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Load Balancing With Offloading Algoritm for xG Heterogeneous Wireless Cellular Network

Jenia A Jeba[1] , Farhana Islam[2] , Sanjana R Tammim[3] , Z I Chowdhury[4] and M S Kaiser[5]
Institute of Information Technology
Jahangirnagar University, Dhaka-1342, Bangladesh
Email : {zeniazeba , farhanaamy2378 }@yahoo.com,
sanjanatammim@gmail.com,
{ zic , mskaiser } @juniv.edu

Abstract— **The ever growing mobile data traffic, due to increasing data demand of increasing number of users, has motivated researchers to analyze performance of next generation heterogeneous wireless network (xGHWnet). The xGHWnet consists of micro base station (mBS) of Long Term Evolution (LTE) or Long Term Evolution-Advanced (LTE-advanced) mobile cellular network and pico hotpot(s) to cover dead zone or number of coverage zone. A handoff algorithm has been proposed to balance the traffic load of LTE and LTE-Advanced and then improving the overall capacity. An offloading algorithm has also been introduced to reduce computation latency and power consumption. Fractional Frequency Reuse (FFR) is used to improve the channel utilization and reduce interference. The performance of the proposed system has been evaluated using MATLAB Simulation. It has been found that the proposed system outperforms traditional system.**

Keywords—heterogeneous network, LTE, LTE-Advanced, traffic offloading, FFR, power allocation, energy efficient.

I. Introduction

Next Generation Heterogeneous Wireless Network (xGHWnet) consists of wireless local area network (WLAN), Worldwide Interoperability for Microwave Access (WiMax),Long Term Evolution (LTE) and offers high speed mobile broadband internet to cellular users. These allow vertical Hand Off (HO) between wireless protocols and thereby mitigate dead zone of mobile cellular network. Vertical HO is used to balance the traffic load and improve the performance of the network. To resolve dead-zones and provide an equal network coverage both in indoor and outdoor, pico cell should be implemented as per an optimal number besides the micro Base Station (mBS). xGHWnet allows integration of low power pico Base Station (pBS) WiFi with micro base station of LTE network. But it will lead increased interference between micro to pico, pico to pico and from other neighboring base stations. To reduce the interference Fractional Frequency Reuse (FFR) and power control algorithm have been proposed by many researchers [10][11][15][23][24], which would let the network to provide highest data speed in the lowest power consumption and negligible intra-cell and inter-cell interference. Again Orthogonal Frequency Division Multiple Access (OFDMA) modulation scheme is to be used to imply the use of multiple carrier frequencies and then providing individual power to individual carrier frequency.

Load Balancing through vertical Hand Off (HO) and data offloading to cloud improve data rate and process power of User Equipment (UE). When the traffic load of an mBS has raised to certain limit, UE can be hand over to pico base station (pBS). Whereas the offloading mobile traffic to cloud can perform CPU intensive apps in cloud. Thus the capacity will be improved.

In this work, our first aim is to study the reasons of dead-zones creation in heterogeneous network and accordingly find out an optimal way for resolving dead-zones such as prioritizing on the deployment of small base stations (BS) to minimize dead zone problem.

Then we propose vertical HO and offloading algorithm that maximizes network throughput by reducing interference, unnecessary vertical HO, and note power consumption. By using OFDMA digital modulation scheme and FFR under LTE and LTE-Advanced technology, it is supposed to increase channel utilization and reduce interference.

Again, multiple carrier frequency and dynamic channel allocation to cellular User Equipment's (UEs) will also improve the traffic load balancing in the xGHWnet. The high speed demand and battery life of User Equipment (UE) is again the main concern. To achieve high speed, a very high power consumption takes place. But as it is very costly, an optimal power allocation algorithm is being proposed which is going to balance between the high speed demand and the power consumption cost. Above all, main concern is to provide load-balancing through the algorithms which takes into account the offloading to cloud and handoff capability.

