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An optimized dynamic fair resource allocation technique in a femtocell

Andrew Ruitie Macharia[1*], Philip Kibet Lang'at [2] and Stephen Musyoki [3]

[1] *Department of Telecommunication Engineering, Jomo Kenyatta University of Agriculture and Technology (JKUAT), P.O. Box 62000-00200, Nairobi, Kenya.*

[2] *Department of Telecommunication Engineering, Jomo Kenyatta University of Agriculture and Technology (JKUAT), P.O. Box 62000-00200, Nairobi, Kenya.*

[3] *Technical University of Kenya (TUK), Department of Electrical and Electronics Engineering, P.O. Box 52428, Nairobi, Kenya.*

[*] *Corresponding Author - E-mail: armachajnr@gmail.com*

Abstract Mobile application usage has grown tremendously over the past few years. This is as a result of increased user tool applications that require multiple bit streams from the mobile providers. These applications therefore tend to make it necessary to look into ways of optimizing on the resources allocation to users in order to accommodate these increasing requests.

In this paper, two techniques that allocate resources to users based on their requests are analyzed. These are Global mobility prediction under the mobility aware algorithm and the proposed Combinational allocation of resources requests to users, in priority order of Signal to Interference plus noise ratio (SINR) values. The combinational scheme also incorporates fairness in resource allocation by considering the low-SINR valued users who have been left out and reallocating them a resource from the next low-SINR valued users to enable all users communicate in the femtocell. Examples of users who are positioned in groups of 4 inside a femtocell at 8 different time snapshots: A to H, are carried out using the two algorithms: Global mobility prediction and Combinational allocation scheme. They are simulated using MATLAB and plots done to determine the best SINR total groups for the combinational scheme and graphical plots drawn from the tabulated results.

The findings of the simulations done show that the combinational approach yields higher SINR totals and also ensures that all users are able to communicate due to the fairness consideration to the low SINR valued users. The combinational scheme also utilizes fairness in resource allocation by considering the low-SINR valued users who are reallocated a resource from the next users with the next low-SINR values. This ensures that all users who request for resources communicate in the femtocell. The global prediction on the other hand allocates resources in the sequence provided and hence results in some users being left out and also low SINR totals for users. Hence higher throughput is realized using the combinational allocation scheme.

Keywords Signal to interference plus noise ratio (SINR), Combinational allocation, Global mobility prediction

1. Introduction

Users mobile resource needs will always grow with modern trends of higher data usage. This has been due to upsurge in data that has come as a result of mobile phones having multiple applications for users [**1**]. This makes it necessary for improvement in methods of allocating users resources for several running applications hence requiring high levels of data streaming [**2**].

2. Comparison of the resources allocation schemes

2.1 Users' mobility awareness scheme

This is a centralized or distributed resource allocation algorithm with the following stages involved: Cluster formation, Cluster-head resource allocation with user mobility awareness [**3**].

The process entails clustering of users with the use of cluster head and cluster members. Resources are then distributed according to the users' mobility prediction models done in two major approaches: Global Prediction and Local Prediction [**3**]. This paper focuses on the Global Prediction scheme and the proposed combinational approach scheme.

2.2 Global mobility prediction algorithm

In this scheme, the users' previous movements are taken into account. The mobility prediction can be outlined in a sequence as shown in figure 1 [**3**].

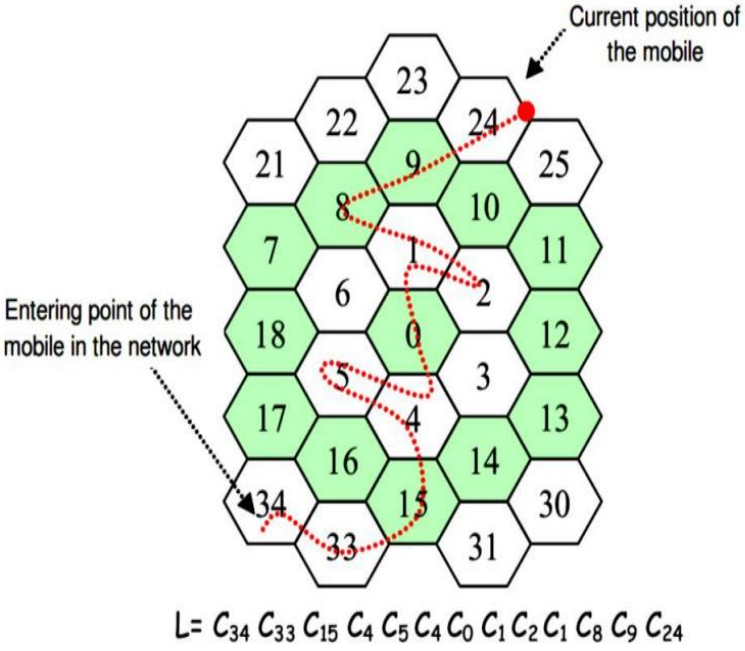

Fig. 1. User Mobility trace [**3**].

