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New strategy for resource allocation using PSO-PFS hybrid

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Abstract: In this article, we study the problem of resource allocation in a tri-sectoral cell in order to have an equal distribution of resources among users taking into account the OFDM transmission technique that has evolved in future wireless networks LTE and 5G. We propose a new strategy for resource allocation schemes able to help the users with a critical position thanks to hybridization PSO-PFS (Particle Swarm Optimization). In addition, PFS (Proportional Fair Scheduling) it take into consideration the channel state conditions of the users and the PSO algorithm provides an optimal solution to the allocation problem and improves the performances of users according to their stat. The simulation results show that the allocation of resources by the PSO-PFS hybrid algorithm guarantee a high throughput of the system by ensuring fairness between users.

Keywords: Resource Allocation; 5G; Tri-sectoral Cell; PSO-PFS; Throughput; Fairness.

1. Introduction

Ensuring a real quality of service QoS in mobile multimedia transmissions is an important challenge. One of the major features of wireless networks are subject to many channel impairments (pathloss, shadowfading, multipath fading) [1]. These phenomena severely affect the quality of service in terms of delays or packet loss, in this case the users can not benefit from the same transmission capacity. Therefore at some point a radio resource may be of good quality for one user as it may be bad for another. In this context, in

recent years, researchers have paid considerable attention to the allocation of resources for digital communication networks. Among all the transmission techniques studied, Orthogonal Frequency Division Multiplexing OFDM has emerged widely for new generation transmission networks, LTE and 5G [2]. On the other hand, the OFDM is an access method that allows the bandwidth to be divided into several sub-frequency bands. In addition, each carrier has a low bandwidth in relation to the total bandwidth used, which leads to a high tolerance for multipath propagation problems. In [3], the authors provide

an equitable distribution of resources to fight against the impact of multipath propagation, but in return, the throughput of the system is reduced. The authors of [4] proposed a resource allocation based on orthogonal frequency division multiplexing (OFDMA), assuming a complete reuse of the frequency between macrocells and microcells.

Various works have generated great interest for new Scheduling and Optimization algorithms. In the first, the opportunistic Scheduling algorithms attribute a higher priority to users with better channel conditions [5]. The research in [6] evaluate different strategies of resource allocation from different schedulers and conclude that performance comprehensively depend upon channel imperfection. The inter-cellular scheduler algorithms control the resource allocation and allow intelligent distribution of the subcarriers in a cellular network. In [2] propose a new inter-cellular Bandwidth Fair Sharing Scheduler (IBFS) able to help the overloaded cells thanks to a dynamic cell bandwidth allocation in multi-user 5G wireless networks. FFRDIBFS is proposed by [7] which distribute the frequencies in the overloaded cells without destroying the QoS of the under-loaded cells, where the objective is to dynamically calculate the minimum bandwidth of an under-loaded cell. In the second, the major advantage of using the evolutionary algorithms is the maximum exploitation and exploration of the search space to find the global optimum solution or near global optimum solution. In [8] a genetic algorithm is proposed for improving efficient resource allocation Macrocell-femtocell, the proposed model encourages femtocell owners to share resources with public users. A dynamic optimization of resources based on the Particle Swarm Optimization algorithm (PSO) considering the fading channel, the change of channel state of the users and the relay stations in a macro-cellular [9] has been suggested to achieve better performance in terms of throughput and

equitability. The resource allocation based on PSO (Particle Swarm Optimization) and hybrid PSO-GA (Genetic Algorithm) [10] have been proposed to maximize the throughput of the two-pair D2D communication system of the whole macro cell.

Although the quality of service (QoS) of intracellular wireless networks has improved significantly, recently several studies have been proposed studying the sectoral spectrum allocation mechanism, which improves system performance. In [11] a new frequency reuse scheme is proposed, the sub-carriers are divided into two groups, in the central region of the sectors, and at the edge of the three sectors. A spectrum distribution into four sub-bands and allocating those to different sectors with six directional antennas macrocell to reduce interference has been studied in [12]; the results show that the utilizing six-sectors, the throughput of macrocells progressively increases. In [13] authors have proposed a sector offset configuration strategy for multi-carrier networks, the pattern offset is 60 degrees.