Above all, the main concern is to propose load balancing and offloading algorithm for xGHWnet. moreover, FFR has also been proposed to improve Signal to Interference plus Noise Ratio (SINR).

This work presents the system model to be used and the SINR calculation according to power consumption is described in

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section III the load balancing algorithm is explained section IV, the criteria for offloading to cloud is depicted in section V, section VII finally draws the conclusion.

II. RELATED WORKS

Many research works have been done on Macro-femto or Micro-femto LTE Heterogeneous wireless cellular network regarding either handover mechanism [6][7][8][16][17][18][19][21][22] or offloading to cloud [1][3][4][5] to reduce the node power consumption, and improve energy efficiency and performance of wireless nodes [20]. In most of the works, we have found in literature until now, authors have considered vertical handoff (HO) mechanism for reducing power consumption and increasing energy efficiency. In this work, we are not only considering HO but also offloading the processing of mobile node to cloud for the purpose of increasing device capacity by letting the CPU intensive computations performed in the cloud rather than in the device itself and thus improving the performance. That is, both the HO and offloading to cloud mechanism are considered at the same time for the downlink of LTE and LTE-Ad Micro-Pico xGHWNet in this work for overall power consumption reduction and increasing energy efficiency. Again the existing works [2] have considered the Reference Signal Receive Power (RSRP) for initiation of HO whereas in this work, available number of subcarriers within the pBS at a certain time is also considered for HO. We are also considering FFR for interference mitigation and increasing the capability of resource reuse as existing works [9][11][10][15][23][24]. In [9][11][13], authors have considered actually two partitioned cell but we are considering three-partitioned cell to increase the frequency reuse factor and increase resources. In [12] the frequency allocation is not dynamic, a priori planning is required, but in this work that approach is considered dynamic. Again here we are combining power allocation scheme with FFR technique, that is dynamically allocating individual power (figure 2) to individual carrier frequency, that is, when re-assigning the same fractional frequency in another different cell, a different amount of power is to be provided to that carrier frequency proportional to the amount of work load of individual UEs, which makes the scheme an improved version than previous works. This scheme is not only helpful in interference mitigation but also in the maximum resource utilization. After the micro cell being allocated the frequency band as per the FFR technique, the pico cells choose the sub-bands which are not used in the micro cell to avoid interference.

III. SYSTEM MODEL

The SNIR of -th micro user equipment (MUE) on -th subcarrier, is presented as :

= Where,

is the power consumption of -th micro user equipment (MUE) on -th subcarrier,

is the channel gain (considering Rayleigh fading, path loss) of -th MUE on th subcarrier,

is the variance of Additive White Gaussian Noise (AWGN),

is the power control factor of i pBS on -th subcarrier,

is the interference power of pBS on -th subcarrier,

is the number of pBSs

is the interference gain (led by path loss) of pBS on -th subcarrier,

The SNIR of pBS at the pUE on -th subcarrier, is presented as :

$$\gamma_{fo}^{n} = \frac{P_{fo}^{n} h_{fo}^{n}}{\sigma^2 + \sum_{k\in\phi_p, k\neq f} \eta_{ko}^{n} P_{ko}^{n} h_{ko}^{n} + \sum_{q\in\phi_m} P_{qo}^{n} H_{qo}^{n}}$$

is the power consumption of pBS at the pUE on -th subcarrier,

is the channel gain (pathloss) of pBS at the pUE on -th subcarrier,

is the number of pBS

is the number of mBS

is the interfering power of mBS at the pUE on -th subcarrier,

is the channel gain (considering Rayleigh fading, path loss) of mBS at the pUE on -th subcarrier,

Here the prime concern is to minimize

Subject to,

$$\gamma_{fo}^{n} \geq 2^{D_{fo}^{n}} - 1$$

= maximum data transmission rate of -th MUE on -th subcarrier,

= maximum data transmission rate of of pBS at the pUE on -th subcarrier,

Scheme for Power control :

$$= \frac{P_m^n H_m^n}{\sigma^2 + \sum_{i=1}^{l} \eta_{im}^n P_{im}^n g}$$

Or, $$\eta_{ko}^{n} \leq \left[\frac{P_m^n H_m^n}{2^{D_m^n}-1} - \sigma^2 - \sum_{i=1}^{l} \eta_{im}^n P_{im}^n g_{im}^n\right]_g^-$$