Figure 1 shows the movement of a user in a range of femtocells that is captured by the sequence L. The user enters a region at femtocell 34 and traverses through femtocells: 33, 15, 4, 5, 4, 0, 1, 2, 1, 8, 9 and finally stops in femtocell 24. This was described in [**3**]. According to this method, the sequence is then used in subsequent movements of the user to predict where he will move next.

The sequence is outlined in the formula below.

$$P_e = \frac{M(F_f, F_{f+1})}{N(F_{f-1}, F_f)} \quad (1)$$

given,

P_e is the Transition probability between previous and future traversed femtocells by a user.

$N(F_{f-1}F_f)$: is the number of the transitions of the previously visited to the current femtocell.

$M(F_fF_{f+1})$ is the number of the transitions from the current femtocell and the future femtocell that a user moves.

F_fF_{f+1} is the sequence of the current femtocell and the future femtocell to be visited.

M and N are the sequences of elements of variables determined by the users' movements in the femtocells [**3**].

The drawback with this approach is that the users' mobility prediction is usually not accurate at times hence low SINR value users can be allocated many resources hence lowering throughput.

In addition, the Global Mobility prediction does not take into account the users' application resource needs so as to determine which users require more resources than others. Therefore, the robustness of allocating resources for communication to a group of users within a range of femtocells is analysed per user in this paper.

2.3 Combinational approach algorithm

This paper seeks to present a technique that is instantaneous in terms of resource allocation for users in a femtocell. This technique is based on combinations and is expressed mathematically as shown below [**4**]

$$^{n}C_x = \frac{n!}{x!(n-x)!} \quad (2)$$

given that:

$^{n}C_x$ is the number of possible combinations 'n' items in a space of 'x'

n! is the factorial of n

x! is the factorial of x

(n-x)! is the factorial of (n-x).

This method is perceived to be advantageous in terms dynamism of checking for the users' resource requests and counter-checking with the available resources. Hyper geometric probability distribution is another selection scheme which does arrangement of values presented. The advantage that Combinations scheme has over the hyper geometric distribution is that combinations considers repetition of arrangement whereas the Hyper geometric considers only without repetition of arrangement [**5**]. This

is an upper hand in terms of considering the robustness of resource requests from users that may be repetitive over time [**5**].

The combination Orthogonal Frequency Division Multiple Access (OFDMA) technology supports multiple user data transmission to users. This is due to category based call admission control (CAC) techniques that enable user applications to simultaneously request for data from the femtocell [**5**]. Hence, users can request for multiple resources as a result. The combinational technique also checks for their SINR values then carries out combinations for all possible arrangement of users [**6**].

2.3.1 Channel Bandwidth.

Adaptive Modulation and Coding (AMC) scheme is used from the measurement reports [**7**]. The correlation with the number of resource blocks and maximum bandwidth is as shown in Table 1.

Table 1. LTE Transmission bandwidth configuration table [**8**]

Channel bandwidth in MHz	Max no of resource blocks that can be transmitted	Maximum occupied bandwidth (MHZ)
1.4	6	1.08
3	15	2.7
5	25	4.5
10	50	9
15	75	13.5
20	100	18

2.3.2 Bits per symbol of transmission.

The LTE transmission bandwidth scheme in table 1 is used together with the number of subscribers in the network. There are 3 modulation schemes used in LTE networks which are shown in Table 2 [**8**].

Table 2. LTE Modulation Schemes [**8**].

Modulation scheme	Bits per symbol transmitted
QPSK(4-QAM).	2 bits per symbol
16 QAM	4 bits per symbol
64 QAM	6 bits per symbol

2.3.3 Calculation of the SINR

The formula for a channel capacity is given by [**7**], [**9**] :

$$C = B\log_2(1 + SINR) \qquad (5)$$

where:

C = Capacity of the channel or throughput
B = Bandwidth of the channel
SINR = Signal to Interference-Noise Ratio

Therefore, SINR is given by:

$$SINR = 2^{[C/B]} - 1 \qquad (6)$$

From the individual users SINR values, the following flow chart gives the process through which users' groups are generated and the selection process selected through the process described in the flow chart shown in figure 2 [**7**].

