Resource Allocation Model Based on Interval for Wireless Network with Guaranteed QoS

Marwan Alakhras, Mourad Oussalah, Mousa Hussein

ABSTRACT—The resource allocation in WLAN network is of paramount importance especially when services are considered to achieve a guaranteed QoS. In this work a two steps algorithm is proposed to model adaptable resource allocation algorithm. Where subcarriers are allocated considering the channel quality and priority of multicast services, then, the power reallocation algorithm is carried out based on small intervals to enhance the system capacity while guaranteeing the whole multicast QoS.

Index Terms—QoS; resource allocation; modelling;

I. INTRODUCTION

The emergence development of the Wireless network technologies improved the logical structure, transmission mode and channel structure in the LTE, to introduce the Multimedia Broadcast Multicast Service (MBMS) in the UMTS by 3GPP [1]. The future wireless network imposes a non-homogeneous structure to any network, which in return makes it hard to manage network resource efficiently especially the ones that supports multicast service.

Power allocation algorithm and subcarrier can be used to improve system throughput against channel fading as regularly done in the literature to optimize the throughput and MBMS fairness. For example, in [2], similar approach is proposed to maximize multicast system throughput, but the basic service quality of the user with poor channel is not guaranteed. Alternatively, some other approaches could guarantee maximum resource allocation but only to users with high priority as proposed in [3] and [4]. Where as in [5], a maximized capacity scheme is proposed with restraint of total power and subcarrier BER.

Traditionally any network is said to be non-homogeneous if it consists of conventional femtocell and macro-cell, where, some area served by macro-cell could be covered by femtocell, in this case the area will be influenced by Co-Channel Interference CCI, and that will make the traditional resource allocation not usable, unless it is been improved to fit the diverse WLAN structure. In this work, the issue of resource allocation algorithm is considered when multicast services exist with diversity in non-homogeneous network for macro and femto-cells based on an interval recourse allocation.

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The objective is to enhance the system capacity while guaranteeing the whole multicast QoS and reducing algorithm complexity.

II. SYSTEM MODEL

A. *System Model*

As shown in Fig.1, the multicast system in heterogeneous network consists of femtocell covered by macro-cell. Where, the corners of femtocell that are served by macro-cell can be influenced by CCI because of frequency reuse.
These requirements are designed to ensure sufficient image

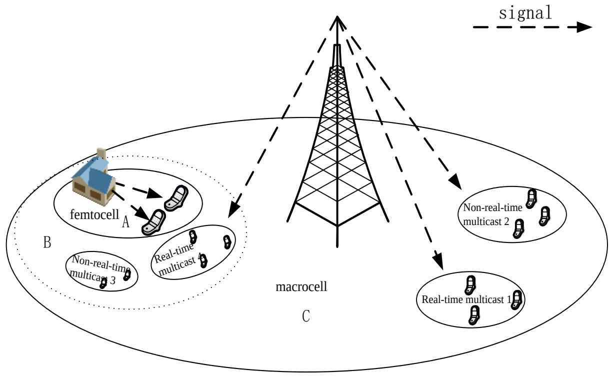

Figure 1 Multicast system in heterogeneous network

The first step is to split the area into two regions by the standard of CCI caused by femtocell. One is influenced by CCI, and another is not. From Fig.1, area B and C are served by macro-cell, whereas area B can be influenced by CCI because of the exiting of the femtocell, and area A is served by femtocell. In this model, D downlink multicast services are transmitted to N users on K subcarriers. Clearly, these users are included in D multicast groups.

Let Ni denote the user set of the ith multicast group. Thus the user set is denoted by $N_1 \cup N_2 \cup \ldots \cup N_D$, which contains all the user in the system. The multicast services in area B and C can be divide into different types service which are real-time service and non-real-time service. The different multicast group receive different services and require different QoS so that the multicast group has different priority. In addition, the channel is Rayleigh fading channel.

