A femtocell users' resource allocation scheme with fairness control

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Abstract—the availability of adequate resources will always remain to be a concern for mobile network operators. Therefore, for Orthogonal Frequency Division Multiple Access (OFDMA) networks, factors such as Signal to Interference plus Noise Ratio (SINR) and resource capacity continue to be feasible areas of research. A combination resource allocation with fairness control is hereby explored with reference to users' individual requests for resources at a given femtocell being taken into account. In addition, their signal to noise ratios is calculated alongside serialized users' requests per individual. This chooses the users with best SINR values with a given resource allocation to each user.

An example of 3 users is considered with the resource requests and SINR values as follows: user 1 requests for 3 resources and has 5dB, user 2 requests for 2 resources and has 7 Decibels (dB) and user 3 requests for 4 resourcesand has 4dB. The total requests are 9 resources and only 5 are available. When the combination is applied it determines that the best allocation would be as follows: user 1 to be allocated 3 resources and user 2 to be allocated 2 resources. The fairness scheme then allocates a resource to user 3 by deducting one from user 1 to enable him to communicate through the femtocell.

KEY WORDS
Femtocell, Orthogonal Frequency Division Multiple Access, Signal to Interference plus Noise Ratio.

I. INTRODUCTION

Services from mobile service providers will always have a growing demand. This makes it inevitable for higher levels of bandwidth to be incorporated in their mobile capacity development. Increasing demands from users and high levels of bandwidth requirements have made it necessary to develop techniques that seek to take care of factors such as Signal to Interference Noise Ratio (SINR) and resource allocation to all users with varying power, noise and signal to noise levels, among others.

Tackling these factors versus accommodating as many users as possible in the network, have remained a challenge and hence an area of continual research for Communication companiesand institutions. Techniques have been developed to deal with issues such as: users' mobility, users' varying data rates and signal power levels and also combinational techniques to determine the optimum approach to allocate users resources in mobile networks. Some of the algorithms include: Genetic algorithm, Ant colony algorithm, maximum fairness and mobility aware algorithm. These methods have tried to prioritize with regard to their individual aspects in terms of signal power levels, mobility and data rates.[1]

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II. LITERATURE REVIEW

The demand for higher bandwidth and faster communication techniques have led to robust development of mobile networks that have evolved from 1G to 4G networks[2].

a) MOBILE EVOLUTION HISTORY

Mobile networks began with the earliest form of communication which was mainly analog in nature. This was characterized by technologies such as Total Access Communications systems (TACS) and Advanced Mobile Phone System (AMPS)[2]. They had serious challenges of switching and roaming. This was the first generation of mobile phones.

The second generation was characterized by introduction of text messaging and packet switching techniques. Technologies such as Time Division Multiple Access (TDMA) were developed [2].

The third generation technologies brought Wideband Code Division Multiple Access(W-CDMA) and Universal Mobile Telecommunications Service (UMTS). These had very high data rates of up to 10Mbps[3].

The generation that features currently is the fourth generation (4G) networks that utilize technology such as Long Term Evolution Networks (LTE) and Worldwide Interoperability for Microwave Access (WiMAX). This is a purely Internet Protocol (IP) network which has very high data transmission rates that can reach up to 100 Mbps [4].

LTE networks are made up of the following:

i). Mobility Management Entity
ii). Enhanced Node-B
iii). Serving Gateway
iv). Packet Data Network Gateway.

The first gadget is the user equipment. This is what the user owns and is used to avail network facilities to the user. [4]

The second component is called Mobility management Entity (MME). It is useful in providing signaling exchanges between users-core network and base stations-core networks and a unit for data flow between the users and the internet[5]. This is as shown in the figure below.

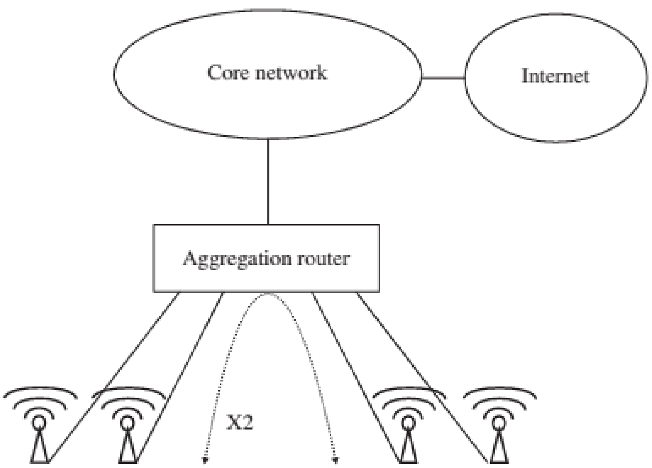


Fig 1: Routing on the MME[5]

This device serves as the termination point for the Non-Access Stratum (NAS) signaling. In addition, it establishes bearers,authenticates, provides SMS support, handover support and handles security key management[5].

