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# Development of a Hybrid Algorithm for User Association and Resource Allocation to Improve Load Balancing and Energy Efficiency in 5G HetNet

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**Abstract:** This paper presents the development and integration of a power control algorithm into the User Association Algorithm with Optimal Bandwidth Allocation (UAAOBA) to form a Hybrid Algorithm for User Association and Resource Allocation (HAUARA). The power control algorithm updates the transmit power of the Base Stations (BSs) towards a minimum transmit power that satisfies the minimum data rate requirement (1 Gbps) of the User Equipment UEs. The power update is achieved using the Newton Rhapson's method and it adapts the transmit powers of the BSs to the number of their connected UEs. The developed HAUARA provides an optimal solution for user associations, bandwidth allocation, and transmit powers to UEs concurrently. This maximizes the network energy efficiency by coordinating the load fairness of the network while guaranteeing the quality of service requirement of the UEs. The network energy efficiency performance of the developed HAUARA is compared with that of the UAAOBA. The results show that the developed algorithm has network energy efficiency improvement of 12.36%, 10.58%, and 13.44% with respect to UAAOBA for increase number of macro BS antennas, pico BSs, and femto BSs, respectively. Also, the network load balancing performance of the developed HAUARA is compared with that of the UAAOBA. The results show that the developed algorithm has network load balancing improvement of 12.62%, 10.04%, and 10.34% with respect to UAAOBA for increase number of macro BS antennas, pico BSs, and femto BSs, respectively. This implies that the developed algorithm outperforms the UAAOBA in terms of network energy efficiency and load balancing.

**Keywords:** Bandwidth allocation, Hybrid beamforming, HetNet, Power control, User association.



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## 1. INTRODUCTION

User association algorithm plays a vital role in enhancing the energy efficiency and load balancing of a mobile network. It determines the particular BS each UE in the network should be associated with before data transmission and reception commences [1]. The current Maximum Reference Signal Received Power (MaxRSRP) and Maximum Signal-to-Interference-Noise Ratio (MaxSINR) user association algorithms as specified by 3rd Generation Partnership Project (3GPP) result in poor load fairness among BSs in massive MIMO antennas enabled Fifth 5G HetNets and poor throughput fairness among UEs in the network [2]. This result to the decreased energy efficiency of the current Long Term Evolution (LTE) network and degraded Quality of Service (QoS) for active UEs. Subsequently, the energy efficiency of the 5G mobile network needs to be improved by 10 times compared with that achieved by the current LTE mobile network to cope with the anticipated 1000 times data rate increase [3]. Achieving this requirement for 5G mobile cellular networks requires development of energy efficient radio resource management schemes (user association, bandwidth allocation, and power control algorithms) and the integration of emerging mobile cellular network technologies which are HetNets, massive MIMO antennas, and mmWave spectrum [2]. This led to the development of a distributed fair user association in massive MIMO enabled HetNets to maximize the network energy efficiency while guaranteeing the SINR received by the UEs [4]. However, the network energy efficiency of the work can be improved by integrating a power control algorithm into the user association algorithm to adapt the transmit power of the BSs with respect to traffic load on the BSs. This will result to a higher network load balancing and energy efficiency. An energy efficient joint optimization algorithm for user association and power control in massive MIMO enabled HetNets was developed in [5]. However, the maximization of the network sum energy efficiency under load constraint of BS was done not considering the QoS requirements of the UEs. This resulted to not guaranteeing the receive throughput of the UEs. Also, the power control algorithm does not affect the user association scheme. This caused decreased load balancing in the HetNet and reduced network energy efficiency improvement. It is important to note that the literatures that deployed massive MIMO used digital beamforming at the BSs which resulted to an increased power consumption of the BS. This is because digital beamforming uses a radio frequency chain per antenna. A user association algorithm with optimal bandwidth allocation for improving the energy efficiency of massive MIMO with hybrid beamforming and mmWave enabled HetNet was developed in [6]. However, the energy efficiency and load fairness of the work can be improve by hybridizing the UAAOBA with a power control algorithm. This enables the control of the power variable to enhance the user association algorithm for improved load balancing of the network and a subsequent improvement of the energy efficiency of the network Thus, this paper is an extension of the authors' work in [6].

## 2. MATHEMATICAL MODELING AND ALGORITHM DEVELOPMENT

### 2.1 Mathematical Models

This paper adopted the channel model, UE throughput model and network energy efficiency model of the authors' previous work and they are given in equation (1), (2), and (3), respectively as [6]:

$$h_k = \sqrt{\frac{1}{\rho}} \sum_{l=1}^{NM} \alpha_l a_t(\theta_l) a_r^*(\phi_l) \tag{1}$$

where $h_k$ is the channel vector of the k^th^ UE from a massive MIMO BS with $NM$ transmitting antennas, $\alpha_l$ is the complex channel gain of the $l^{th}$ path, $\rho$ is the distance-dependent path loss between the BS and UE, $a_t(\theta_l)$ and $a_r^*(\phi_l)$ are the transmit steering vector and conjugate receive steering vector respectively.