B. *Problem Formulation*

The system consists of K subcarriers and the whole bandwidth is B. Let σ^2 be the variance of the Gaussian noise p_i is the transmit power of macro-cell on subcarrier i. As it is well known that the maximum data rate of d^{th} multicast on the i^{th} subcarrier can be represented by

$$M_{d,i} = \log\left(1 + p_i \alpha_{d,i}\right) c_{g.m} = \log\left(1 + p_m \alpha_{g.m}\right) \quad (1)$$

Where $\alpha_{d,i}$ is the equivalent channel gain of the d^{th} group on the i^{th} subcarrier. It is defined by:

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$$\alpha_{d,i} = \min_{n \in N_d} \left\{ \frac{|H_{n,i}|^2}{\Gamma \sigma_*^2} \right\}$$

$$\alpha_{g,m} = \min_{k \in K_g} \left\{ |H_{k,m}|^2 \, \Gamma \, \sigma_*^2 \right\} \quad (2)$$

Where as $H_{n,i}$ is the channel coefficient of user n of the d^{th} group on the i^{th} subcarrier, σ_*^2 is the equivalent noise variance. For area B, $\sigma_*^2 = \sigma^2 + h_{f,n}\sigma^{(i)}$. where $h_{f,n}\sigma^{(i)}$ is the same frequency interference signals caused by femtocell. $\Gamma = -ln(5BER)/1.5$, is the SNR gap parameter which indicates how far the system is operating from capacity.

As mentioned in [6] Real-time services can be translated to rate QoS as:

$$R_i = \sum_{j=1}^{K_i} \frac{Size_{i,j}}{Max_i - All_{i,j}} \quad (3)$$

$Size_{i,j}$ is the size of j^{th} frame in queue *i*. Max_i is the maximum allowable Delay Bound in the i^{th} queue. $All_{i,j}$ is the present delay of j^{th} packet in queue *i*, and the number of packets in the queue is K_i. Then the rate of real-time multicast service can be defined by $R_{\mathrm{d}} = \max_{\mathrm{i} \in \mathrm{N_d}} \{R_i\}$.

The optimization technique used here is adapted from similar work done in [7], where a single subcarrier is assumed to be assigned to single multicast group. Using $\omega_{\mathrm{d,i}}$ the as binary weight indicator, and representing service set in area B and C as {X} and {Y} respectively. While the real-time service set is {Z}. Then the optimization problem can be formulated as follows:

$$\max_{\omega_{d,i}, P_i} \sum_{d=1}^{D} N_d \sum_{i=1}^{K} \frac{B}{K} \omega_{d,i} \log\left(1 + p_i \alpha_{d,i}\right) \quad (4)$$

$$\sum_{i=1}^{K} p_i \le P_T \quad and \quad p_i \ge 0, \;\; (1 \le i \le K) \quad (5)$$

$$\sum_{d=1}^{D} \omega_{d,i} = 1\,, \;\; (1 \le i \le K) \; and \;\; \omega_{d,i} \in \{0,1\} \quad (6)$$

$$\sum_{i=1}^{K} \omega_{d,i} \log\left(1 + p_i \alpha_{d,i}\right) \ge R_d^{min} \quad (7)$$

$$R_d^{min} = \max_{i \in N_d} \{R_i\} = \max_{i \in N_d} \{ \sum_{j=1}^{K_i} \frac{Size_{i,j}}{Max_i - All_{i,j}} \}, \; d \in \{Z\} \quad (8)$$

III. ALGORITHM FORMULATION

In the proposed interval based algorithm with guaranteed QoS for non-homogeneous networks. It is formulated by initially allocate subcarrier with multicast priority and channel gain. This step is taking place after number of subcarrier in area B is guaranteed. To achieve maximum throughput and minimize the complexity of allocation algorithm, then a power allocation algorithm based on interval is proposed.

Assuming that both types real-time and non-real-time multicast services exist in B and C. While the average channel gain and bit rate R_{g-temp} are calculate-able. Then the allocation algorithm can be described as follows:

1. Initially, number of subcarrier in area B and C can be determined as:

$$K_B = \sum_{d \in X} \frac{R_d^{min}}{R_{d-temp}} \quad , \quad K_C = \sum_{d \in Y} \frac{R_d^{min}}{R_{d-temp}} \quad (9)$$

2. Allocate subcarrier to either multicast sets B or C. if $i < \mathrm{K_B}$, $\{S\} = \{X\}$, then {S} is the multicast set in area B. Otherwise, {S} = {Y}, then {S} is the multicast set in area C.

