Performance Evaluation of Opportunistic Schedulers based on Fairness and Throughput in New Generation Mobile Networks

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Performance Evaluation of Opportunistic Schedulers based on Fairness and Throughput in New Generation Mobile Networks

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Abstract

This paper is focused on the study of the allocation of radio resources using the scheduling and opportunistic techniques. This allows us to compare the quality of service afforded to each user when the types of traffic transmitted are highly heterogeneous and efficiently evaluate the performance of resource allocation algorithms and schedulers. Many scheduling algorithms are used for resource allocation and scheduling: Round Robin, MaxSNR and PF. The main objective of this research work is to analyze and develop the main performances relating to schedulers deployed by telecommunication operators. It should be noted that scheduling is a primodridial phase preceding the phase of allocation and allocation of radio resources in a mobile radio telecommunications system. We will focus in this paper on the major advantages and the contribution of opportunistic scheduling techniques in conjunction with classical approaches. This will further enable us to present recommendations allowing a notable gain in terms of resources for telecommunication opera- tors for evaluation and improvement performances based on throughput and fairness.

Keywords: Scheduling; Opportunistic, Fairness; Throughput, Performance Evaluation, Wirelesss Networks

1 Introduction

Previous years have witnessed a great development in the field of communica tion and multimedia. The number of subcarriers in the communication system has increased and the demand for a higher rate still persists. Indeed, the challenge of the telecommunications sector is firstly, to ensure a good sharing of radio resources and secondly, to guarantee the best quality of service (QoS). Furthermore, Orthogonal Frequency Division Multiple Access (OFDMA) has appeared as the best auspicious physical layer technique for new generation wireless networks. OFDMA is widely implemented in most recent wireless systems like 802.11a/g or 802.16 and has clearly emerged for future broadband wireless multimedia networks. However, This access technique must be married with algorithms to enhance the resources allocation process. These algorithms are called schedulers. The scheduler, considered as a main component in communications systems, is used to allocate the resource units (RU) to all active users in a cell. The main goal of the scheduler is not only to optimize spectral efficiency in order to maximize the overall system throughput but also to ensure fairness and service differentiation between different users in order to guarantee the best QoS. Several mobile radio communication networks deploy resource management, sharing and scheduling opportunistics techniques. Next generation 4G and 5G networks are promising examples and consequently opportunistic networks are born [25], [28]. Several scheduling techniques with different levels of complexity are present in the literature [26], [29], [33], [34], [36], [37], [38], [39], [40], [41], [42], [43], [44].

Similarly, opportunistic scheduling techniques have been deployed in telecommunication networks in general and in computer networks in particular to optimize and saving energy [30], [31], [32].

The growth of wireless technology has made opportunistic scheduling a widespread theme in recent research. Providing high system throughput without reducing fairness. allocation is becoming a very challenging task. A suitable policy for resources allocation among users is of a crucial importance. The main objective of this research paper is to analyze and implement opportunistic scheduling techniques on new generation networks. We approached the problem by analyzing the performances and characteristics of the schedulers. In view of the large number of proposed schedulers, the first problem is to try to compare them to classify. However, we see later that usual measurement systems are in adequate to judge correctly on the same level playing field. Several works have been carried out on scheduling in computer networks. The same work has been applied to scheduling strategies in new generation mobile networks. Indeed, these scheduling techniques are applied in computer and telecommunication networks in order to schedule resources before they are used by the network users [27].

We also study and develop the impact of scheduling algorithms on the throughput and fairness. To achieve these objectives, many scheduling algorithms have been considered: Round Robin (RR), MaxSNR and Proportional Fair (PF).

2 Schedulers Classifcation

Many types of resources allocation algorithms (schedulers) exists. These types will be classified into three categories . The following figure illustrate this classification :

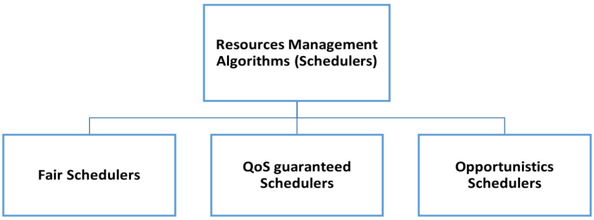

Fig. 1 Schedulers classification graph

2.1 Fair schedulers

Several research were carried out in order to propose more effective schedulers. This range of schedulers makes it possible to significantly improve fairness.

2.1.1 Round Robin algorithm (RR)

Round Robin (RR) is one of the simplest and most commonly used scheduler [1,2]. With RR, backlogged flows are served in sequence, one packet at a time. RR algorithm consists of allocating the same quantity of RUs to all active users, one after the other. Each user in a cell will have all the subcarriers during a time slot. Each user is therefore sure not only to have the same number of the RUs but also to reach the medium regularly which allows making this allocation strategy fair (the level 1 fairness hierarchy). However, RR has several weaknesses :

- The distance from the BS : the transmission capacity of a user close to BS is not the same as that away from it (path loss). Thus, RR does not allow ensuring the same rate for all users (no the level 2 fairness hierarchy).
- Services differentiation : even if the users are located at the same distance from the BS, they would not obtain an even throughput. This is due to the differentiation of the QoS constraints.