$$R_{i,k} = w_{i,k} \log_2\left(1 + \beta_k p_{i,k}\right) \tag{2}$$

where $R_{i,k}$ is the achievable throughput of the $k^{th}$ UE from the $i^{th}$ BS, $w_{i,k}$ is the bandwidth allocated by the $i^{th}$ BS to the $k^{th}$ UE, $p_{i,k}$ is the power received from the $k^{th}$ UE from the $i^{th}$ BS, and $\beta_k$ is the interference to noise ratio at the $k^{th}$ UE.

$$\xi = \frac{\sum_{i=1}^{B} \sum_{k=1}^{K} x_{i,k}\left(w_{i,k} \log_2(1 + \beta_k p_{i,k})\right)}{\sum_{i=1}^{B} \left(p_{ci} + \frac{1}{\eta} \sum_{k=1}^{K} x_{i,k} p_{i,k}\right)} \tag{3}$$

where $\xi$ is the energy efficiency of the network, $x_{i,k}$ is the user association index, $p_{ci}$ is the static power consumption of the $i^{th}$ BS, $\eta$ is the amplifier efficiency of the BS, B is the total number of BSs, and K is the total number of UEs in the network.

Similarly, in modeling the load fairness index of the three tier HetNet, the Jain's fairness index is modeled to capture the differences of the macro BS, pico BS, and femto BS. These differences are the BS capacity, BS associated number of UEs and other resources [7]. Therefore, the tiered fairness index is derive. Let $\varsigma_{P,F}$ be the average tier 2 and 3 load relative to the avarage tier 1 load. The $\varsigma_{P,F}$ is defined as follows:

$$\varsigma_{F,P} = \frac{\frac{1}{M_N} \sum_{i=1}^{M_N} l_{M,i}}{\frac{1}{P_N} \sum_{i=1}^{P_N} l_{P,i} + \frac{1}{F_N} \sum_{i=1}^{F_N} l_{F,i}} \tag{4}$$

Then the fairness index is modify to give the tiered fairness index as:

$$J(l_i) = \frac{\left(\sum_{i=1}^{M_N} l_{M,i} + \sum_{i=1}^{P_N} \varsigma_{P,F} l_{P,i} + \sum_{i=1}^{F_N} \varsigma_{P,F} l_{F,i}\right)^2}{T\left(\sum_{i=1}^{M_N} l_{M,i}^2 + \sum_{i=1}^{P_N} \left(\varsigma_{P,F} l_{P,i}\right)^2 + \sum_{i=1}^{F_N} \left(\varsigma_{P,F} l_{F,i}\right)^2\right)} \tag{5}$$

where $l_{M,i}$, $l_{P,i}$, and $l_{F,i}$ is the load in each macro BS, pico BS, and femto BS in the three tier HetNet, respectively, and $T$ is the number of tiers in the HetNet.

### 2.2 Problem Formulation

The energy efficient joint user association and optimal bandwidth allocation with power control problem to be solved is:

$$f(X,P) = \max_{X,P} \sum_{k \in K} \sum_{i \in B} x_{i,k} \log\left(\frac{R_{i,k}}{l_i p_i}\right) \tag{6}$$

Equation (6) is subjected to the constraints of equations (7) to (11) because the variable $x_{i,k}$ is considered.

$$\sum_{i \in B} x_{i,k} = 1, \quad \forall k \in K \tag{7}$$

$$\sum_{k \in K} x_{i,k} = l_i, \quad \forall i \in B \tag{8}$$

$$\sum_{k \in K} x_{i,k} p_{i,k} \le p_{\max}, \quad \forall i \in B \tag{9}$$

$$\sum_{i \in B} x_{i,k} R_{i,k} \ge R_{\min}, \quad \forall k \in K \tag{10}$$

$$x_{i,k} \in \{0,1\} \quad \forall i \in B,\ \forall k \in K \tag{11}$$

where $p_{\max}$ is the maximum transmit power of each BS, $R_{\min}$ is the minimum data rate that guarantees the QoS received by each UE.

The problem of equation (6) subjected to the constraints from equations (7) through (11) is a mixed – integer non–

linear optimization problem which lacks convexity due to the objective function of logarithmic utility and the user association indicator binary nature. This makes the problem NP-hard. To solve the problem, the user association indicator is relaxed as $x_{i,k} \in [0,1]$ and the Lagrangian dual analysis of the problem is presented with the view to making the problem convex. The Lagrangian L, therefore, associated with the optimization problem is given as:

$$L(X, P, \mu, \lambda, v) = \sum_{k\in K}\sum_{i\in B} x_{i,k}\log\left(\frac{R_{i,k}}{l_i p_i}\right) + \sum_{i\in B}\mu_i\left(\sum_{k\in K} x_{i,k} - l_i\right) - \sum_{i\in B}\lambda_i\left(p_{\max} - \sum_{k\in K} x_{i,k}p_{i,k}\right) - \sum_{k\in K} v_k\left(\sum_{i\in B} x_{i,k}R_{i,k} - R_{\min}\right) \quad (12)$$

where, $\mu = [\mu_1, \mu_2, ..., \mu_B]^T$, $\lambda = [\lambda_1, \lambda_2, ..., \lambda_B]^T$ and $v = [v_1, v_2, ..., v_K]^T$ are the Lagrange multipliers used to relax the coupled constraints.