Next device is the Packet Data Network Gateway. This device is useful in interconnecting user equipment to the internet and external packet data networks. It also assists with routing and forwarding user data packets plus also storage and management of user equipment contexts[4].

b) REVIEW OF EXISTING USER RESOURCE ALLOCATION SCHEMES

1. Maximum Fairness Algorithm

In this method, user's data rates are scanned. Here, a min-max technique is employed which involves minimizing the power of the users with the highest data rates and SINR values and distributes them to the users with the lowest values [6].

This approach has the problem of improper allocation of resources.This is occasioned by allocating the most resources to the low rate users have low signal to noise ratio. [6].

The problem of this method is deducting SINR values from the high valued users and transferring to the low valued ones. This way, the throughput is reduced and robustness of the system is greatly affected.

2. Proportional Rates Algorithm

In this technique, the sum of throughput through the transmission system is maximized.

This is achieved with the use of a predetermined system parameter βk.This parameter isused as a constraint to transmission data rates for all individual users [6]. This is as expressed by the formula below where the data rate for users is given by R_k.

$$\frac{R_1}{\beta_1} = \frac{R_2}{\beta_2} = \cdots \ldots \ldots \ldots \ldots .. \frac{R_K}{\beta_k} \qquad (1)$$

This method is adequate in terms of handling throughput but in order to improve on it, a dynamic scan for the available resources. Using combination approach is a better placed technique since the best users with best SINR levels to allocate resources are determined[6].

3. Mobility Aware Resource Allocation Algorithm

This technique utilizes user position prediction in a given cluster of femtocells to determine allocation of user resources.

It follows the following procedure: First, grouping of users into clusters then one of them is chosen to be the leading femtocell.A group of clusters is formed where in one cluster. The clusters consist of a one user being the cluster head and the others being the cluster members [7].

Furthermore, the method users two major sub-techniques to predict users resource allocation.

Global prediction algorithm: In this technique, the movements of the user form the history of the mobility prediction and thus a sequence is craftedto predict the most probable cell into which the user will move [7].

The global approach is expressed in the formula below.

$$P_e = P\left(\frac{X_{f+1}=Y}{X_f=Y}\right) = \frac{M(X,F_{f+1})}{N(F_{f-1},F_f)} \qquad (2)$$

Where:

Perefers to Transition probability between previous and future femtocells

F_1, F_2, F_3……..F_{f-1}, $F_f$refers to the mobility history trace of a mobile user [2].

$F_{f-1}F_f$refers to the sequence of the previously visited to the current femtocell

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

M and N are sequences of elements of variables outlined in the equations determined by the users' movements in the femtocells[7].

For local prediction, the formula outlined is used.

$$P_m = P\left(\frac{X_{f+1}=Y}{X_f=Y}\right) = \frac{N(F_f,F_{f+1})}{Z(F_f)} \qquad (3)$$

Given that:

X = $F_{f-1}F_f$is the sequence in V of the previously visited femtocell and the current femtocell of the mobile user [2].
Y = $F_fF_{f+1}$is the sequence of the current femtocell and the future femtocell to be visited.
Z(F_f) refers to the number of times the femtocell F_f appears in the mobility trace[7].
This method relies on historical movements to predict movement of a user to a femtocell and secondly, assumes a user will move to either of the adjacent cell in the case of local prediction. A combinational resource allocation technique is better placed in a dynamic environment due to random movement of users.

4. Genetic Algorithm

This technique involves a natural process of individuals' selection based on their traits that are carried on from one stage to another[8]. The process entails: Selection, crossover and mutation. In the first process, the chosen users are the ones with the best and moved to the subsequent stages with priority placed on fitness function [8].Next stage is the crossover where good common traits among the ones chosen in the selection stage are moved to the mutation stage. Finally, the mutation stage involves the alteration of traits of the children from the parent users from the crossover stage in order to achieve the best traits[8].
This method is applicable in iterative systems where the next stage depends on the previous one but in a case where resources allocation is instantaneous in terms of SINR valuesamong the users in a femtocell hence the combinational allocation technique is more appropriate.