2.1.2 Fair Queuing (FQ)

With Fair Queuing (FQ) [1],[6],[7],[8] for a possible link of rate D, each active user K will be served at the height of D/K. Fair Queuing is fairer than the Round Robin since it ensures the same throughput for each user. The level 2 fairness hierarchy is, accordingly, reached here. However, taking into consideration the users needs is still neglected, MSs needing further throughput remain always penalized compared to the others. The QoS requirements are always far from being respected. Consequently, the level 3 fairness hierarchy is not achieved.

2.1.3 Max-Min Fair (MMF)

The principle of the Max-Min Fair allocation algorithm [9],[10] consists of as- signing the RUs in a repetitive way so that the rate offered to each user increases gradually and in an identical way. When a user receives the rate he asked for, no other RU is assigned to him and the execution of scheduling continues with other users. The execution of Max-Min Fair stops when all the users are satisfied or when all RUs are distributed. The result of such allocation is illustrated in Figure.2. This allocation is close to Fair Queuing and then it has the same specificities. Indeed, here, the MSs obtain equal throughput. Finally, the consumers with little needs are largely favored because their desired flow is practically always provided; they are consequently very often fully satisfied. On the other hand, the other users who require more share the remaining resources fairly which is often insufficient to satisfy them (note that in the case where all users would have the same needs, RR scheduling would be equivalent to MMF).

Some researchers consider that a QoS as that obtained with the max-Min Fair is satisfactory. However, we think that this vision, which is relevant at the beginning of the internet, is obsolete today. It is not certainly possible at the present time, where multimedia applications are increasingly profitable and are required by the public and the operators, to continue to satisfy primarily the users who ask little, pulling finally the QoS down. On the one hand, we think that it is not fair and on the other hand, we realize that it does not provide an effective use of the bandwidth. Indeed, granting to a user only a part of the rate that he asked for, generally leads to the impossibility of ensuring a QoS. Finally, we can add that the MMF is not opportunistic and if we always consider the three levels of fairness described in the introduction, only the level 2 fairness hierarchy is achieved.

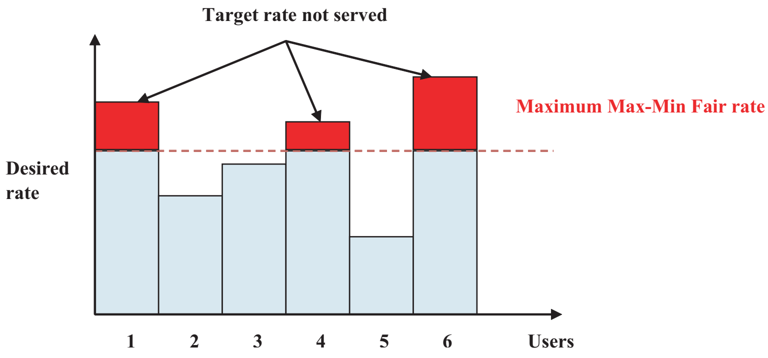

Fig. 2 Max-Min Fair allocation

2.2 QoS guaranteed schedulers

2.2.1 Weighted Round Robin (WRR)

In WRR [3, 4] queuing packets are first classified into various service classes and then assigned to a queue that is specifically dedicate to that service class. Each of the queues is serviced in a round robin order. Thus, the WRR has the ability to serve all classes of service, though it does not treat all the classes of services with the same manner. Furthermore, it provides fairness among all queues. However, the WRR is not opportunistic and the level 3 fairness hierarchy is partly reached here.

2.2.2 Deficit Round Robin (DRR)

Deficit Round Robin (DRR) [5] is a variation of RR. In DRR, each flow is assigned a quantum (Qi). The quantum is proportional to the flows weight.

The DRR scans all non empty queues in sequence. When a non empty queue is selected, its deficit counter is incremented by its quantum value. Then, the value of the deficit counter is a maximal amount of bytes that can be sent at this turn: if the deficit counter is greater than the packets size at the head of the queue, this packet can be sent and the value of the counter is decremented by the packet size. Then, the size of the next packet is compared to the counter value, etc. Once the queue is empty or the value of the counter is insufficient, the scheduler will skip to the next queue. If the queue is empty, the value of the deficit counter is reset to 0. Based on this policy, the DRR offers a minimal rate to each flow whatever the size of the packets is. However, the DRR is not opportunistic and the level 3 fairness hierarchy is partly reached here.

2.2.3 Weighted Fair Queuing (WFQ)

Weighted Fair Queuing (WFQ) [11],[12], is an improvement of the Fair Queuing (FQ) algorithm. This algorithm uses a system of weight which makes it possible to privilege certain flows by granting them more bandwidth. This strategy makes it possible to control QoS and to manage, even if it is only in a rudimentary way, the differentiation of services. However, the WEQ is not opportunistic and the level 3 fairness hierarchy is partly reached here.