The process shown in Figure 2 of allocating users has been presented in previous publications: [4] and [**7**]. In these presentations, the scheme was in development stage whereby, first, it considered that a user was only requesting for a single resource. This was presented in [4]. In the subsequent presentation, [**7**], a user could request more than one resource and the allocation would be done on the level of SINR for an individual request. This is also explained by Call admission control that is category based per applications as explained in [**5**].

This paper goes ahead to compare the throughput and the level of SINR values for all the users. This is done by evaluating different algorithms using the same user's requests for resources to communicate in the system.

3. Simulation comparison between combinational approach and global prediction scheme

A set of users are chosen in a given femtocell recorded at eight random intervals. Table 3 shows example random users with resources requests having SINR values for analysis of the two algorithms that have been mentioned.

Table 3. Summary of users' resource requests with corresponding SINR values

User	Resources Requests	SINR (dB)
1	3	8
2	2	10
3	4	6
4	5	2
5	3	9
6	2	7
7	4	3
8	3	4

Analysis can be done in comparison with the Global prediction technique with mobility awareness scheme. The Global prediction scheme uses the historical movements of a user to predict which movement he/she will make next [**10**]. The movement is illustrated in Figure 1. An example is used in this paper where users make sequence of movements through a femtocell taken at 8 different snapshot intervals whose available resources are shown in Table 4. The users' positions are also shown in Table 4.

Table 4. Summary of users present at the femtocell during trials A to H.

Intervals	Available resources	Users present in the Femtocell			
A	12	1	2	3	4
B	9	1	3	7	8
C	8	2	4	5	6
D	7	3	5	6	7
E	6	1	2	4	5
F	10	2	4	7	8
G	11	1	4	7	8
H	9	4	6	7	8

Comparison is therefore done between Combinational technique and Global mobility prediction scheme per interval in the femtocell to determine the best optimal technique to be used to allocate resources. In INTERVAL A, the sequence of the users would be as shown in table 5:

Table 5. Users' resource requests with corresponding SINR values during INTERVAL A

TIME INTERVAL A		
USER	REQUESTS	SINR (dB)
1	3	8
2	2	10
3	4	6
4	5	2
Available resources = 12, requested = 14		

When the combinational sequence is carried out, the allocation would be in the sequence shown in table 6. All the 4 users are allocated resources hence no fairness scheme is required.

For the global prediction scheme, the users are allocated in the sequence of requests which, in this case, coincidentally occurs in the same arrangement with the combinational algorithm.