QoS cannot be guaranteed when the users are located in critical positions. The position of users has a direct relationship to channel conditions, and the constraint of induced path losses has an unequal spectral efficiency, typically for users in regions of sectoral overlap, causing cross-sectoral interference and a low SINR. However, for such a constraint implies an inequality in terms of throughput and fairness between different users. 5G systems should take over the design of techniques that effectively manage all spectral resources; in addition, these main objectives are to provide high throughput in the cell with low latency [14]. The opportunistic Scheduling favors users with better channel conditions and the major concern for the scheduling discipline should be to maximize the total throughput for all users. In this context, to resolve this problem, the contributions of this paper are summarized as follows. First, we exploit frequencies in an opportunistic way, do not

make a 50/50 frequency distribution in each sector of the cell but adapt it according to the position of the users and their requests. Second, in order to overcome the limitation of the Scheduler Proportional Fair in terms of throughput, we propose a hybrid PSO-PFS that can improve the performance of PFS in a tri-sectoral cell, we present and explain the concept of resource allocation in a Tri-sectoral cell, which corresponds to the amount of radio resources that can be allocated while maintaining frequency reuse1.

The remainder of this work is organized as follows. System model is presented in section 2. Scheduling algorithm strategies are given in section 3. Section 4 presents the performance evaluation results of our proposed resource allocation schemes. Finally, in section 5, we outline the conclusion of this paper and future work.

2. System Model and Problem Description

2.1.Channel Model

We consider a tri-sectoral cell with a base station (BS) and K mobile stations (MS) uniformly distributed in the cell, An equal frequency distribution is applied, sharing a total number of N subcarriers in the cell (see figure.1).

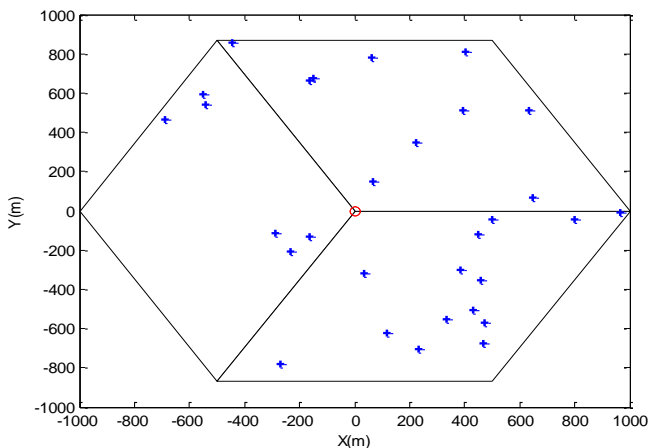


Figure 1 Location of the users in the cell.

In our scheme, we propose an allocation of resources according to the position of the users.

Note that in this way users with high interference between sectors and at the ends of the cell will benefit from the same quality of service as users with high SINR. The signal to interference and noise ratio (SINR) of user k on subcarrier n at time t is given by:

$$SINR_{k,n}^s(t) = \frac{p_{k,n}^s G_{k,n}^s}{\left(\sum_{m=1}^M p_{m,n}^s G_{m,n}^s \right) + P_N} \quad (1)$$

where $p_{k,n}^s$ is the transmit power on the n^{th} subcarrier to k^{th} mobile in S sector, P_N is the noise power spectrum density Gaussian at each time slot, $p_{m,n}^s$ is the power for user k^{th} on the same subcarrier m^{th} , and $G_{k,n}^s$ is the channel gain, the users suffers from the Path loss, multipath fading and Shadow fading.

The overall channel gain is calculated as a sum of individual gains :

$$G_{k,n}^s(t) = G_A * G_P * |h_{k,n}(t)|^2 * G_S \quad (2)$$

The antenna gain of each BS sector is given by:

$$G_A = G_{\max} + G_{\varphi} + G_{\theta} \quad (3)$$

where $G_{\max} = 15\text{dBi}$ is the maximum antenna gain and we applying the two formulas below for horizontal and vertical radiation patterns respectively [15, 16] :

$$G_{\varphi} = -\min \left(12 \left(\frac{\varphi}{\alpha} \right)^2, A_m \right) \quad (4)$$

where φ ($-180^\circ \leq \varphi \leq 180^\circ$) is the azimuth angle, $\alpha = 65^\circ$ (3sectors) is horizontal halfpower beam-width, and $A_m = 30\text{dB}$ is the front-back attenuation.

$$G_{\theta} = -\min \left(12 \left(\frac{\theta}{\alpha} \right)^2, SLA_v \right) \quad (5)$$

where θ ($-15^\circ \leq \theta \leq 0^\circ$) is the tilt angle, and $\alpha = 10^\circ$ is vertical halfpower beam-width and $SLA_v = 10^\circ$ is side lobe attenuation.