2.2.4 Fair and Effective Queueing (FEQ)

In [13] the authors presented a management system of queue for the various types of traffic of the WiMAX network. The allocation of the bandwidth is achieved in two parts. During the first phase, the queues are served according to WRR algorithm. Indeed, the system allocates a bandwidth equal to Minimum Disastrous Reserved (MRR) for each type of traffic. The MRR relative to each type of traffic represents the weight of the corresponding file during phase 1. The more demanding the traffic is, the larger the value of MRR which corresponds to it, and the higher the weight of the queue. This policy supports the traffic having little tolerance compared to those having less requirements. Thus, the packets which are not served during phase 1, will be placed in the Earliest Deadline First system (EDF) queue to be treated during phase 2. During the second phase, the EDF is used (see Figure.3). FEQ allows reducing the packet loss rate by serving the packets having a waiting time closest to the maximum tolerated time first. However, FEQ is not opportunistic and the level 3 fairness hierarchy is partly reached here.

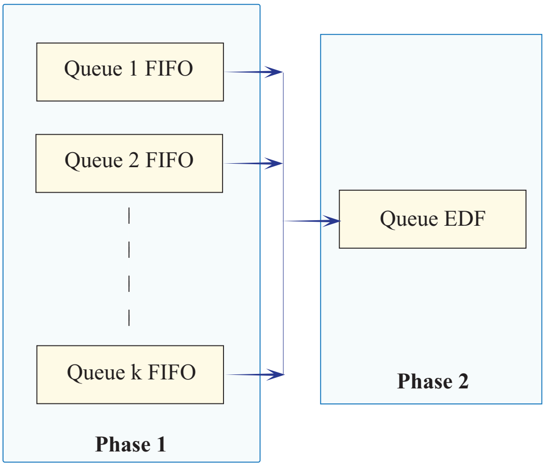

Fig. 3 Analytic model of FEQ algorithm

2.2.5 Channel-aware Qos Scheduling (CQ)

Another system of queue management has been proposed in [15]. This algorithm ensures the scheduling of the *rtPS*, *nrtPS* and BE traffics. Once the connection is accepted, the packets will be classified according to their type in the corresponding queue. Management of the three queues affected by the scheduling system is done through the WFQ algorithm. Moreover, selecting a packet to serve it takes into consideration the value of its Virtual Start Service Time (Si) and its Virtual Finish Service Time (Fi) (see Figure.4).

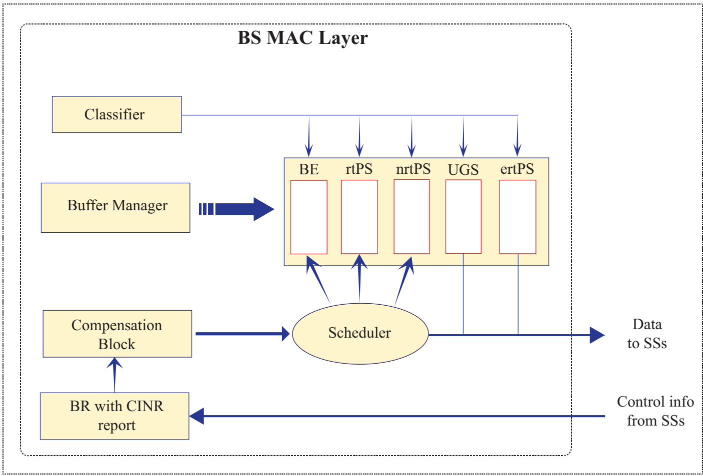

Fig. 4 Channel-aware Qos Scheduling algorithm

Channel-aware Qos Scheduling scheme is unfortunately non opportunistic and if we consider the three levels of fairness described in the introduction, the level 3 fairness hierarchy is partly reached here.

2.3 Opportunistic schedulers

The algorithms mentioned below are unable to get the best out of the bandwidth and offer a global system throughput very remote from the theoretical limits. Many studies have, therefore, sought to address this critical issue for current and future networks. They have concluded that an opportunistic approach is a paramount solution to achieve an optimal allocation of radio resources. Based on this idea, two classes of algorithms have emerged: the Maximum Signal-to-Noise Ratio (MaxSNR) and the Proportional Fair (PF). Taking advantage of frequency diversity and multiuser to allocate, mainly, resources that have the conditions of transmission/reception the most favorable (the best Signal/Noise), they maximize the flow rates of OFDMA networks.