The priority of multicast service should be considered when allocating the subcarrier, since various multicast services while separated into real-time or non-real-time services would definitely require rate of QoS. But for same type of services the priority is considered to be relatively similar or difference is relatively very small, which is referred to as multicast group. Thus, $\sum_{\mathrm{d}=1}^{\mathrm{D}} \gamma_d = 1$ for whole group. The standard formula used to allocate subcarrier is defined by:

$$d_i = \arg\max_{d \in S} \{\alpha_{d,i} \, \gamma_d\} \quad (10)$$

3. The bit rate is updated by using the following formula, but after at least subcarrier is allocated to a multicast d.

$$R_{d_i} = R_{d_i} + \log_2(1 + \left(1 + \frac{P_T \, \alpha_{d,i}}{K}\right)) \quad (11)$$

This algorithm would contain more detail formulation, and special cases that have to be taken into consideration, however it is found that it should be more suitable to ignore it for the sake of simplicity, since it will be detailed in an extended version of this work.

Traditionally every subcarrier can be allocated by average power allocation. But in order to enhance the system capacitance the power should be reallocated. Where, it is not necessary to allocate too much power to the multicast group in area B with CCI. It can work well as long as its QoS is guaranteed. So the power excess in area B can be reallocated to the multicast group in area C.

Basically, different objective is set to each area in order to optimize power allocation, i.e., to minimize the total power in area B and maximize the total throughput in area C.

For all the multicast group d $(1 \le \mathrm{d} \le \mathrm{D})$, the optimal power allocation $P_{\mathrm{i}}^{\mathrm{min}}$ can be derived from [7], as follows:

$$P_i^{min} = \max(L_d^{min} - \frac{1}{\alpha_{d,i}}, 0) \quad (12)$$

When the guaranteed QoS is reached by P_i^{min} such that $\mathrm{p}_i \ge 0$. Then the access power can be reallocated to another multicast group, such as area C to improve the system capacity. And when the power of each subcarrier in area C is greater than P_i^{min}, and its QoS is satisfied then the power of area C can be reallocation as follows:

$$P_T' = P_T - \sum_{i \in K_B} P_i \quad (13)$$

Where P_T the total power and P_T' is the left over power reusable in the system. Keeping P_m^{min} as the lowest boundary of each subcarrier power [8]. Then power allocation in area C can be reformulated by:

$$\max_{P_i} \sum_{d \in \{Y\}} N_d \sum_{i \Omega_d} \frac{B}{K} \log\left(1 + p_i \alpha_{d,i}\right) \quad (14)$$

According to Qilin et. el. [9], the optimal power allocation is the multiple water level of water-filling algorithm. Which can be extrapolated to our algorithm, such that.

$$P_i^* = \max(N_d \eta - \frac{1}{\alpha_{d,i}}, P_i^{min}) \quad (15)$$

According to the above equation it is necessary to find available value for parameter η to make the sums of the allocated power of subcarrier approach P_T' as far as possible, this assumption is to improve the system capacity. Then it can be derived that

$$\min_{d \in \{Y\}} \{\frac{L_d^{min}}{N_d}\} \le \eta \le \frac{1}{\min_{d \in \{Y\}} \{N_d\}} (\frac{P_T'}{K_B} + \frac{1}{\sum_{\mathrm{i} \in \mathrm{N_B}} \alpha_{d_i,i}}) \quad (16)$$

Bearing in mind that, in order for (14) to hold, then η can't

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be the maximum of the inequality. So, it is necessary to find the optimal value to make the sums of each subcarriers power approach the total power from the interval. Clearly, there should be several values of parameter η according to the different channel gain of the multicast group.

So it is very possible to get several small intervals, for example $[P_d^{min}, P_1^*]$, $[P_2^*, P_3^*]$,..., $[P_{k-2}^*, P_{k-1}^*]$, $[P_{k-1}^*, P_d^*]$. It is obvious to observe that $[P_{k-1}^*, P_d^*] > [P_d^*, P_1^*]$. The number of the small intervals is N_C can be set search for the best power allocation in each small intervals from top interval to the bottom interval. Then the power allocation algorithm on interval based can be summarized as follows:

1. Initially, According to the value of $\eta^{\mathrm{up}} = \eta_{\mathrm{N_C-1}}$, $\eta^{\mathrm{up}} = \eta_{\mathrm{N_C}}$and $\alpha_{\mathrm{d_i,i}}$, then, the big interval is divided into smaller intervals $[P_d^{min}, P_1^*]$, $[P_2^*, P_3^*]$,..., $[P_{k-1}^*, P_d^*]$.

2. Determine the available water level as:
$$\eta = \frac{\eta^{low} + \eta^{up}}{2}$$
3. Determinep_i^* according to equation (15).

