in the BS-HS link rate. This sub channel allocated to the link with the best rate. This sub channel allocated to the link with the best rate. This sub channel is allocated to the link with the best rate.

We repeat this until all the n_{BR} subchannels are allocated, or the until the rate of the direct user becomes larger than the BS-HS rate.

A. Fixed allocation with the Time Division:

In this algorithm referred as multiple HS parallel (MRP) algorithm, then the basic algorithm described above the performed for the frame depicted in Fig 3. However, since the same sub channels are used at the same time, the opposite HS transmitting in parallel interface with each other, even though it may be negligible. In the simulation, this interface has also been taken into account. Namely, if user *k* attached to HS_1 was scheduled on a subchannel n, then the interface is equal to the signal power of HS_4 to user *k*, on a sub channel n. By assuming the interference to be an additive Gaussian noise, the signal-to-interference-plus-Noise-Ratio (SINR) of user k on sub channel n denoted $SINR_{k,n}$ is

$$SINR_{k,n} = \frac{p_{k,n} \times \left|h_{k,n}^{RS1}\right|^2}{p_{k,n} \times \left|h_{k,n}^{RS4}\right|^2 + \sigma^2} \tag{4}$$

By denoting $SNR_{k,n}$ the Signal-to –Noise-Ratio (SNR) of user *k* on subchannel n

$$SNR_{k,n} = p_n \times \frac{\left|h_{RS1,k,n}\right|^2}{\sigma^2} \tag{5}$$

We obtain:

$$SINR_{k,n} = \frac{SNR_{k,n}}{1 + SNR_{k,n} \times \frac{\left|h_{k,n}^{RS4}\right|^2}{\left|h_{k,n}^{RS1}\right|^1}} \tag{6}$$

While the subchannel allocation will be made based on the SNR values, the SINR values $SINR_{k,n}$ will be used to determine the BER values, and thus the achieved throughput continue by removing the next worst HS and redistributing the frame , otherwise the previous frame configuration kept. This algorithm stops when $\tau_i - 1 > \tau_i$ or when there is only the BS subframe left. This algorithm will be referred as Multiple-HS adaptive activation(MRAA) algorithm. The subchannel allocation aim at reducing the outage probability, but the per-frame HS activation focuses on increasing the overall throughput. Therefore, this algorithm makes tradeoff between throughput and outage.

DESIGN OF OPTIMIZED ALGORITHM FOR PERFORMANCE ASSESSMENT

In order to assess the performance of our proposed algorithms, some optimized algorithms are designed. In our algorithms, the path selection and the subchannel/time allocation are separated in order to reduce algorithm complexity and to avoid the feedback of the CSI of relayed users to the BS. However, to obtain the best performance, the path selection and the resource allocation should be performed simultaneously at the BS. To ensure that upper/lower bounds are obtained, some infeasible assumptions are considered as:

- Full buffer, e.g., there are always packets to be sent to users
- The data sent to HS is immediately forwarded to the user in each frame (in practice, the data sent to a HS can only be forwarded to the destination during the next frame.)

A. Optimized Algorithm for Throughput

For simulation giving the throughput upper bound, denoted HS-max Full Buffer algorithm, the user on the link with the highest achievable rate among the all direct or relayed users is scheduled in each sub channel. Moreover, to compare the possible gain in throughput by introducing HS compare to the case without any HS, the Max C/I algorithms with full buffer assumptions without relays, denoted BS-Max Full buffer algorithm is performed without the full buffer assumptions as a reference algorithm. In this algorithm queued packets are taken into account, e.g., the user with the best rate $r_{k,n}$ and who has queued packets is allocated to each subchannel. This algorithm will be referred as BS-Max algorithm.

B. Optimized Algorithm for System Outage

In the case of system outage, all algorithms are evaluated with the fill buffer assumptions. That is, user is considered to be in outage when he has not been given any resource, although he has queued packets. But if he has not been given any resource, although he has queued packets, is does not constitute any outage event. Since the outage is based on the number of users who didn't receive a rate higher than reference rate R, we define our algorithm as follows: in each subchannel, all users are ordered according to their priority metric in all the access points, and the subchannel is allocated to the best user. The priority metric is φ defined in the Eq.(1), but the here the average user rate $\bar{\beta}_k(i)$ is updated after every subchannel allocation, in order to obtain a finer allocation namely

$$\beta_k(i, n_c) = \frac{p-1}{p} \times \bar{\beta}_k(i-1) + \frac{1}{p} \times \sum_{n=1}^{n_c} c_{k,n}\, \tau_{k,n}(\mathrm{i}) \tag{7}$$

With n_c the currently served subchannel. This algorithm is denoted Optimized outage algorithm.