2.3.1 Maximum Signal-to-Noise Ratio (MaxSNR)

Many high performance schedulers are derived from MaxSNR (also known as Maximum Carrier to Interference ratio (Max C/I)). With MaxSNR, priority is given to the active user that has the highest SNR (Signal-to-Noise Ratio

(SNR)) [16],[17]. If we denote by mk,n, the maximum number of bits that can be transmitted during a time interval of the subcarrier n if it is allocated to the user k, the MaxSNR allocation consists of allocating the R.U considered time interval, subcarrier n to the user j that has the highest $m_{k,n}$:

$$i = \text{argmax}_k \left(m_{(k,n)} \right), k = 1, .., K \tag{1}$$

Taking advantage of the multiuser and frequency diversity, MaxSNR scheduling constantly allocates the RU to the user who has the best spectral efficiency. By dynamically adjusting the modulation, it allows for an extremely efficient use of radio resources and getting closer to the Shannon capacity limit enabling it to greatly increase system throughput. What is worth being noted is that this allocation strategy has a negative impact: users close to the access point always have a disproportionate priority over distant users. Taking advantage of a lower path loss and therefore a greater SNR, nearby MSs will often be, if not always, selected before remote MSs which will be allocated only the remainder. Maximizing flow rate via MaxSNR accentuates the sys- tem unfairness. Figure 5 illustrates this phenomenon: in the green area MSs get access to radio resources and hence have their needs met. In the red zone, however MSs are penalized and are given the residual bandwidth when the priority area is served.

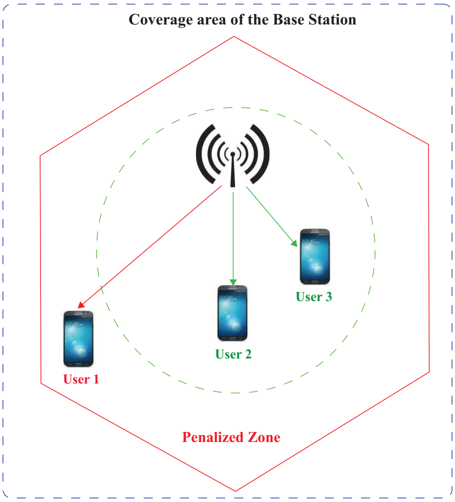

Fig. 5 Unfairness problem induced by the geographic location of users

2.3.2 Proportional Fair (PF)

Proportional Fair Scheduling has been proposed with the ability to incorporate some degree of fairness while keeping the benefits of MaxSNR in terms of throughput maximization. Because it is known in the scientific community for its simplicity and its excellent performance, much research focuses on this scheduler whether in the development of new algorithms based on the PF [18],[19] or in the study of their characteristics and performances. The principle of PF is to allocate a time interval of the subcarrier n to the user j which has the most favorable conditions for transmission in relation to its average throughput :

$$i = \text{argmax}_k \left(\frac{m_{(k,n)}}{M_{(k,n)}} \right), k = 1, .., K \tag{2}$$

Where $M_{k,n}$ is the mean value of $m_{k,n}$. Thanks to this allocation strategy, bad channels for each user are unlikely to be selected. On the other hand,the PF awards an equal share of bandwidth to all MSs, the same way like the Round Robin, along with a much higher throughput. The same amount of resource units are ,therefore, allocated to all users whatever their positions and such an fairness provided by PF is of the level 1, which is a real breakthrough against the MaxSNR.

2.3.3 Multimedia Adaptive OFDM Proportional Fair (MAOPF)

The Multimedia Adaptive OFDM Proportional Fair (MAOPF) [20] offers an interesting evolution of PF taking into account the amount of data transmitted/received by each stream in the allocation process. The principle is to allocate bandwidth between users in proportion to their desired throughput. The subcarrier n is then allocated, for the time interval, to the mobile j with:

$$i = \text{argmax}_k \left(\frac{m_{(k,n)} \times R_k}{M_{(k,n)}} \right), k = 1, .., K \tag{3}$$

Where R_k refers to the desired throughput by user k.

Due to this development, establishing a service differentiation according to the desired flow rate is now possible which allows the coexistence of different rates of applications. However QoS constraints (packet loss rate, maximum delay, etc.) are still not considered which consequently has made service differentiation incomplete. Because the problems of unfairness and different distances from the access point remain, the value of the improvement has been minimized.

2.3.4 Hybrid opportunistic algorithms

Many original methods allow achieving a more or less opportunistic allocation while allowing incorporating some degree of fairness in the network [21],[22],[23],[35] are two examples. They are trying to achieve a compromise between con- ventional and opportunistic allocation. The method consists of preselecting a subgroup of users in an opportunistic manner, depending on their radio con- ditions. The resource is allocated in Round Robin only between the mobile stations of the preselected subgroup. However, given the observed results, the preselection in subgroups leads to a sub-optimal allocation from the viewpoint of maximizing the overall throughput. The overall throughput achieved remains much lower than that provided by the MaxSNR or PF and the gain in terms of fairness is not significant. Opportunistic approaches and algorithms can be used for implementation and evaluation in routing protocols for wireless and new generation networks [24].

Research conducted in this thesis has focused on the opportunistic problem. In fact, we will focus on RUs allocation algorithms where the main objective is not only to maximize the overall system throughput but also to ensure a high fairness.