The dual problem of the optimization problem with respect to the dual variables is written as:

$$\min_{\mu,\lambda,v} g(\mu, \lambda, v) = \begin{cases} \max_{X, I, P} L(X, \mu, \lambda, v) \\ s.t. \\ \sum_{i\in B} x_{i,k} = 1, \quad \forall k \in K \\ 0 \le x_{i,k} \le 1, \quad \forall i \in B, \forall k \in K \\ \mu, \lambda, v \ge 0 \end{cases} \quad (13)$$

The optimal user association matrix that maximizes equation (4) is given as:

$$x_{i,k} = \begin{cases} 1, & \forall\ i = i^* \\ 0, & \forall\ i \ne i^* \end{cases} \quad (14)$$

where

$$i^* = \arg\max_i \left(\log(R_{i,k}) - \mu_i + \lambda_i p_{i,k} - v_k R_{i,k}\right) \quad (15)$$

Equation (15) is the judgment criterion for UE to determine the BS providing the best service.

Similarly, the optimal load condition for maximizing equation (6) is given as:

$$l_i^* = \frac{e^{\mu-1}}{p_i} \quad (16)$$

In solving the dual problem of equation (13), a closed form expression for the optimal solution cannot be obtained directly. This is because the second derivative of the dual function $g(\mu, \lambda, v)$ with respect to $\mu_i$, $\lambda_i$, and $v_k$ are all less than zero. Therefore, the subgradient method is employed to update the Lagrangian variables as follows [8]:

$$\mu_i(t+1) = \mu_i(t) - \delta(t)\left(l_i(t) - \sum_{k\in K} x_{i,k}(t)\right), \quad \forall\ i \in B \quad (17)$$

$$\lambda_i(t+1) = \lambda_i(t) - \delta(t)\left(p_{\max} - \sum_{k\in K} x_{i,k}(t)p_{i,k}(t)\right), \quad \forall\ i \in B \quad (18)$$

$$v_k(t+1) = v_k(t) - \delta(t)\left(\sum_{i\in B} x_{i,k}(t)R_{i,k}(t) - R_{\min}\right), \forall\ k \in K \quad (19)$$

where $t$ represents the iteration index and $\delta(t)$ is the step size.

By updating the Lagrange multipliers $\mu_i(t)$, $\lambda_i(t)$, and $v_k(t)$ using the respective equations of (17), (18) and (19), $x_{i,k}(t)$ is updated accordingly using equation (14) and (15). This enables the dual problem to converge to the global optimum since it is convex.

### 2.3 Development and Integration of the Power Control Algorithm into the UAAOBA

From the Lagrangian function given in equation (12), the power optimization function is given as:

$$f(p_{i,k}) = \sum_{i\in B}\sum_{k\in K} x_{i,k}\log\left(\frac{R_{i,k}}{l_i p_i}\right) - \sum_{i\in B}\lambda_i\left(p_{\max} - \sum_{k\in K} x_{i,k}p_{i,k}\right) \quad (20)$$

The total power consumption of the $i^{th}$ BS, $p_i$ is given:

$$p_i = p_{c,i} + \frac{1}{\eta}\sum_{k=1}^{K} x_{i,k}p_{i,k} \quad (21)$$

Substituting equation (19) into (18) gives:

$$f(p_{i,k}) = \sum_{i\in B}\sum_{k\in K} x_{i,k}\log\left(\frac{R_{i,k}}{l_i\left(p_{c,i} + \frac{1}{\eta}\sum_{k=1}^{K} x_{i,k}p_{i,k}\right)}\right) - \sum_{i\in B}\lambda_i\left(p_{\max} - \sum_{k\in K} x_{i,k}p_{i,k}\right) \quad (22)$$

Since the first and second order partial derivative of $f(p_{i,k})$ with respect to $p_{i,k}$ exists, the variable $p_{i,k}$ is updated using the Newton – Raphson method as follows [9]:

$$p_{i,k}(t+1) = p_{i,k}(t) - \delta(t)\Delta p_{i,k} \quad (23)$$

where $\Delta p_{i,k}$ is given as:

$$\Delta p_{i,k} = \frac{\left|\frac{\partial f}{\partial p_{i,k}}\right|}{\left|\frac{\partial^2 f}{\partial p_{i,k}^2}\right|} \quad (24)$$

The first derivative of equation (22) with respect to $p_{i,k}$ is given as:

$$\frac{\partial f}{\partial p_{i,k}} = \sum_{i\in B}\sum_{k\in K} x_{i,k}\left(\frac{\beta_k}{(1+\beta_k)\ln 2 \log_2(1+\beta_k p_{i,k})} - \frac{\sum_{k\in K} x_{i,k}}{\eta\left(p_c + \frac{1}{\eta}\sum_k x_{i,k} p_{i,k}\right)}\right) + \sum_{i\in B}\lambda_i \sum_{k\in K} x_{i,k} \tag{25}$$