NUMERICAL RESULTS

In the simulations, we consider a single cell with a BS and 6 HS. Users are uniformly distributed over the whole cell area. To evaluate the performance of the proposed algorithms, simulation are made over 100000 set of channel realizations, each set of channels consisting of independent user channels.

The channel models and other simulation parameters used are taken from[7]. There is equal power distribution in each subcarrier. There are 48 subcarriers and 12 subchannels, each composed of 4 contiguous subcarriers and the number of users is varied from 5 to 20. User packets arrive at the BS queue following in poisson process. With our path selection algorithm, each user is first attached either to the BS or the HS, next the time/subchannel allocation is made. The path selection is renewed each time the average user SNRs change. We use the goodput and the system outage to characterize the system performance. The goodput γ in [b/s/Hz], where the over head for CSI feed back is included is defined as

$$\gamma = \tau \times \frac{\eta_{data}}{\eta_{data+\eta_{OH}}}, \quad (8)$$

Where τ is the throughput, η_{data} the number of OFDM symbols in the frame carrying the data and η_{OH} the number of symbols carrying the CSI. Moreover, the coverage performance of the algorithms was evaluated. Since we consider the coverage after scheduling, we define the system outage probability as the probability that the allocated user rates r_k are the lower than a reference rate R, where r_k is the average over p=20 frames. The system outage probability p_{out} is expressed as

$$p_{out} = \frac{\sum_{s=1}^{S} K_s}{K \times S} \quad (9)$$

Where K_s denotes the number of users in outage for the sample s and Sis the total number of samples,

$$K_S = Card\{K, (\tau_k) < R\}_s \quad (10)$$

If I is the total number of iterations during the simulations, S=I/p since the number of users in outage taken every p=20 frames. The achieved goodput was evaluated for the outage, the number of users was fixed to 20.

First, it can be observed from Fig.6 that the throughput achieved by the proposed algorithms is lower than BS-Max full and BS-Max, since these are optimized for the throughput only, while the proposed ones optimize also the outage. Fig.7 shows that the proposed algorithms achieve a much lower outage than HS-Max full and BS-Max full. Moreover Fig.6 shows that there is not clear difference between the time division based algorithms, MRP and MRPA, and the frequency-division based ones, MRFF and the MRFA. We can observe that, although MRP and MRFF are both fixed schemes, the throughput. This is because the time allocated to the BS-subframe is reduced with the fixed time division, thereby decreasing the overall throughput, where as with the frequency division, the BS-subframe occupies the half of the frame, thereby supporting a higher number of the direct users. However, Fig.7 shows that concerning outage, frequency division performs better than time division. This is explained in the same way: reducing time affects more the performance than reducing frequencies, since the time allocated to each subframe with MRP is only the half compared to MRFF, while a certain degree of frequency diversity can still achieved by allocating the third of the subchannels or 16 subcarriers. Thus, the frequency division algorithms MRFF and MRFA are better schemes than the time division ones, MRP and MRPA. However, with per frame HS activation made by MRAA, the throughput can be really increased. MRAA, the throughput among all the outage based algorithms, and even higher than Optimized Outage which assumes a full buffer. Concerning outage, MRAA achieves the second best performance among the proposed algorithms for R<0.3Mbps, and the best one for R $\geq$ 0.3Mbps. So MRAA achieves a good trade-off between throughput and outage, since it achieves the best throughput and the second outage performance.

Finally, the comparison between the proposed algorithms shows that the static time/frequency allocations are quite inefficient, especially for the throughput. This is due to the unused subframes, where no users are attached to the corresponding HS pairs. This result validates the fact that by introducing the HS activation with a little bit higher complexity, the performance can be much improved

CONCLUSION

This paper investigated the problem of resource allocation for relay-aided cellular system based on OFDMA. Algorithms for subchannel/time allocation for different frame structures such as time division or frequency division have been proposed. The proposed algorithms are designed in such a way that the required signaling information is minimized compared to optimal solution. The simulation results show that they achieved a very good trade-off between outage and throughput compared to reference algorithm, especially the adaptive algorithms such as MRFA and MRAA algorithm which made use of the proposed adaptive HS activation. As an extension of this work, other algorithms are being designed in order to approach even more the performance bounds.

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