The multipath fading channel $h_{k,n}(t)$ is modeled using Rayleigh fading, the channel is time-varying, this time variation due to the movement of the mobile or objects within the channel [17].

The propagation path loss $G_P = (d_0/d_k^s)^\alpha$ dependent on the $d_0 = 1Km$ is the reference distance, α is the path loss exponent, for the location of the user k in the sector s , we calculate the distance d_k^s is given by:

$$d_k^s = \sqrt{(x_s - x_k)^2 + (y_s - y_k)^2} \quad (6)$$

The shadow fading G_S are generated with log-normal distribution and the random variations in signal amplitude follow a Gaussian distribution with mean of zero and standard deviation of σ [18]. Sectors from the same base station site use the same shadow fading values [13].

The transmission rate of each k^{th} user terminal is calculated as from the SINR, is got by [17]:

$$r_{k,n}^s(t) = W \log_2(1 + SINR_{k,n}^s(t)) \quad (7)$$

On the other hand the achievable rate of the cell can be given by:

$$R_{k,n}^s(SINR_{k,n}^s) = \sum_{s=1}^3 \sum_{n=1}^N \rho_{k,n}^s r_{k,n}^s \quad (8)$$

where $SINR_{k,n}^s$ is the signal to interference plus noise ratio of users including the location of each user. $\rho_{k,n}^s = 1$; indicates that the subcarrier n^{th} is assigned to the user k^{th} ; else $\rho_{k,n}^s = 0$

2.2.Problem Description

In this section, we present a mathematical model that is used in this article. Compared to other proposed models, the optimization approach proposed has the advantages of simplicity, flexibility and high accuracy that can be applied to other scenarios. The proposed resource allocation scheme is formulated as follows:

$$C = \{b_1, b_2, \dots, b_N\}, \text{ where } b_n \in (1, K) \quad (9)$$

C as the matrix of the resource assigned to the b_n^{th} mobile in n^{th} subcarrier during a time interval according to PF Scheduling.

In this scenario the optimization problems can be formulated as follows, our objective is to maximize the utility of all users, is defined as follow

Problem:

$$\delta = \max_t u_t(C) \quad (10)$$

Obviously t is the index of time for different slot.

On the other hand, to achieve our goal, constraints are added to the optimization problem of proposed resource allocation schemes, two constraints, namely

- The total transmit power assigned to users must be less than or equal to maximum transmitted power allowed P_{\max} [19].

$$\sum_{n=1}^N p_{k,n}^s \leq P_{\max} \quad \forall k \in [1, K] \quad (11)$$

- In our system, the number of active users can change position and also the channel state conditions of the users change, all these factors are contained in the SINR.

The System Throughput performance of all users is defined as follows

$$ST = \frac{1}{T} \sum_{t=1}^T (k^*, gbest) \quad (12)$$

The System Fairness performance as a function of the number of users is defined as:

$$SF = - \sum_{k=1}^K C_k \frac{\log C_k}{\log K} \quad (13)$$

where C_k is the resources allocated to user k and the $\log K$ term is a normalized factor.

3. Resource Allocation Algorithm

Our contribution relies on the use of Hybridation PSO-PFS algorithm. We will give a preview on the scheduler Proportional Fair in section 3.1. After, the overview of the PSO Algorithm in section 3.2. In section 3.3 we develop the Hybridation PSO-PFS Based Resource allocation algorithm in detail.