5. Ant Colony Optimization

This technique uses the analogy of ants that move around randomly in search of food from their nest. During their movement, they drop pheromone trails along the paths that they follow [9]. The main aim is to create a trail for other ants to follow later while searching for food hence shorten the time that they need to wander in search for food [9]. These pheromone trails evaporate which means that the trails that remain are fewer for longer distances. This method encourages shorter distances which maintain trails. When applied to systems such as networking and smart grid systems, it becomes usefulfor finding the best routing techniques to improve system throughput.
This method relies on historical data for determining the best paths for routing information. In a dynamic environment, users factors such as SINR are randomly changing and do not rely on historical information. Hence, this becomes a drawback for this approach compared to combinational scheme.

III. METHODOLOGY

This paper brings forward a combinational technique to allocate users resources in a femtocell.
Combination refers toan arrangement technique in mathematics that finds all possible arrangements of items in a given space. [1]

It is expressed mathematically as shown below

$$\frac{\boldsymbol{n}!}{\boldsymbol{x}!(\boldsymbol{n}-\boldsymbol{x})!} \qquad (4)$$

Where:
n! refers to the factorial of n
x! refers to the factorial of x
(n-x)! refers to the factorial of (n-x).

The method seeks to scan for all users who have requested for resources in the femtocell then it arranges them in terms of the groupSINR values. It is after this step that it does the totals of all the SINR groups then allocates the users with the best SINR values [1].

The first step in this method would be to determine the SINR values for the users. This is described in the steps below:

1. Channel bandwidth Calculation.At this stage, the Adaptive Modulation and Coding (AMC) scheme is used from the measurement reports sent from the user equipment[1].

2. Bits per symbol of transmission derivation. This is determined from the AMC scheme and the number of subscribers in the network [1].

3. System throughput calculation.
First, symbol transmission duration is calculated as follows

$$\frac{0.5\ ms}{7} = 71.43\mu S \qquad (5)$$

Then, the Throughput is given by =

$$\frac{No\ of\ bits\ transmitted}{symbol\ transmission\ duration\ (71.43\ \mu s)} \qquad (6)$$

4. Calculation of the SINR.
Given the expression for a channel capacity as

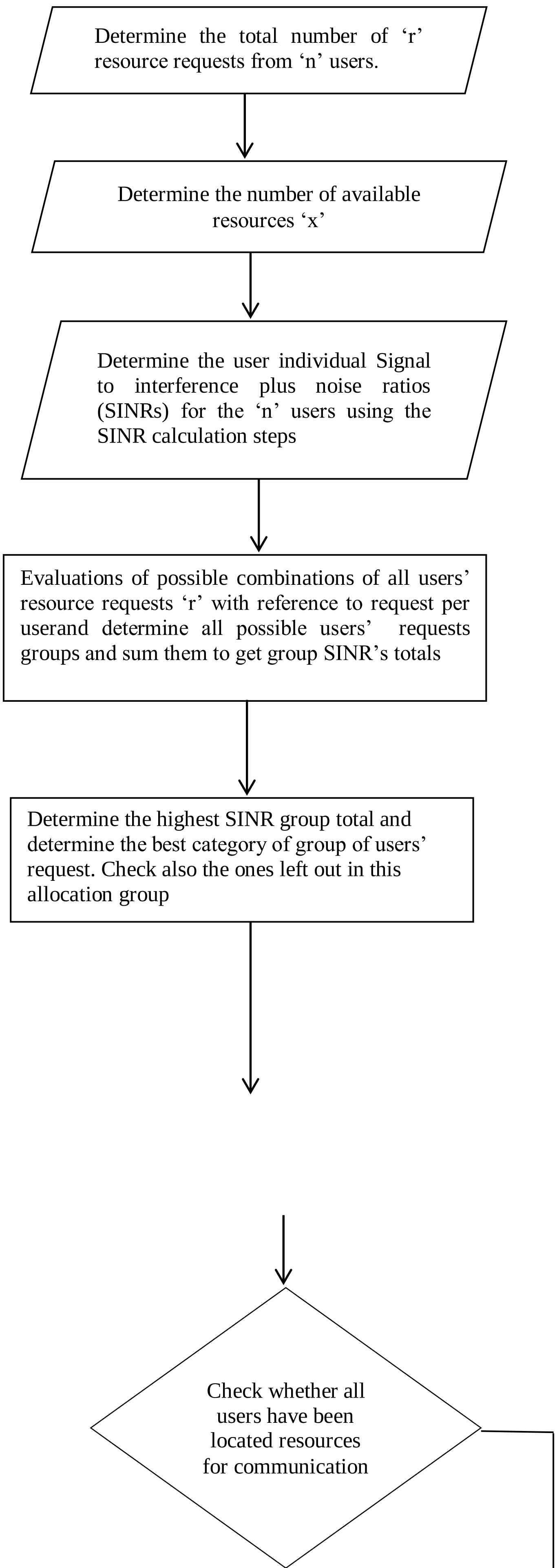
$$C = Blog_2(1 + SINR) \qquad (7)$$

Where:
C = Capacity of the channel or throughput (bps)
B = Bandwidth of the channel (Hz)
SINR = Signal to Interference-Noise Ratio

This makes the expression of the SINR to be

$$SINR = 2^{[C/B]} - 1 \qquad (8)$$

Having determined the individual users SINR values, the users are selected through the process described in the flow chart below as described in [1].