And the second derivative of equation (21) with respect to $p_{i,k}$ is given as:

$$\frac{\partial^2 f}{\partial {p_{i,k}}^2} = \sum_{i\in B}\sum_{k\in K} x_{i,k}\left(\frac{\beta_k}{\ln 2}\left(\frac{(1+\beta_k)}{(1+\beta_k p_{i,k})^2 \log_2(1+\beta_k p_{i,k})} + \frac{\beta_k}{(1+\beta_k p_{i,k})^2 \ln 2 (\log_2(1+\beta_k p_{i,k}))^2}\right) - \left(\frac{\sum_{k\in K} x_{i,k}}{\eta\left(p_c + \frac{1}{\eta}\sum_{k\in K} x_{i,k} p_{i,k}\right)}\right)^2\right) \tag{26}$$

The minimum transmit power for the BS required to achieve the updated BS transmit power of equation (24) is derived by substituting equation (2) into QoS constraint of equation (10) to give:

$$\sum_{i\in B} x_{i,k} w_{i,k} \log_2\left(1+\beta_k {p^*}_{i,k}\right) \geq R_{\min} \tag{27}$$

But for user association with optimal bandwidth allocation, the following expression is obtained [5]:

$$w_{i,k} = \frac{W_i}{\sum_{k\in K} x_{i,k}}, \quad \forall i \in B \tag{28}$$

Substituting equation (26) into equation (25) gives:

$${p^*}_{i,k} = \frac{1}{\beta_k}\left(2^{\frac{R_{\min}}{W_i}} - 1\right) \tag{29}$$

Now, if the transmit power, $p_{i,k}$ is less than the minimum transmit power, ${p^*}_{i,k}$, then:

$$p_{i,k} = {p^*}_{i,k} \tag{30}$$

The integration of the power control algorithm into the UAAOBA to form an HUAAOBAPC enables the updating of the transmit powers of the BSs to adapt to the number of UEs connected to the respective BSs and leads to the improved load balancing and energy efficiency of the network. The power control algorithm allocates the minimum transmit power to the UEs while satisfying the QoS requirement in order to achieve a better energy efficiency of the network.

The flowcharts for integrating the power control algorithm into the user association algorithm with optimal bandwidth allocation algorithm is shown in Figure 1. Also the power control algorithm flowchart is provided in Figure 2.

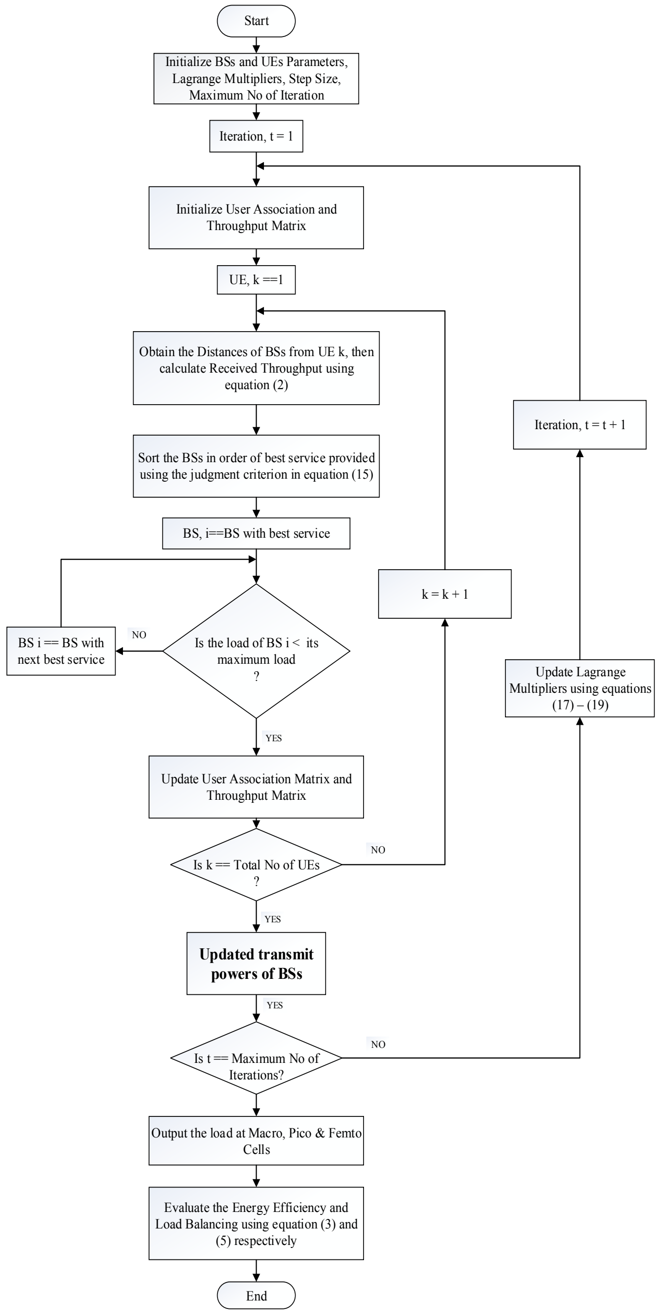


Figure 1. Developed Hybrid Algorithm for User Association and Resource Allocation

## 2.4 Simulations

The performance of the developed HAUARA is evaluated by simulation. The minimum number of macro BS (one) which can be deployed in a HetNet is considered. The macrocell is under-layed with picocells and femtocells to form a three-tier HetNet. The cell radii of the picocells and femtocells are 0.1 km and 0.01 km, respectively as specified by LTE release 12 and beyond [10]. The standard parameters used for the simulation are shown in Table 1, which are consistent with the simulation scenario used in a system level simulator for 5G mobile networks [11].