Again for simplicity, the iterative process that this algorithm might contain is omitted. It is useful to mention some of these cases. For example, if $\sum_{(i \in K_C)} P_{up} \geq P_T'$ then the upper and lower interval values should be reconsidered and algorithm is repeated to insure the optimal power allocation for the guaranteed QoS is satisfied.

IV. SIMULATION AND RESULS

In the test bed of the simulation part, the downlink for a macro-cell with a femtocell radio environment is considered, the downlink transmissions system is assumed to have K=64 subcarriers with a total bandwidth of 1MHz. The total power $P_T = 1W$ and noise power density -90 dBm/Hz.

Fig.2 shows a comparison of the proposed resource allocation based multicast capacity in area B with the water filling resources allocation algorithm.

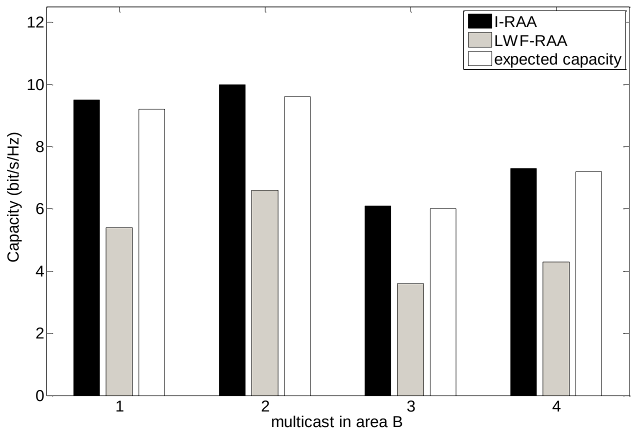

Figure 2 multicast capacity comparison in area B

Where the x-axis represents the ith multicast. It is obvious from the four shown multitask samples in area B, that, the proposed resource allocation algorithm based on interval is achieving the expected capacity, due to its adaptability to a reserved subcarrier scheme which guarantees the basic transmission rate. On the other hand, water filling resources allocation algorithm is not capable to guarantee the capacity, because it always chooses the best channel while allocating subcarrier in the interference area.

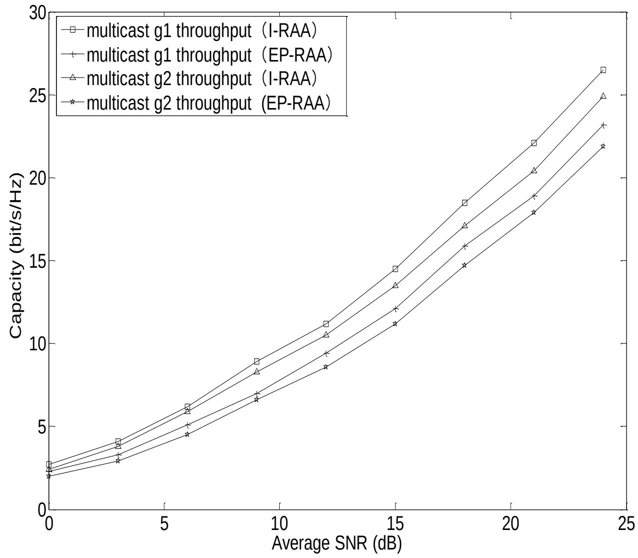

Figure 3 multicast capacity comparison before and after power allocation for g1 and g2

Fig.3 shows the difference in multicast capacity before and after interval-based power allocation. To make the comparison, two multicast services were chosen (g1 and g2), while the power in each subcarrier is kept equal during the period of subcarrier allocation. The comparison is done between the proposed algorithm and another known algorithm called Efficient Optimizing Resource Allocation EP-RAA [2]. Fig.3 shows that the proposed technique out-performs the EP-RAA for the two services. And, as a consequence the total system capacity is enhanced after power reallocation as shown in Fig.4. So power reallocation step using interval based algorithm seems to be promising future resource allocation algorithm, especially when multicasting services are considered. Off course with increasing demand on the WLAN services in the future WLAN generations.