3 Schedulers analyzing and performance evaluation

The first part of our research paper attempts to summarize the level of performance of the best known schedulers in terms of throughput maximization, fairness contribution and service differentiation. The first criterion is essential to successfully accept the users in the network while the second and third are necessary to guarantee QoS. In Table.1, we present the analyzed algorithms classified into families by taking into account its common characteristics.

Table 1 Classification of algorithms by families

Algorithme	References	Family
RR	[1,2]	Fairness Based
WRR	[3,4]	QoS Guaranteed
DRR	[5]	QoS Guaranteed
FQ	[6,1,7,8]	Fairness Based
MMF	[9,10]	Fairness Based
WFQ	[11,12]	QoS Guaranteed
FEQ	[13]	QoS Guaranteed
PBF	[14]	QoS Guaranteed
CQ	[15]	QoS Guaranteed
MaxSNR	[16,17]	Opportunistic
PF	[18,19]	Opportunistic
MAOPF	[20]	Opportunistic

In order to better evaluate the schedulers, the system throughput and the level 3 fairness hierarchy are scored from lowest to highest [23] :

- For throughput, the lowest indicates that the scheduler do not ensure a throughput maximization and highest represents the maximum attainable objective which is desirable to reach,

- For level 3 fairness hierarchy, lowest indicates that there is no service differentiation, important indicates that the scheduler ensures a service differentiation according to the context and highest indicates that the scheduler ensures an equal satisfaction among users regardless of the context.

In Table 2, we can appreciate the main characteristics shown by the most important schedulers analyzed. In this table, the main evaluation criterion is based on:

- Channel conditions,
- Buffer occupancy,
- Throughput maxizimation
- Fairness.

Table 2 Comparison between different Algorithms

Algorithms	C.Conditions	B.Occupancy	T.Max	Fairness Level 1	Level 2	Level 3
RR	-	-	-	$\surd$	-	-
WRR	-	-	-	-	-	Low
DRR	-	-	-	-	-	Important
FQ	-	-	-	-	-	-
WFQ	-	-	-	-	-	Important
MMF	-	-	-	-	$\surd$	-
FEQ	-	-	-	-	-	Important
PBF	-	-	-	-	-	Important
CQ	-	-	-	-	-	Important
PF	$\surd$	-	High	$\surd$	-	-
MaxSNR	$\surd$	-	Highest	-	-	-
MAOPF	$\surd$	-	High	-	$\surd$	-

4 System modeling

4.1 AWGN model

It is initially considered that the channel used is a AWGN (Additif White Gaussian Noise) type. The received signal results from the addition of transmitted signal and from the White Gaussian Noise. This noise models in the simplest possible way all the noises which disturb the signal coming from the transmission. The global noise is entirely characterized by its variance considered as the sum of the variances of the different noises assumed to be all Gaussian and independent. For decision making, the decision variable Y is given by:

$$Y = r = e + n \tag{4}$$

Where e corresponds to the useful signal and n is a noise variable following a Gaussian distribution, with zero mean and σ^2. Thus, the decision variable Y

follows a normal distribution, of variance σ^2 and of mean $m_Y = e$ depending on the emitted bit $i = 0$ or $i = 1$. Figure 6 represents the channel modeling principle:

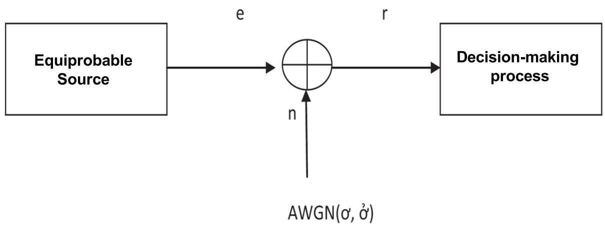

Fig. 6 AWGN channel Modeling

5 Resource block allocation deploying scheduling approach

In our research, we have focused on resource allocation in a single cell downward path. Access points therefore have packets to deliver to users located in their coverage area. Then we define a Resource Block (RB) as a grid of time-frequency resources. Each resource block can be allocated, according to the criteria of the system scheduler, to one of the mobiles belonging to the coverage area of the access point.

Therefore the scheduler has perfect knowledge of the link states. For this, the attenuation undergone on each channel and for each mobile is estimated by the access point from measurements relating to SNR (Signal to Noise Ratio). In addition, we consider that the transmissions on different BRs by different mobiles undergo independent link state variations as a function of time.

5.1 Description of the model

In this research, we consider a downlink transmission of an OFDM multiuser system. We assume that the overall bandwidth B is divided into N orthogonal narrowband subcarriers. Each user measures the channel gain of each subcarrier and feeds back channel status information to the base station (BS) via a separate return channel.

The simulation parameters are shown in the table below. In order to analyze the resource block allocation process, we opted for numerical simulation based on the implementation of the most widely answered schedulers in the literature, namely Round Robin (RR), MaxSNR and Proportional Fair (PF).