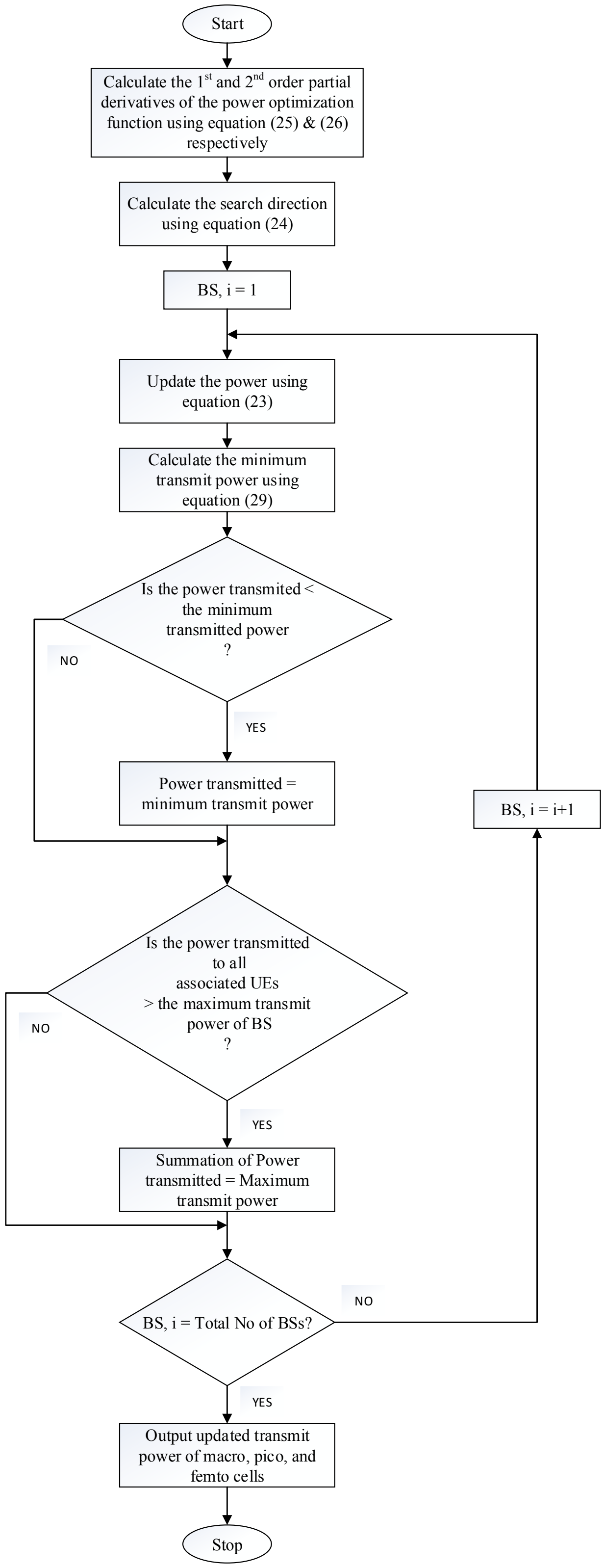


Figure 2. Power Control Algorithm

Table 1. Standard Simulation Parameter

| Parameters | Values |
|---|---|
| Macro BS bandwidth | $20\,MHz$ |
| Macro BS frequency | $2\,GHz$ |
| mmWave BS bandwidth | $5\,GHz$ |
| mmWave BS frequency | $38\,GHz$ |
| Macro BS transmit power | $20\,W$ |
| Pico BS transmit power | $1\,W$ |
| Femto BS transmit power | $0.1\,W$ |
| Noise power density | $-174\,dBm/Hz$ |
| Minimum UE data rate | $1\,Gbps$ |

The circuitry power of the different BS is also simulated using parameters shown in Table 2 [12].

Table 2. Circuitry Power of the Different BSs Components

| BS Type | Baseband Power | Radio Frequency Chain Power | Phase Shifter Power | Power Amplifier Efficiency |
|---|---|---|---|---|
| Macro BS | 100W | 5W | 1W | 0.7855 |
| Pico BS | 0.5W | 0.25W | 0.05W | 0.8500 |
| Femto BS | 0.2W | 0.12W | 0.02W | 0.9000 |

## 3. RESULTS AND DISCUSSION

The performance of the HAUARA is first given in terms of time of convergence of the network energy efficiency and load balancing with respect to the UAAOBA. The optimal solutions of the algorithms are taken at convergence. Consequently, the performance of the HAUARA using the network energy efficiency and load balancing with respect to the UAAOBA is analyzed for increase number of macro BS antennas, pico BSs, and femto BSs. This is to ascertain the algorithm with the best performance.