3.1. PFS Algorithm

The Scheduling is currently hosted in the MAC layer are based on opportunistic resource allocation. First appearance was proposed in [20]. The scheduler must efficiently allocate available bandwidth resources provided by the physical layer to maximize system performance [21], in terms of throughput, fairness and delay. A mobile with a high SINR has a high priority, compared to users with a low SINR. Since PFS is based on variation in channel conditions mainly due to multipath fading, all mobiles get the same probability of access to resources across time [22]. As such, this algorithm offers a tradeoff between throughput and fairness [23].

However, its principle is based on a kind of feedback between the base station and the users to obtain an estimation of the channel state for each user and the instantaneous data rate in each subcarrier. The PF scheduler assigns each resource on the subcarrier n in (t) slots, and then it monitors the average throughput in each subcarrier at each Transmit Time Interval (TTI) in a window of length t_c [24, 25].

The objective function representing the PF Scheduling algorithm is

$$k^* = \arg \max \left(\frac{R_{k,n}^s(t)}{Th_{k,n}^s(t)} \right); k = 1, \dots, K \quad (14)$$

where $R_{k,n}^s(t)$ is the estimated instantaneous data rate $Th_{k,n}^s(t)$ the average throughput.

The updated for scheduling as in (15),

$$Th_{k,n}^s(t+1) = \begin{cases} \left(1 + \frac{1}{t_c}\right) Th_{k,n}^s(t) + \frac{1}{t_c} R_{k,n}^s(t); k = k^* \\ \left(1 + \frac{1}{t_c}\right) Th_{k,n}^s(t); k \neq k^* \end{cases} \quad (15)$$

3.2. Overview of PSO Algorithm

A Particle Swarm Optimization algorithm is a stochastic optimization technique, based on the population, was proposed by Kennedy and Eberhart, inspired by behavior of bird flocking and fish schooling [26], looking for an optimal solution to the problem posed. Employing a whole of solutions potentials called Particles. Two factors characterize each particle its position and its velocity. Throughout successive iterations, each particle updates its position using its historical best position (pbest) in sight to reach the global best position (gbest) according to the following equations [27]:

$$V_j(ite\text{r}+1) = Z(W * V_j(ite\text{r}) + c_1 r_1 (lpbest_{par} - C_j(ite\text{r})) + c_2 r_2 (gbest_{par} - C_j(ite\text{r}))) \quad (16)$$

$$C_j(ite\text{r}+1) = C_j(ite\text{r}) + V_j(ite\text{r}+1) \quad (17)$$

where j is the number of particles. $ite\text{r}$ is the iteration number. Z is construction factor; w is inertia weight; c_1, c_2 are the coefficient acceleration; r_1, r_2 are random numbers uniformly distributed in the range $[0, 1]$.

The updating process is essentially based on three components. The first term $V_j^{ite\text{r}}$ is the particle

previous velocity; it serves as memory of the previous flight direction preventing particle from drastically changes of its direction. The second term $(c_1 * r_1 * (pbest(j) - C_j^{iter}))$ is personal experience of the particle also called cognitive component. The effect of this term is that particle is drawn back to its own best position, modeling its tendency to return to places that were most satisfying on the past. The third term $(c_2 * r_2 * (gbest - C_j^{iter}))$ represents the cooperation among particles, also named social component. The effect of this term is that each particle is also drawn towards the best position found by its neighbor [28].

3.3. Hybridation PFS-PSO-Based Resource Allocation Algorithm

For the optimal allocation of resources, the base station collects mobile location information, if users in a cell sectoral are distributed in critiques locations with a low SINR cannot obtain a good quality of service. The idea in this paper, we propose a new resource allocation program in a tri-sectoral cell based on location of mobiles, channel conditions of users and their demands. This new program combines an evolutionary algorithm and the proportional fair scheduling. Hybridization between PSO and PFS provides a favorable sharing of resources for users in critical locations. However, the particle swarm optimization (PSO) policy is adapted to improve the performances of proportional fairness which is incorporated a set of constraints into the optimization problem.

The process of Resource Allocation scheme using Hybridation PSO and PFS algorithm operates as follows:

First, we generate the resource allocation matrix by using Algorithm 1 which is defined as the vector of j-th particle.

$$C_j = \{b_{j1}, b_{j2}, \dots, b_{jN}\}, j = 1, \dots, J. \quad (18)$$

Second, the velocity of j-th particles v_j is defined as the change of the particle positions.