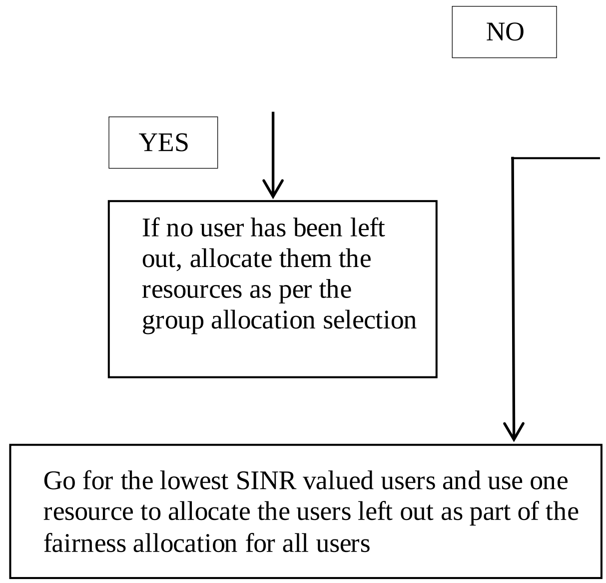


Fig 2: Flow chart for the resource allocation technique with fairness control

The above procedure is an improvement on the method described in [1]. The aspects improved are:

First, the method described in [1] assumed an ideal situation where all users only requested for one resource which was ideal in their case. In this paper, users can request for quite a number of resources. These requests are summed at the end of all the requests into one grand total of resource requests number ‘r’. This ‘r’ figure is what is used to do the combinations technique together with ‘x’ available resources so as to find all possible arrangement of ‘r’ requests in ‘x’ available resources. The request maintain the label of the original users for example: user 1’s request will always maintain ‘1’ label for all the requests for unique identification.

Second, an improvement is done on the aspect of fairness in resource distribution to all users as compared to [1].Once all the combinations are done and the best group of SINR values and henceusers are determined, the method seeks to be fair to all users who have request for a resource. This is done by traversing through the group chosen to find out if all the users have been at least taken care of. If there is a user who has not been allocated even a resource due to low SINR value, then one of the resources is deducted from the one of the users with low SINR values among the allocated with more than one resource. This resource is then given to the user(s) who did not have a resource for communication. This hence creates a balance in terms of resource distribution among all the users who need to communicate hence fairness is achieved without affecting the high value SINR users as used in technique described in [6] that affects the throughput of the communication channel.

IV. RESULTS AND DISCUSSION

The following example is used in this paper. Given a femtocell has 3 users with the respective resource requests and SINR values as outlined in the table given.

Table 1: Users, Resource requests and SINR values

User	Resource requests	SINR values
1	3	5 dB
2	2	7 dB
3	4	4 dB
Total	***9***	

The available resources in the femtocell are 5 and from the above table the total requested is 9.

When combinations is done on the number of arrangement of the 9 requested resources with regard to 5 available ones, a matrix of 126 by 5 is obtained with 126 different ways of arranging the serialized user requests in 5 available resources in the femtocell. These requests are arranged with respect to their corresponding SINR values and the totals done.

From this, the best SINR total value is obtained and the users bearing the SINR values determined to be the following arrangement of requests: *[1 1 1 2 2]*. This corresponds to users 1 and 2 and leaves user 3 out.

Since one of the objectives of this method is to encourage fairness to all users requesting resources, a quick scan shows user 1 has a lower SINR compared to user 2. This user has 3 resources allocated to him and hence one resource can therefore be removed from him and allocated to user 3 to give him a chance to communicate through the system and hence takes care of fairness for all users in the system.

V. CONCLUSION

The combinational technique with fairness control proves to be effective in terms of use of user SINR values todetermine the best users to allocate resources for communication in a femtocell. This is effective in a dynamic environment where user factors such as SINR often fluctuate due to various aspects in the environment. This makes it appropriate in robust and busy environment due to instantaneous user selection.

VI. ACKNOWLEDGEMENT

My gratitude goes to my supervisors Dr. Philip KibetLang'at and Professor Stephen Musyoki for their outstanding guidance while conducting my research for documentation and preparation of this paper.

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