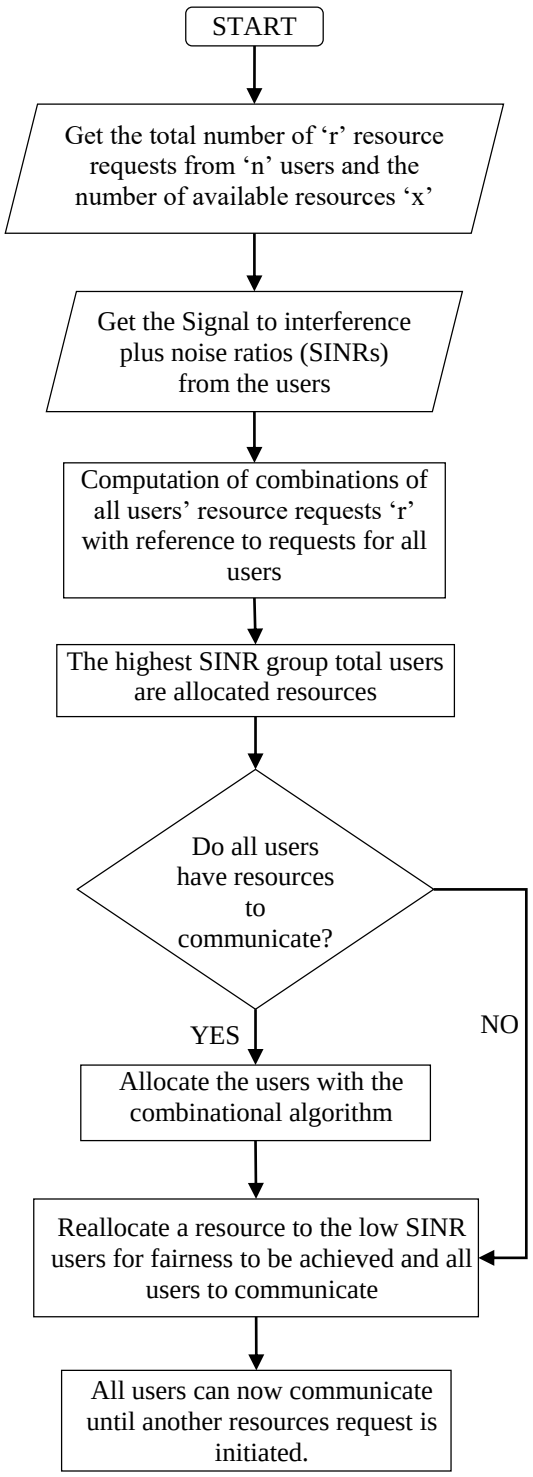

Fig. 2. Fairness resource allocation technique flow chart [**7**]

Table 6. Allocation sequence to users during INTERVAL A

Combinational sequence	1 1 1 2 2 3 3 3 3 4 4 4.
Global Prediction	1 1 1 2 2 3 3 3 3 4 4 4

The total SINR for both approaches is **74 dB.** In INTERVAL B, the sequence of the users' allocation would be as shown in Table 7.

Table 7. Users' resource requests with corresponding SINR values during INTERVAL B

TIME INTERVAL B		
USER	REQUESTS	SINR (dB)
1	3	8
3	4	6
7	4	3
8	3	4
Available resources = 9 , requested = 14		

In trial B, the users' requests are as shown in Table 7. These requests are then subjected to a combinational computation which the arrangement shown in Table 8.

Table 8. Allocation sequence to users during INTERVAL B.

Combinational sequence Without (fairness)	1 1 1 3 3 3 3 8 8 *SINR TOTAL = 56 dB*
Combinational sequence With (fairness)	1 1 1 3 3 3 3 8 7 SINR TOTAL = 55 dB
Global Prediction	1 1 1 3 3 3 3 7 7 SINR TOTAL = 54 dB

The combinations done during this trial first of all yields a sequence that leaves out user 7. For fairness to be achieved a check is done through the allocation and the next lowest user SINR is determined: User 8. A resource is then reallocated from user 8 to user 7. The SINR values are as indicated in table 8.

For the Global prediction scheme as described in [**10**], the allocation is done as per the prediction which is in the order of the requests provided. This therefore means the first 9 requests would be granted and the rest left out thus the sequence is as shown above. User 8 is left out of this sequence and the total SINR value is as indicated.

A third trial is done at time INTERVAL C. The requests are as indicated in Table 9.

Table 9. Users' resource requests with corresponding SINR values during INTERVAL C

TIME INTERVAL C		
USER	REQUESTS	SINR (dB)
2	2	10
4	5	2
5	3	9
6	2	7
Available resources = 8 , requested = 12		

The two computations: Combinations and Global prediction are carried out and they yield the results shown in Table 10.

Table 10. Allocation sequence to users during INTERVAL C

Combinational sequence	2 2 4 5 5 5 6 6 SINR TOTAL = 63 dB
Global Prediction	2 2 4 4 4 4 4 5 SINR TOTAL = 39 dB

From trial done during interval 10, it can be seen that the combinational approach first of all allocates all users resources compared to the Global prediction that only allocates 3 users and leaves out user 6. Secondly, the SINR total for the combinational sequence is higher than that of Global prediction which uses the sequence of the requests provided.

Another trial is done during INTERVAL D. In this trial, the users' requests are as shown in table 11.

Table 11. Users' resource requests with corresponding SINR values during INTERVAL D

TIME INTERVAL D		
USER	REQUESTS	SINR (dB)
3	4	6
5	3	9
6	2	7
7	4	3
Available resources = 7 , requested = 13		

The combinational algorithm and the global prediction sequences are done and tabulated as shown in Table 12.