Once the first population is generated, fitness evaluation is performed. The fitness function evaluation to be optimized used in the particle swarm optimization algorithm is the objective function given by Equation (10)

After updating the particles, the fitness function evaluate the new swarm is according as follows

$$f(C_j^{iter+1}) = \delta_j^{iter+1} \quad (19)$$

Update the pbest for each particle is calculated:

$$lpbest_j^{iter+1} = lpbest_j^{iter} + f, lpbest_j^{iter} \geq f(C_j^{iter}) \quad (20)$$

Update de gbest represent the maximal fitness:

$$gbest^{iter+1} = \max\{f(lpbest_j^{iter+1})\} \quad (21)$$

Algorithm 1 PF Scheduling

- 1: **for** user k=1 to K **do**
 - 2: Locating the position of the mobiles in the cell
 - 3: Generate different channel responses for each users, sub-carrier and time slot using (1)
 - 4: **for** slot t=1 to T **do**
 - 5: **for** carrier n=1 to N **do**
 - 6: Storing in a matrix, different values of rate, for each user, sub-carrier and time slot using (7)
 - 7: **end for**
 - 8: **end for**
 - 9: **end for**
 - 10: Initialize average throughput for all users
 - 11: k=1: users
 - 12: **for** slot t=1 to T **do**
 - 13: **for** carrier n=1 to N **do**
 - 14: Generate matrix PFS using (14)
 - 15: Updated for scheduling using (15)
 - 16: **end for**
 - 17: **end for**
-

The proposed solution of the resource allocation using the Hybridation PSO-PFS is described in Algorithm 2. The swarm size is a dependent problem and generally kept in between 20 and 50 [29]. The positions and velocities of particles are updated until the number of iteration is achieved; the maximum number of iteration is set to 100 according to the constraints posed. In this problem, the acceleration coefficients and construction factor are set to 1 and 0.7 respectively, at each iteration the inertia weight is calculated as follows

$$w = (\max_iterations - iter) / \max_iterations$$

Algorithm 2 RA- Hybrid PSO-PFS

- 1: Initialize max_iterations
 - 2: Initialize swarm and velocities
 - 3: Evaluate initial population, personal best position and global best position
 - 4: **Star iterations**
 - 5: **while** iter<max_iterations **do**
 - 6: iter=iter+1
 - 7: **for** each particle j **do**
 - 8: Generate PFS algorithm
 - 9: Calculate the fitness value according to (10)
 - 10: **end for**
 - 11: Update the velocity V_j^{iter} using (16)
 - 12: Update particle position using (17)
 - 13: Update the best local position and global best for each particle according to the fitness value
 - 14: **end while**
 - 15: Output gbest
 - 16: Compute the system performances for each users using (12, 13)
-

4. Simulation and Results

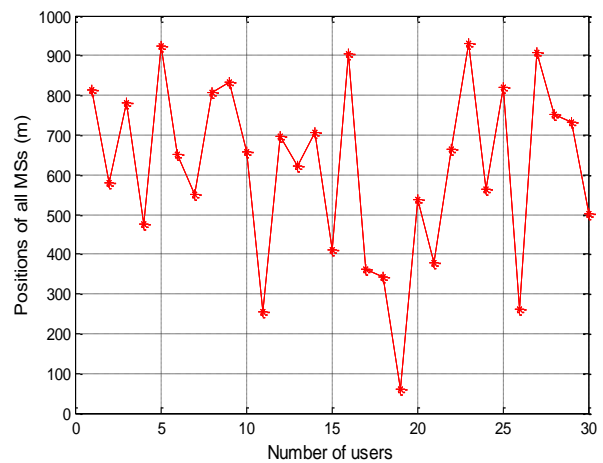
In this section, we present the evaluation of the proposed algorithms. The system-level parameters are summarized in table 1; we have designed a simulation area of 1km×1km. We assume three types of services, video, voice and transmit data. Furthermore, the approach studied must satisfy a high quality of service, namely a very high throughput, fairness between users and delay

constraint. However, a comparison between the proposed schemes is analyzed.