5.2 Simulation results

According to the obtained numerical simulation results, we can see in Figure.7 that all users have the same channel response. The RR algorithm assigns the

Table 3 Simulation parameters related to the study of RB attribution

Parameters	Value
Number of Base Station	1
Frequency	2.4 GHz
Number of time slot	4
Users number	6
Number of subcarriers	4

RBs to the users one after the other in each timeslot. The scheduler does not taking advantage of multiuser diversity, an unusable portion of the bandwidth is saved regardless of the traffic load. Indeed, RR does not take into account the CSI (Channel State Information) during the allocation of resources, it performs regularly and constantly bad allocations of resource blocks.

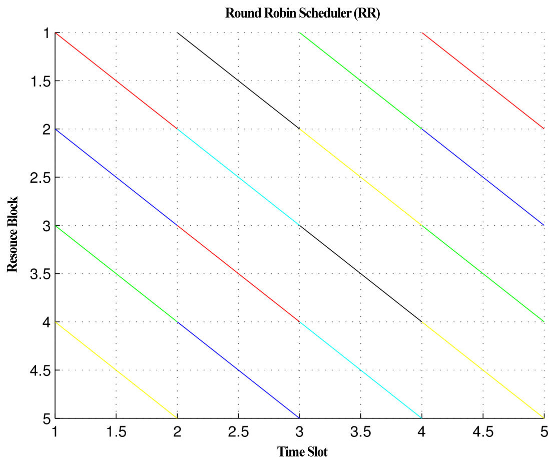

Fig. 7 Resource Block (RB) allocation using Round Robin algorithm

In Figure.8, the MaxSNR algorithm is considered to be the scheduler responsible for the allocation of resource blocks. It should be noted that MaxSNR does not maintain the policy of fairness since it allocates RBs to users according to the flow requirements and the signal to noise ratio (SNR). MaxSNR scheduler allocates RBs to users close to the Base Station as long as these users admit the best SNR. This algorithm will only serve distant mobiles once all nearby mobiles are fully served and inactive. In doing so, it all turns out as if the MaxSNR is constantly benefiting from only part of the multiuser diversity. When the users do not have the same channel response, one can notice the difference between MaxSNR and PF in terms of resource allocation to users. We can see in Figure.9, that equity is well considered. There is no dominant (strong) user like the case of user 6 (red) in the case of the MaxSNR scheduler.

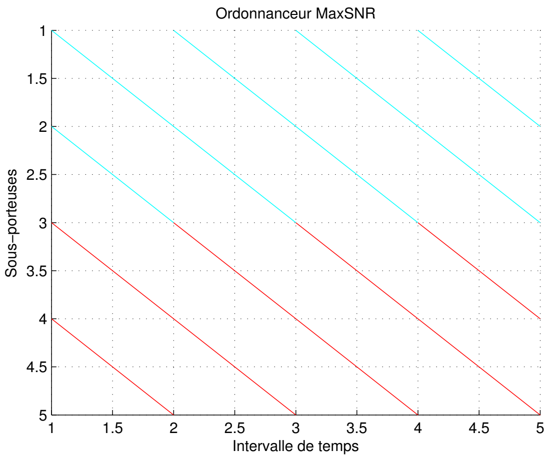

Fig. 8 Resource Block (RB) allocation using MaxSNR scheduler

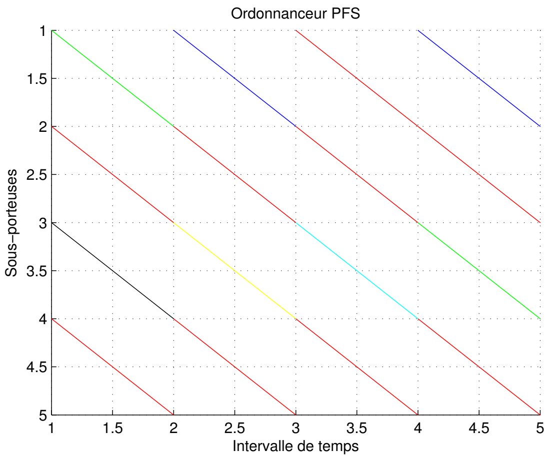

Fig. 9 Resource Block (RB) allocation using Proportional Fair (PF) scheduler

6 Relative study on Fairness

Our research now focuses on the ability of the scheduler to ensure fairness. Being fair is to ensure that all flow the same level of quality service and in particular the same percentage of packets to different traffic loads with particular attention to the difference in treatment between mobile located at a different distance from the base station (BS).

6.1 Model Description

In the simulations, we consider an OFDM system operating on a carrier frequency of 2.4 GHz. To evaluate the fairness we simulate different numbers of users. We assume that users have the same data to be transmitted. Each subcarrier is assigned to each user in three scenarios using three different algorithms, RR, PF and MaxSNR.

Table 3 shows the simulation parameters related to the case study.