Table 12. Allocation sequence to users during INTERVAL D

Combinational sequence Without (fairness)	3 3 5 5 5 6 6 *SINR TOTAL = 53 dB*
Combinational sequence With (fairness)	3 7 5 5 5 6 6 SINR TOTAL = 50 dB
Global Prediction	3 3 3 3 5 5 5 SINR TOTAL = 51 dB

From the yielded results in table 12, it can be seen that the SINR total for the Global prediction allocation is slightly higher than that of the combinational sequence. However, the numbers of users who are allocated resources are: 2 for Global prediction and 4 using the combinational approach. This is because the combinational sequence has fairness in distribution of resources and also tends to give to the high SINR users first. Thus, it allocates resources to all users as a result therefore achieving fairness whereby even the lowest SINR user is able to communicate. The Global prediction just allocates in the sequence of the prediction indicated earlier which in this case was coincidentally high but the resources get exhausted before all users can be allocated.

Furthermore, at INTERVAL E, another allocation trial is done in the femtocell. This is for the users in table 13 with their details provided.

Table 13. Users' resource requests with corresponding SINR values during INTERVAL E

TIME INTERVAL E		
USER	REQUESTS	SINR (dB)
1	3	8
2	2	10
4	5	2
5	3	9
Available resources = 6 , requested = 13		

Upon simulations of the two methods, the arrangement generated in shown in Table 14.

Table 14: Allocation sequence to users during INTERVAL E

Combinational sequence Without (fairness)	1 2 2 5 5 5 *SINR = 55 dB*
Combinational sequence With (fairness)	1 2 2 4 5 5 SINR = 48 dB
Global Prediction	1 1 1 2 2 4 SINR = 46 dB

From the results in table 14, the combinational sequence has high SINR allocation to users when allocating initially to 3 users. But due to the need for fairness, a resource is reallocated to user 4 who is a very low SINR user to make the SINR total 48 dB. This is still higher than that of Global prediction which allocates only 3 users but still the SINR total is 46 dB.

In addition, another sequence of allocation is done at INTERVAL F whereby, the users present at the femtocell are as shown in Table 15.

Table 15. Users' resource requests with corresponding SINR values during INTERVAL F.

TIME INTERVAL F		
USER	REQUESTS	SINR (dB)
2	2	10
4	5	2
7	4	3
8	3	4
Available resources = 10, requested = 14		

When the allocation is done, using the two techniques the following results yield the layout of users shown in Table 16.

Table 16. Allocation sequence to users during INTERVAL F

Combinational sequence	2 2 4 7 7 7 7 8 8 8 SINR TOTAL = 46 dB
Global Prediction	2 2 4 4 4 4 4 7 7 7 SINR TOTAL = 39 dB

From the results in table 16, it is found that the combinational approach allocates to all the 4 users. The Global prediction technique, which follows the sequence of request directly, allocates up to user 7, hence user 8 is left out and the SINR value is also lower.

In INTERVAL G test, the data shown in Table 17 is recorded from users.

Table 17. Users' resource requests with corresponding SINR values during INTERVAL G.

TIME INTERVAL G		
USER	REQUESTS	SINR (dB)
1	3	8
4	5	2
7	4	3
8	3	4
Available resources = 11 , requested = 15		

The data tabulated in table 17 is then subjected to the two algorithms to yield the allocation sequences as shown in Table 18.

Table 18: Allocation sequence to users during INTERVAL G

Combinational sequence	1 1 1 4 7 7 7 7 8 8 8 SINR TOTAL = 50 dB

Global Prediction	1 1 1 4 4 4 4 4 7 7 7 SINR TOTAL = 43 dB

From the results in table 18, it is seen again that the combinational sequence yields higher SINR upon allocation since it chooses the best SINR total group. Also it allocates to all 4 users requesting resources as compared to Global prediction which follows the sequence of request of prediction and leaves out user 8.

Finally, the last test is done at INTERVAL H. At this interval, the users' requests and details are mapped as outlined in Table 19.

Table 19: Users' resource requests with corresponding SINR values during INTERVAL H

TIME INTERVAL H		
USER	REQUESTS	SINR (dB)
4	5	2
6	2	7
7	4	3
8	3	4
Available resources = 9, requested = 14		

With the application of the two algorithms stated earlier, the data obtained is as shown in table 20.

Table 20: Allocation sequence to users during INTERVAL H.