### 3.1 Convergence Behaviour of Algorithms

The performance of the developed HAUARA with respect to UAAOBA is first illustrated by analyzing its convergence behavior and computational cost in terms of network energy efficiency as shown in Figure 3. The convergence analysis is carried out to ensure that the algorithm converges and therefore provides an optimal solution for energy efficiency.

From Figure 3, it is observed that the UAAOBA obtains an optimal solution for energy efficiency after the sixth iteration as against the HAUARA that obtains an optimal solution after the fourteenth iteration. This is because, in the UAAOBA, the algorithm iterates for optimal user association with the subgradient method to provide for the best quality of service of UEs using equation (15) as the judgment criterion. While the HAUARA iterates simultaneously to obtain an optimal user association and transmit powers of BSs using the subgradient method and Newton method, respectively. Subsequently, the HAUARA obtains a higher energy efficiency at convergence with respect to UAAOBA. The maximization of the network energy efficiency in the HAUARA is attributed to the BS transmit power updates algorithm that minimizes the transmit power of the BSs and efficiently coordinates cross-tier interference and inter-tier interference. Therefore, the HAUARA enables the UEs in the network to receive better throughput distribution and load balancing as against the UAAOBA as shown in Figure 4, which therefore leads to better energy efficiency of the network.

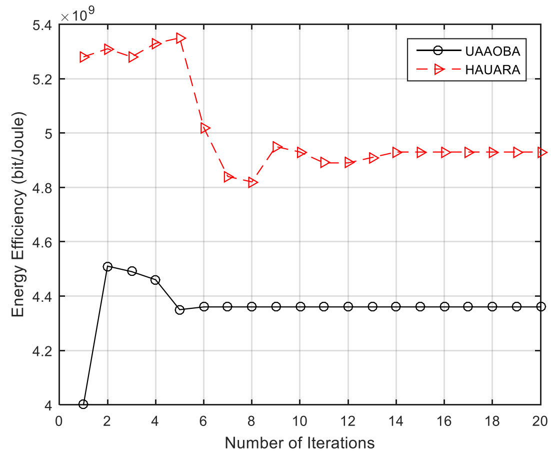


Figure 3. Algorithms Convergence Behaviour of Energy Efficiency

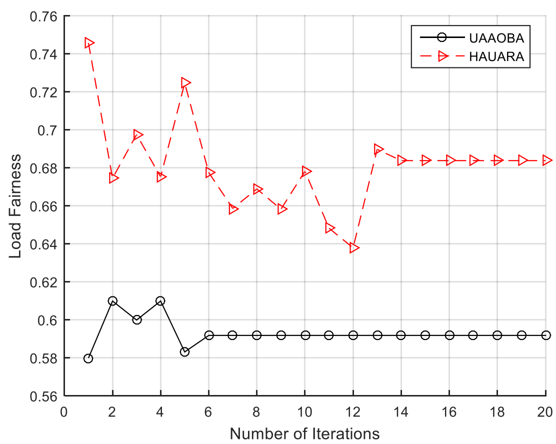


Figure 4. Algorithms Convergence Behaviour of Load Fairness

Therefore, the HAUARA cannot only achieve an optimal solution, but it also provides a load balancing property that favored HetNet deployment in order to maximize the network energy efficiency under the QoS requirements.

### 3.2 Performance of Algorithms with Increasing Number of Macro BS Antennas

Secondly, the performance of the HAUARA with respect to UAAOBA is illustrated by evaluating the energy efficiency and load balancing of the network with increase number of Macro BS massive MIMO antennas while keeping the number of antennas at the pico BS and femto BS constant at 400 (this is because of their same carrier frequency). In evaluating the network energy efficiency with the increasing number of macro BS antennas, the number of macro BS antennas is set to be less than or equal to the mmWave BSs antennas (that is, the antennas at the pico BS and femto BS). This is because the number of massive MIMO BS antennas is a function of its carrier frequency and the mmWave BSs utilizes higher carrier frequency than that of the macro BS. In these simulations, two pico BSs and twenty femto BSs each are randomly deployed in the macro cell coverage area while maintaining the simulation parameters shown in Table 1 and 2. The results obtained for the energy efficiency of the network with the varying number of massive MIMO antennas at the macro BS for the HAUARA with respect to UAAOBA is as illustrated in Figure 4.

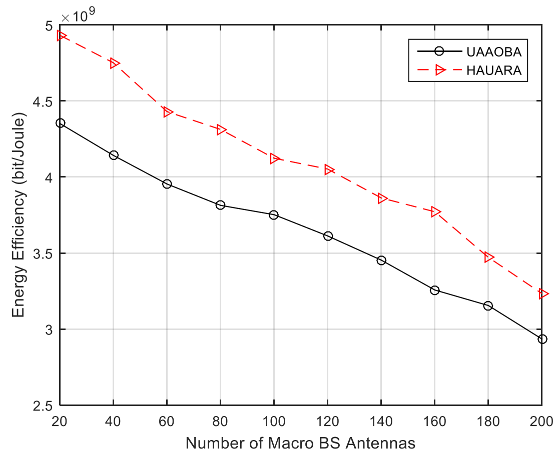


Figure 5. Energy Efficiency for increase Number of Macro BS Antennas

As observed in Figure 5, the energy efficiency of the network for both algorithms decreases with increased number of massive MIMO antennas at the macro BS. This is because increasing the number of antennas at the macro BS results in an increase of the number of UEs associated with it. This result to more UEs be associated to the macro BSs and hence decreasing load balancing of the network as shown in Figure 6.