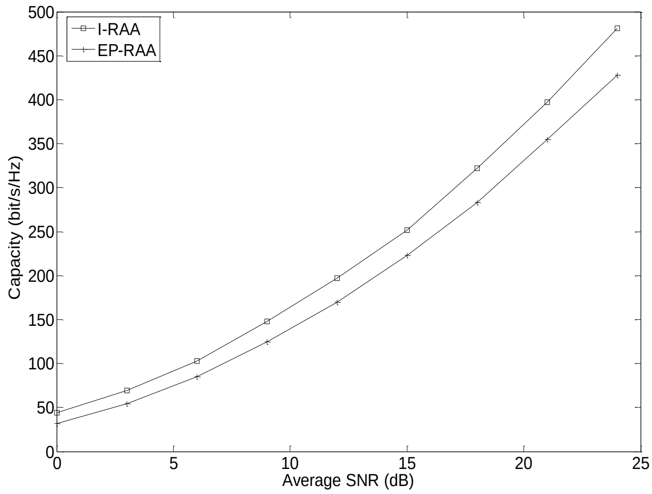

Figure 4 Total system capacity comparison before and after power allocation

Fig.5 shows a comparison for in capacity of the whole system, area B and area C, using the resource allocation algorithm based on interval and the Linear Water-Filling resource allocation algorithm (LWF-RAA). It is easy to judge

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that the proposed has gained larger capacity than the LWF-RAA in area B. But the full system capacity shown in Fig.5 is not gaining the same factor, this could be because, the subcarriers in area C are allocated to the multicast that has better channel, but not necessarily all the multicast can achieve the expected rate. Especially the multicast in area B which can be influenced by femtocell. Even though the proposed algorithm may suffer a little from low system capacity as shown in Fig. 6, but at least, it can guarantee the QoS of all multicast services composed of real-time and non-real-time, which comprise a conventional WLAN architecture with macro-cell and femtocell.

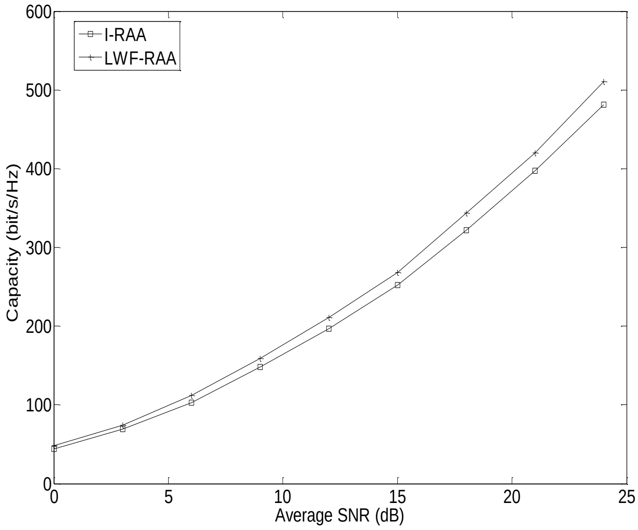

Figure 5 system capacity comparison

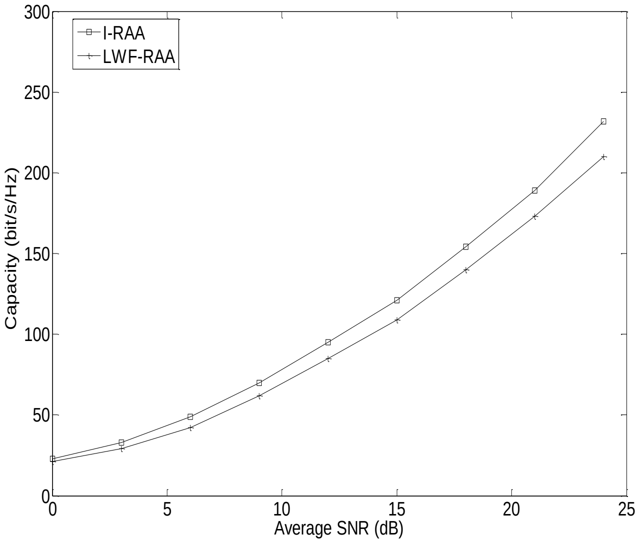

Figure 6 capacity comparison in area B

V. CONCLUSIONS

In this paper, a resource allocation algorithm with interval based is proposed with mixed macro-cell and femtocell network architectures, and with real-time and non-real-time multicast services. The algorithm is outperforming other traditional allocation. Moreover, the proposed algorithm is available for muticast, and non-homogeneous WLAN architecture, and capable to reserves the QoS. While the two step reallocation sound very promising especially when the power reallocation is considered to increase the capacity. Results also showing that the algorithm suffers from some throughput, but at least it could guarantee the whole QoS of a multicast services.

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