Combinational sequence (Without fairness)	6 6 7 7 7 7 8 8 8 SINR TOTAL = 38 dB
Combinational sequence (With fairness)	6 6 4 7 7 7 8 8 8 SINR TOTAL = 37 dB
Global Prediction	4 4 4 4 4 6 6 7 7 SINR TOTAL = 30 dB

When the results for INTERVAL H are finally analysed, it is found out that for the combinational sequence, the initial allocation is done to 3 users with a SINR total of 38 dB. One user has been left out: user 4. Hence, one resource is reallocated from user 7 to user 4 to enable him to communicate. The total SINR is lowered by 1 dB and becomes 37 in this process to accommodate user 4. This ensures that all users communicate. But for the Global prediction, the sequence of allocation to users is done in view of initial prediction and hence the order is as given which gives a low SINR and leaves out user 8.

These findings are then recorded as shown in the Table 21 for analysis with fairness consideration and Table 22 for analysis without fairness consideration. These are meant to compare the SINR values and the allocation to users against the requests for each of the methods discussed: Combinational users resources allocation and Global prediction allocation.

Table 21. Summary of resources requests and allocation to users using Global prediction and Combinational approach with fairness.

TRIALS	Number of users who have requested for resources	Number of users allocated resources using the stated technique	
		Global prediction technique	Combinational technique (with fairness)
A(1)	4	4	4
B(2)	4	3	4
C(3)	4	3	4
D(4)	4	2	4
E(5)	4	3	4
F(6)	4	3	4
G(7)	4	3	4
H(8)	4	3	4

Table 22. Summary of resources requests and allocation to users using Global prediction and Combinational approach without fairness.

TRIALS	Number of users who have requested for resources	Number of users allocated resources using the stated technique	
		Global prediction technique	Combinational technique (without fairness)
A(1)	4	4	4
B(2)	4	3	3
C(3)	4	3	4
D(4)	4	2	3
E(5)	4	3	3
F(6)	4	3	4
G(7)	4	3	4
H(8)	4	3	3

Table 23: Summary of SINR total using Global prediction and Combinational approach with fairness.

TRIALS	SINR total values in dB	
	Global mobility prediction	Combinational Technique (with fairness)
A(1)	74	74
B(2)	54	55
C(3)	39	63
D(4)	51	50

E(5)	46	48
F(6)	39	46
G(7)	43	50
H(8)	30	37

The graph in Figure 3 shows the plot of users who are requesting for resources to communicate in the femtocell against the ones allocated using the two techniques.

The graph in Figure 4 compares the SINR levels achieved with the two mentioned resources allocation techniques.

The graph in Figure 5 compares the allocation to users with fairness consideration for the Combinational scheme. It is seen that all users requesting resources are allocated a resource as described in the fairness scheme in topic 5.

4. Discussion

The plot in figure 3 shows the SINR totals for the simulations of Combinational scheme and the Global prediction scheme. During trials: 2, 5, 6, 7 and 8 as shown in Table: 6, 8, 12, 14, 16, 18 and 20 respectively, the output for Combinational scheme is higher than that of Global mobility prediction. This is because the Mobility prediction uses the sequence presented in the historical movement of users but the combinational technique seeks to determine the best SINR total group and allocate the resources in order determined.

At interval 3, the SINR total for Combinational prediction is higher by 24 dB. This is because at this point, the users who are requesting resources such as user 4 have a very low SINR and hence following the sequence of requests, the SINR total is very low. On the other hand, the combinational technique does the best combination of SINR total prioritizing the high SINR users and hence the user 4 gets last priority. This makes the difference to be 24 dB.

5. Fairness scheme

This scheme is applied during instances where not all users who are requesting resources for communication are allocated resources. This mainly applies to low SINR valued users. It is meant to ensure that they are able to get a resource at least to communicate.

Using the combinational technique, a check is done to see if all users have been allocated a resource for communication [**7**].

Ideally, the combinational technique is meant to prioritize high SINR value users, for high throughput in the system. During allocation, they take the most resources for communication and low valued ones tend to be left out.

However, fairness is now incorporated to assist the low valued users to communicate. This occurs in the event a low SINR value user has been left out completely while applying the combinational technique. Then, a resource is then reallocated from the next lowest valued SINR to the user who has been left out so as to get a single resource to enable him/her to communicate. This is clearly seen at interval D. It lowers the SINR total by 1 dB below the Global prediction scheme, but ensures that all 4 users communicate. During the same interval D, the Global prediction just allocates in order of prediction sequence and only allocates to 2 users thus the other 2 users are locked out from communicating in the femtocell.