Table 1: Simulation parameters

Parameters	Values
Channel Bandwidth	20MHz
Carrier Frequency	2.4Ghz
Number of subcarrier	1200
Grid layout	1 cell hexagonal
Cell radius	1 km
BS Transmitter Power	43 dBm
Slot duration	0.5ms
Subcarrier Modulation	16QAM
Number of users	30
Swarm size of PSO	50

Figure 2: Positions of all users in the cell



In a tri-sectoral 5G cell, for each sector the users can have different throughput. In this scenario, at the cell level the reuse of frequency 1 is applied, the users are uniformly distributed as well as the service type; Figure 2 shows the position of each user in the cell. In addition, users with critical positions suffer interference and cause high delays and user’s dissatisfaction. In this context, the PFS algorithm takes into consideration the users channel conditions and the PSO is a tool to solve the allocation problem. Figure 3 illustrates the utility of all users and the convergence of the PSO for a number of iterations is 100, this confirms that the PSO is an algorithm capable of solving the

allocation problem and improving the scheduler performance.

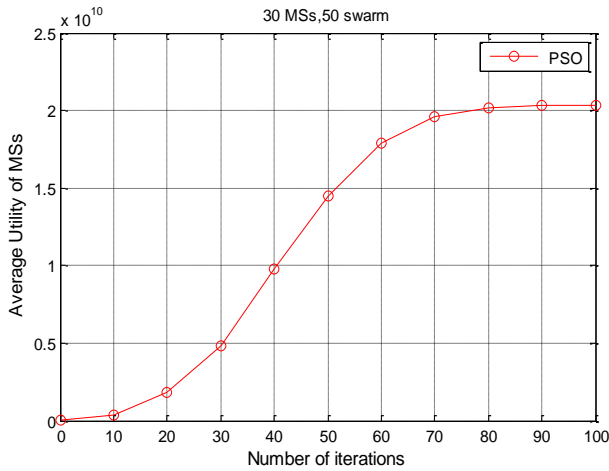


Figure 3: Convergence of PSO iterative algorithm

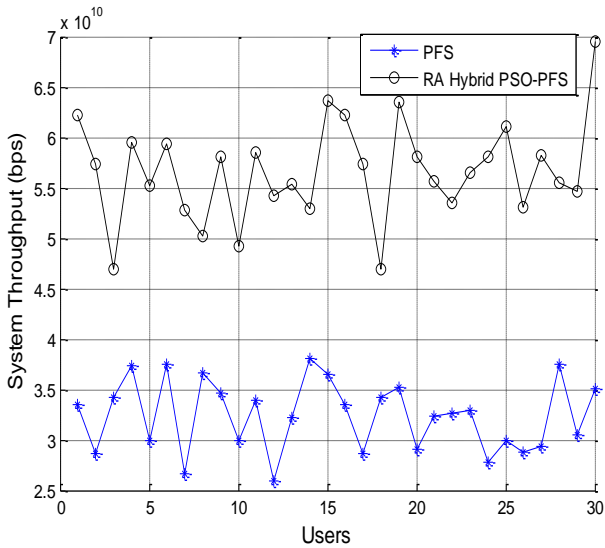


Figure 4: Throughput performance

We had a look at the resource allocation for each user taking into account their channel conditions using the PFS algorithm and the resource allocation with PSO-PFS hybridization, as we can see in Figure 4, a random flow distribution is made taking into consideration the user's position and channel status of each user, the throughput performance of the RA hybrid PSO-PFS is higher than that of the PFS, due to the particularity of the

PSO algorithm, which makes maximum use of the research space, which allows convergence and achieves higher system throughput.

Figure 5 shows the Fairness performance as a function of the number of users. As it can be seen that the equity index is between 0.9 and 1, it is shown that the allocation by hybrid PSO-PFS ensures fairness between the users.