Table 4 Simulation parameters related to the study of fairness

Parameters	Scenario A	Scenario B	Scenario C
Number of Base Station	1	1	1
Number of subcarriers	8	5	16
Number of time slot	16	50	100
Users number	4	5	16

6.2 Experiment validation of Scheduling Algorithms

We can see from numerical simulation results (see Figure 10) that the classic Round Robin scheduler performs very poorly and is unable to provide the same QoS to different groups of mobiles. Indeed, the RR allocates the RBs to the mobiles equitably but never takes into consideration the fact that the mobiles furthest from the access point have a much lower spectral efficiency than the closest mobiles. This results in an inequality in the instantaneous speeds provided and therefore an inequity in terms of QoS. In addition, the RR does not take advantage of multiuser diversity which results in underutilization of bandwidth and very low overall system throughput.

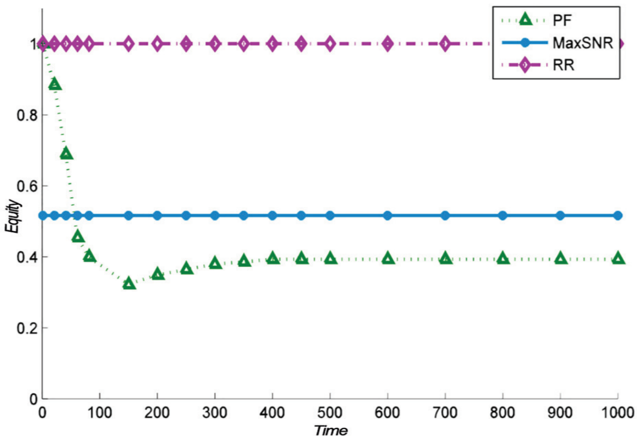

Fig. 10 Fairness assessment (Scenario A)

The MaxSNR scheduler is not a fair scheduler, it allocates system resources to the users who have the best signal-to-noise ratio, so the results obtained by this scheduler are almost identical. The more demanding users become in terms of service, the more the equity decrement, this is because MaxSNR often serves the strongest users. The simulation results in Figure 11 confirm that the MaxSNR is not fair. It guarantees a high level of QoS and satisfaction to mobiles close to the base station and penalizes distant users.

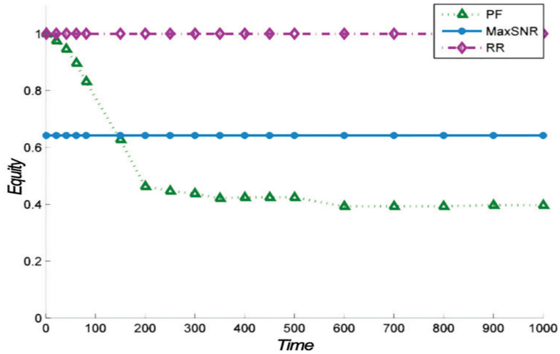

Fig. 11 Fairness assessment (Scenario B)

The Proportional Fair scheduler considered to be the most equitable, favors and gives priority to remote mobiles, by providing each with the same number of resource blocks. However, this process remains suboptimal since distant mobiles do not have the same spectral efficiency as the closest mobiles. Despite an equal sharing of the bandwidth between the mobiles, different speeds are therefore obtained, inducing disparities in the packet transfer time and in the QoS levels. These same simulation results illustrated in Figure.12 show that increasing the level of fairness generally increases the level of the overall QoS of a system.

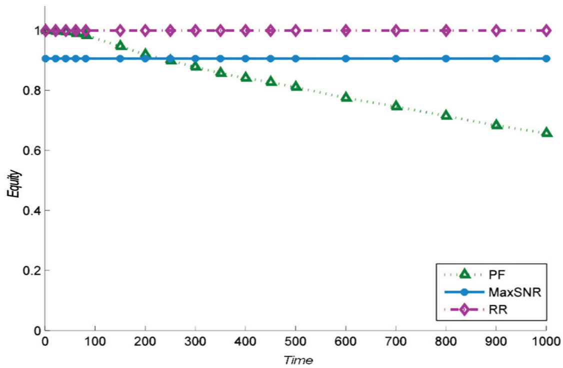

Fig. 12 Fairness assessment (Scenario C)

7 Experiment study related to throughput evaluation

In this section, we will discuss one of the most important properties of network system namely the flow. The flow is generally regarded as a framework to optimize system performance and a measure of the amount of information that can be transmitted and received per unit time. We evaluate three scheduling algorithms under three different scenarios at the end to find the best performance.

7.1 Model Description

The measures proposed rate is based on the proportion of resources allocated for different time intervals. In order to evaluate the throughput, we propose three different scenarios for three algorithms namely RR, MaxSNR and PF. In the simulations, a system is an OFDM system operating in a frequency band is 2.4GHz. We assume that users have the same data to be transmitted. Each resource block is assigned to a user for a specific timeslot.

Table 4 shows the simulation parameters considered.