6. Conclusions and recommendations

In general, from the comparisons done, it can be seen that the combinational users allocation scheme maintains high SINR levels by ensuring that high SINR valued users get priority in resource allocation. In addition, it also ensures fairness for low SINR users are able to get at least a resource to enable them communicate.

This proves that the combinational technique has a higher throughput than the global prediction technique suggested by the Mobility aware algorithm.

However, the fairness slightly lowers the SINR while performing the reallocation for example in interval D by 1 dB.

Therefore, as a recommendation, future research can look into ways of accommodating all users without compromising on SINR levels.

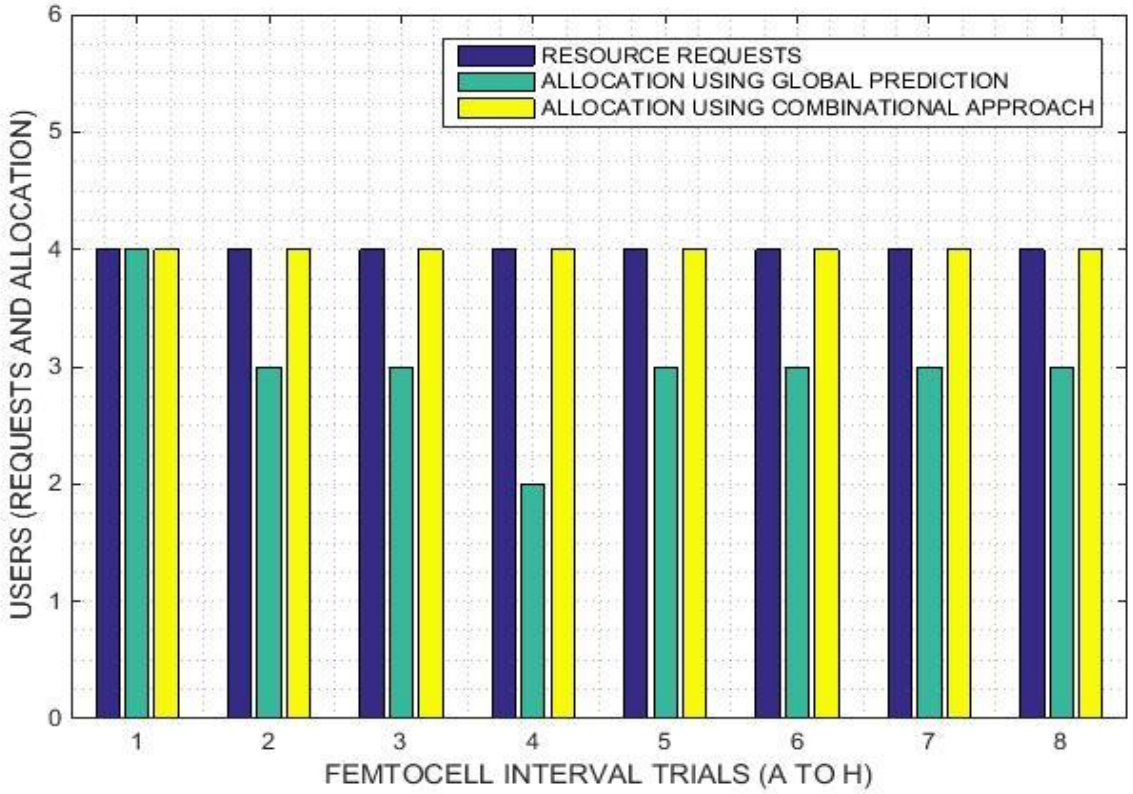

Fig. 3. Plot of users' resources allocation for various trials in a femtocell

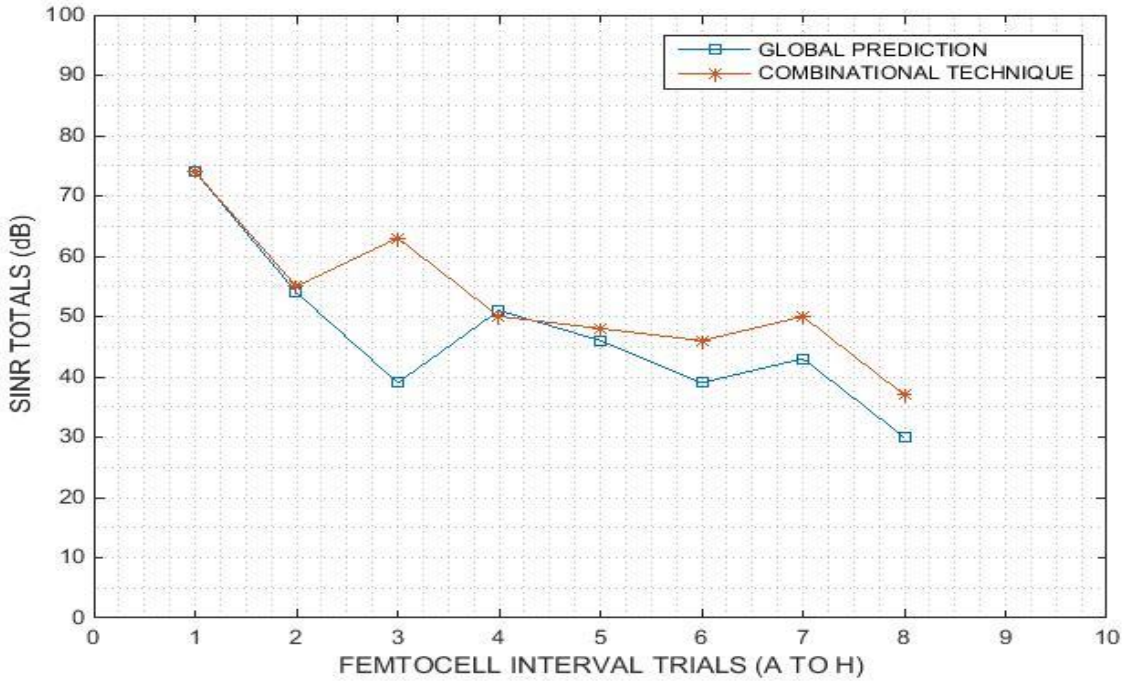

Fig. 4. A plot of SINR totals using combinational technique against Global prediction technique

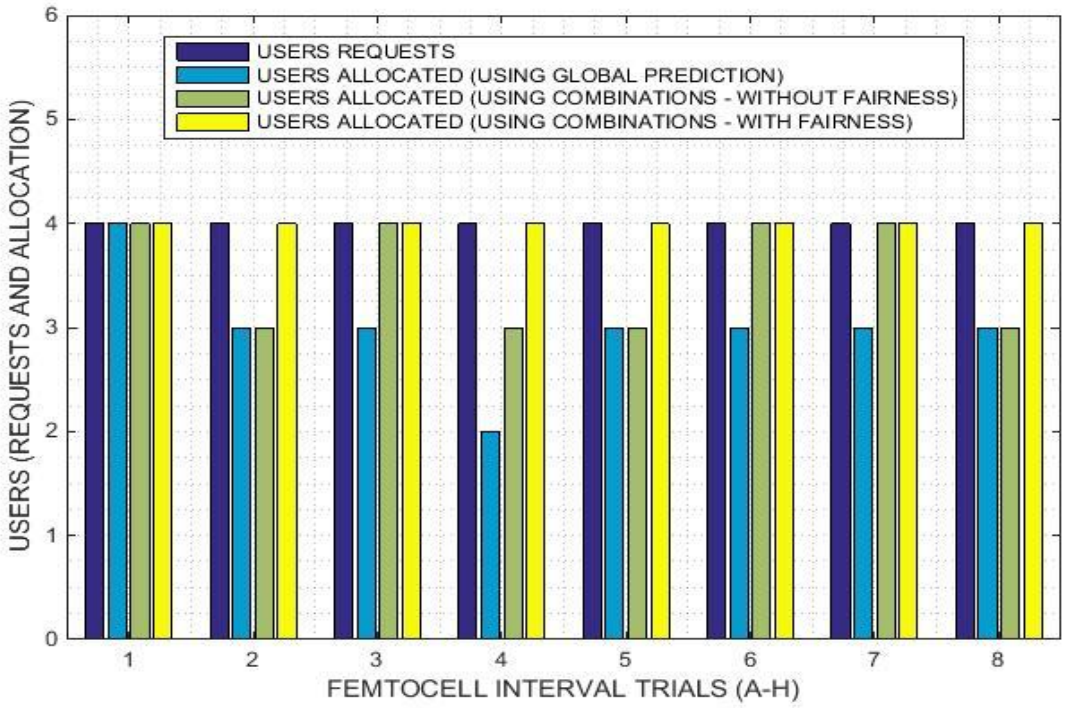

Fig. 5. Plot of users' resources allocation with fairness comparison

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