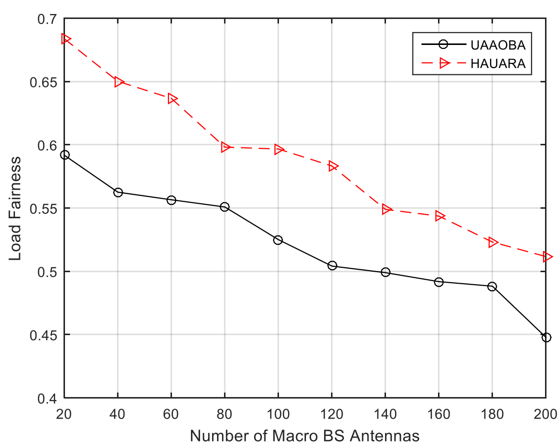


Figure 6. Load Fairness for increasing Number of Macro BS Antennas

The decreasing load balancing of the network with increasing macro BS antennas leads to the decrease of the energy efficiency of the HetNet due to the higher transmit power of the macro BS. This is attributed to the fact that the high transmit power of macro BS leads to an increase in the receive powers of UEs at different distances from the macro BS. The increase receive powers of the UEs cause increase power radiation by the macro BS to its serving UEs which corresponds to the increase of the dynamic power consumption of the macro BS. This contributes to the overall increase in the power consumption of the network and a subsequent reduction in the energy efficiency of the network. Also, increasing the number of antennas of a BS result to a corresponding increase of the static power consumption of the BS. This leads to the overall power consumption of the network and subsequently, causes a decrease of the energy efficiency of the network. Consequently, it is observed that regardless of the number of macro BS antennas, the HAUARA achieves better energy efficiency and load balancing than the UAAOBA. The average energy efficiency for the HAUARA and UAAOBA from Figure 5 is computed as $4.0992 \times 10^9$ bit/Joule and $3.6424 \times 10^9$ bit/Joule, respectively. Thus, the HAUARA has network energy efficiency performance improvement of 12.62% with respect to UAAOBA. This is because the HAUARA maximizes the network energy efficiency by coordinating the load fairness of the network. Also, From Figure 6, the load balancing improvement of HAUARA as compared to UAAOBA for increasing number of macro BS antennas is computed as 12.36%.

### 3.3 Performance of Algorithms with Increasing Number of Pico BSs

Similarly, the energy efficiency and load balancing of the network is evaluated for an increasing number of pico BSs. This is to ascertain the performance of the HAUARA with respect to UAAOBA when increasing the number of pico BSs in the three-tier HetNet. In this simulation, the number of macro BS and mmWave BSs (pico BSs and femto BSs) massive MIMO antennas are arbitrarily set as 20 and 400 respectively. This is because the mmWave BSs is operating at a higher frequency than the macro BS with a frequency ratio of 1:20. Hence, the mmWave BSs support larger number antennas. The results obtained for the energy efficiency of the network with a varying number of pico BSs with the constant deployment of 20 femto BSs is as shown in Figure 7.

From Figure 7, the energy efficiency of the network for HAUARA and UAAOBA increases with the number of Pico BSs up to 18 pico BSs per macro cell. Thereafter, for UAAOBA, the energy efficiency of the network began to decrease with the increasing number of pico BSs and remains fairly constant for HAUARA. This is attributed to the overwhelming increase of the static power consumption of the pico BSs component. For the HAUARA, as the number of pico BSs increases, the algorithm as compare to UAAOBA has higher load fairness as shown in Figure 8. This leads to the increase sum rate of the network. This, therefore, causes a subsequent increase in the energy efficiency of the network due to the decrease of the dynamic power consumption of the network.