Table 5 Setting scenarios: study on the flow

Parameters	Scenario A	Scenario B	Scenario C
Number of Base Station	1	1	1
Number of subcarriers	8	5	16
Number of time slot	16	50	100
Users number	4	5	16

7.2 Analysis and Simulation Results

The numerical simulation results presented in Figure 13, let appear that the capacity obtained by the MaxSNR scheduler reaches the highest value since the algorithm takes into account multiuser diversity and allocates the resource blocks to the users having the highest signal-to-noise ratio (SNR) at each time interval, regardless of channel condition and user requirements.

As usual and in the same context, the MaxSNR scheduler, depending on the system capacity, achieves the best result as it allocates to the users with the highest signal to noise ratios and it maximizes the overall system throughput. Consequently it penalizes the distant users of the base station, hence the importance of the obtained results confirmed by the Figure 14.

We can see in Figure 15 that the PF algorithm performs optimally as it achieves a fairly high level of system throughput without compromising fairness. In this case, users compete for resources that are not calculated based on their signal-to-noise ratios (SNR), but are normalized by their average rates.

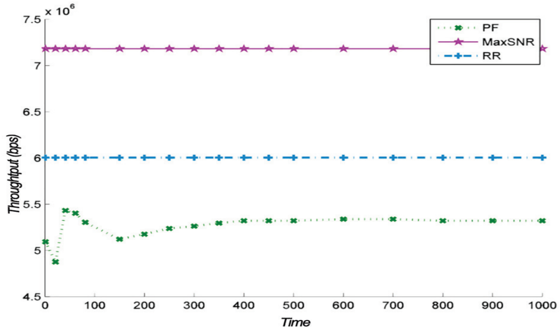

Fig. 13 Throughput variation over time (Scenario A)

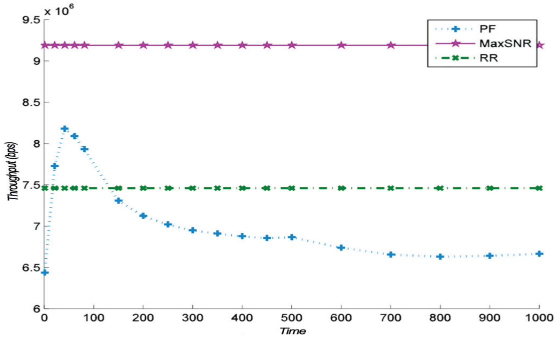

Fig. 14 Throughput variation over time (Scenario B)

In this case, PF exploits the fact that the propagation channel between the base station and the user are independent of each other, giving rise to multi-user diversity. Contrary to Round Robin, with opportunistic schedulers, we can observe an inflection of the characteristic of the evolution of the throughput when the load increases.

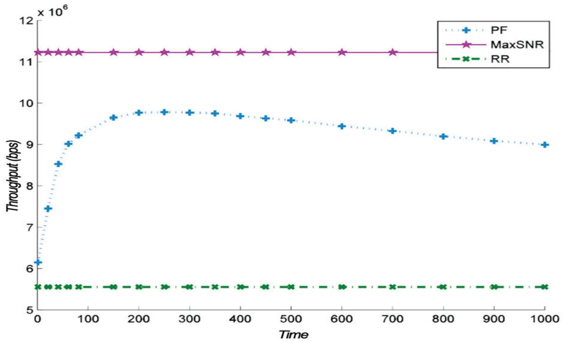

Fig. 15 Throughput variation over time (Scenario C)

8 Conclusion

Scheduling algorithms have been implemented on a downlink. The scheduler is a very important element of the base station. It allocates blocks of resources to different users. We studied three scheduling algorithms including: Round Robin, MaxSNR and PF. The Round Robin scheduling algorithm allocates resource blocks to the users, one after another. As its name suggests, the MaxSNR allocates resource blocks to the user who has the maximum SNR. PF can be considered as a compromise between speed and fairness.

A comparative analysis between these algorithms based on their rates for different scenarios (variation rate, number of users) was conducted. We can see that the rate is the highest MaxSNR. We observe that when the round robin scheduler is used, the speed is almost the same during the time interval and thus the Round Robin does not take into consideration the state of the channel. But we can see that the rate increases with the implementation of algorithms and opportunistic MaxSNR and PF.

Future work can be done in order to maximize throughput and promote fairness, we can improve the scheduling algorithms and PF and MaxSNR. The aim would be to propose a scheduler that can benefit the users involved in the proper functioning of the network and possibly penalize others. Wineskins its advantages in terms of maximizing throughput, fairness and service differentiation, another track is outstanding but worth exploring would be to study how to maker outing algorithms using opportunistic approach. With such systems, and after our initial research in this area, the heart rates in networks could be greatly increased.

Declarations

Some journals require declarations to be submitted in a standardised format. Please check the Instructions for Authors of the journal to which you are submitting to see if you need to complete this section. If yes, your manuscript must contain the following sections under the heading 'Declarations':

- Funding
- Conflict of interest/Competing interests (check journal-specific guidelines for which heading to use)
- Ethics approval
- Consent to participate
- Consent for publication
- Availability of data and materials
- Code availability
- Authors' contributions

"Not applicable" for that section.

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