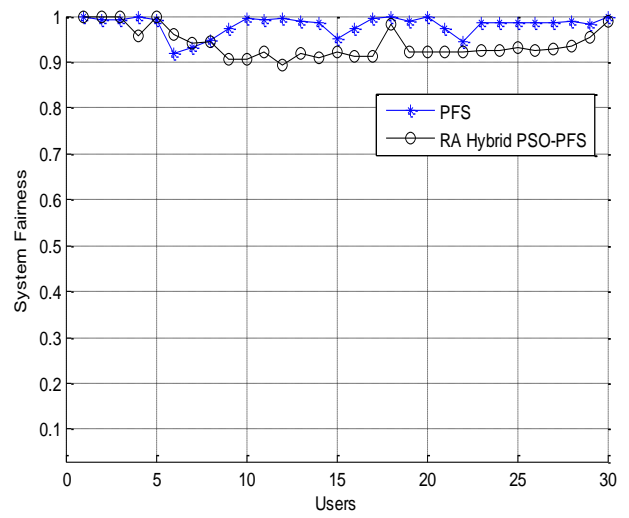
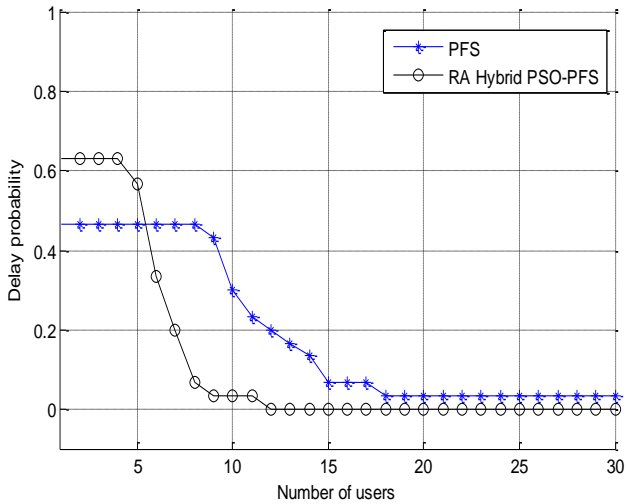
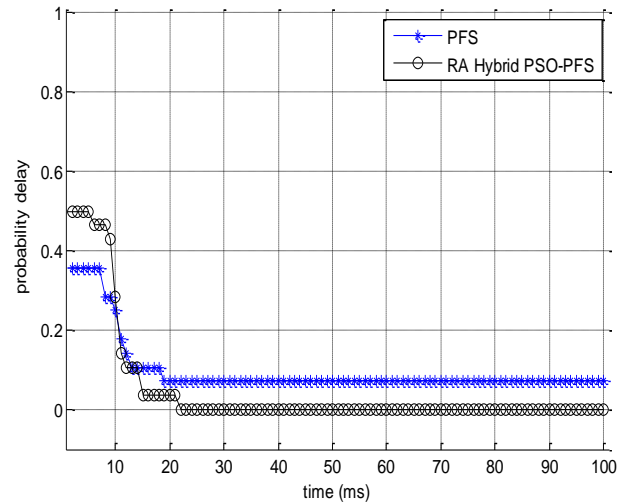


Figure 5: Fairness performance

Concerning the delay constraint, if we compare the two proposed schemes, the simulation results give us an approximation of the number of users that can be served; namely, the larger the number of users in the cell, the delay constraint is important, in that case, with zero delay probability the hybrid PSO-PFS algorithm can serve 60% compared with the PFS which is 40% (see figure 6 (a)), as we can also see in the figure 6 (b) the PSO-PFS hybrid algorithm reaches zero probability faster thanks to its convergence towards the optimal solution, which allows it to transmit more resources in each timeslot, and they are sufficient to satisfy the needs of all users with different types of service and according to their position.



(a) Probability delay as a function of the numbers of users



(b) Probability delay as a function of the time

Figure 6: Delay constraint

5. Conclusion

In this work, we proposed an optimization approach to solve the resource allocation problem in sectoral cellular networks (4G and 5G system) whose objective is to maximize throughput and ensure users satisfaction. First, we introduced a mathematical model studying the state of channel conditions of each user position. Then, the proposed approach was optimized using the PSO-PFS hybrid algorithm, the evolutionary particle-based PSO is adapted to make maximum use of the research space. In addition, our proposed scheme revealed an improvement in the quality of service. Finally, the performance evaluation of the studied system confirms that the PSO-PFS hybridization approach allows a high throughput for all users by ensuring fairness while respecting constraints. However, resource allocation through hybridization could be extended to other approaches such as ensuring a high quality of service for loaded sectors.

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