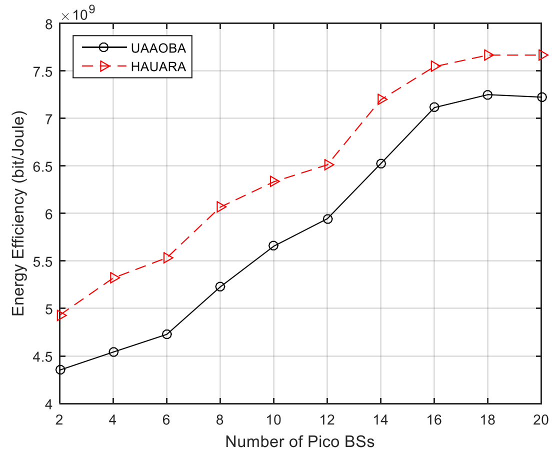


Figure 7. Energy Efficiency for Increasing Number of Pico BSs

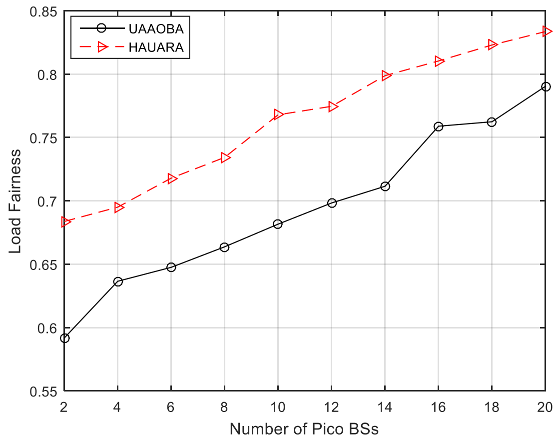


Figure 8. Load Fairness for increasing Number of Pico BSs

The average energy efficiency of the HAUARA and UAAOBA for an increasing number of pico BSs are computed as $6.4778 \times 10^9$ bit/Joule and $5.8567 \times 10^9$, respectively. Therefore, the HAUARA has network energy efficiency improvement of 10.61% as compared to UAAOBA. Also, From Figure 8, the load balancing improvement of HAUARA as compared to UAAOBA for increasing number of pico BSs is computed as 10.04%.

### 3.4 Performance of Algorithms with Increase Number of Femto BSs

Consequently, the energy efficiency and load balancing of the network is evaluated with an increasing number of femto BSs. The results obtained for the energy efficiency of the network of varying number of femto BSs with the constant deployment of 2 Pico BSs is shown in Figure 9.

As shown in Figure 9, the energy efficiency of the network for UAAOBA increases with the number of femto BSs per macrocell for a number of femto BSs up to 140 femto BSs. Thereafter, the energy efficiency of the network began to decrease. But, for HAUARA, the energy efficiency of the network increases with the number of femto BSs per macrocell up to 180 femto BSs and decreases thereafter. The decrease of the energy efficiency beyond these values of femto BSs for both algorithms is attributed to the overwhelming increase of the static power consumption of the femto BSs component which then leads to the overall reduction of the energy efficiency of the network. For the HAUARA, as the number of femto BSs increases, the algorithm as compare to UAAOBA has higher load fairness as shown in Figure 10, which leads to the increase sum rate of the network.

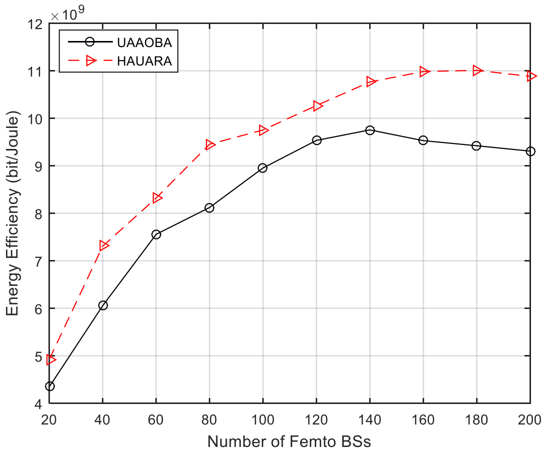


Figure 9. Energy Efficiency for Increasing Number of Femto BSs

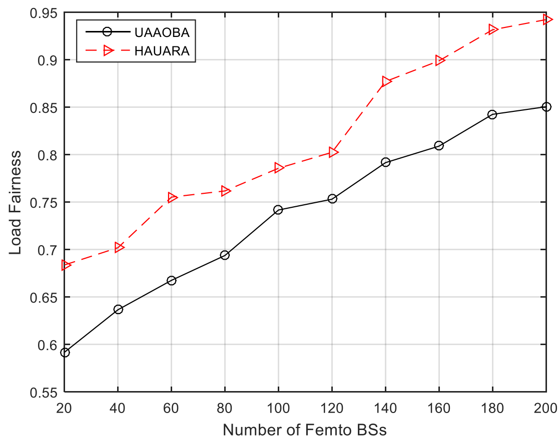


Figure 10. Load Fairness for increasing Number of Pico BSs

This, therefore, causes a subsequent increase in the energy efficiency of the network due to the decrease of the dynamic power consumption of the network. The average energy efficiency of the HAUARA and UAAOBA for an increase number of femto BSs are computed as $9.3701 \times 10^9$ bit/Joule and $8.2619 \times 10^9$ bit/Joule, respectively. Therefore the HAUARA has network energy efficiency improvements of 13.44% as compared to UAAOBA. Also, From Figure 10, the load balancing improvement of HAUARA as compared to UAAOBA for increasing number of femto BSs is computed as 10.34%.

## 4. CONCLUSION

The paper presents the development of a hybrid algorithm for user association and resource allocation to improve load balancing and energy efficiency in 5G HetNet that integrates massive MIMO and mmWave with hybrid beamforming. The developed algorithm provides for optimal solution for user association, bandwidth allocation, and power allocation to UEs simultaneously. This lead to the maximization of the network energy efficiency by the coordination of the load fairness of the network while guaranteeing the quality of service requirement of the UEs. The developed algorithm outperforms the user association algorithm with optimal bandwidth allocation in terms of network energy efficiency and load balancing with the increasing number of massive MIMO antennas, pico BSs, and femto BSs.

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