The pico BS adjusts its transmit power in the following way :

$$\eta_{ko}^{n} = \min\left[\left[\frac{P_m^n H_m^n}{2^{D_m^n}-1} - \sigma^2 - \sum_{i=1}^{l} \eta_{im}^n I\right]\right.$$

$$\gamma \geq \frac{(2^{D_{fo}^{n}} - 1)(\sigma^2 + I_f + I_m)}{(\gamma_m^n - a) P_{ko}^n h_{ko}^n}$$

= and =

Where is instant SNIR of -th micro user equipment (MUE) and are some constants with relevant values

<

Fractional Frequency Reuse:

Fractional frequency reuse (FFR) is an interference management and subcarrier frequency reuse technique. It is well-suited to multicarrier modulation technique OFDMA where the cells are partitioned into spatial regions and different frequencies are reused to each region.Fractional Frequency Reuse applied to wireless cellular network suggests using the same frequencies over diverse geographic areas for intensifying the number of users. The procedure is to let a fraction of the total frequency band in each cell such a way, that no two neighbor cells use the same set of carrier frequency. Let us consider that the total frequency spectrum is divided into 4 set of carrier frequencies indicated by 4 different colors (figure 1). Typically in LTE network 3 or 7 is the number of cell pattern that the frequency band is divided into and repeated after, here in (figure fig1) a 7 cell pattern is shown where each cell is assigned 4 different set of subcarrier frequencies and divided into 3 sectors in different combination to mitigate interference between neighboring cells and to increase spectrum utilization. Since each sector is divided into inner, middle and outer region and assigned three unique set of carrier frequencies among the 4 set of carrier frequencies (figure1}), so in total each cell is utilizing all the 4 set of carrier frequencies yielding that a 7-cell pattern using 4*7= 28 different combination. A fractional frequency reuse factor of 1/28 has been offered in this work. The neighboring sector would have just the opposite combination of frequency set for inter-cell interference avoidance.

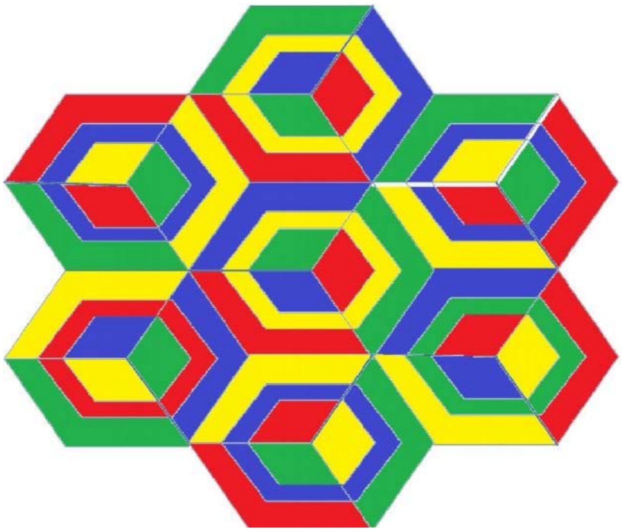

Fig 1: Fractional Frequency Reuse pattern for the prosed system

The carrier frequency allocation idea that is followed in each sector is a bit different than traditional designs because for each cell a set of subcarrier frequency is common for all the three sectors (figure 1), in the middle region). The design pattern is differentiated nothing but by the amount of power assigned to it (figure 2). The allocated amount of power is more (figure 2) when it is required to provide network coverage to an UE residing in the cell edge because of the distance from the micro BS. But the UEs near the BS or in the center region require less power. A certain amount of equal power is allocated to the subcarrier frequency set which is common for all the sectors (figure 2) in each cell i.e. the middle region.

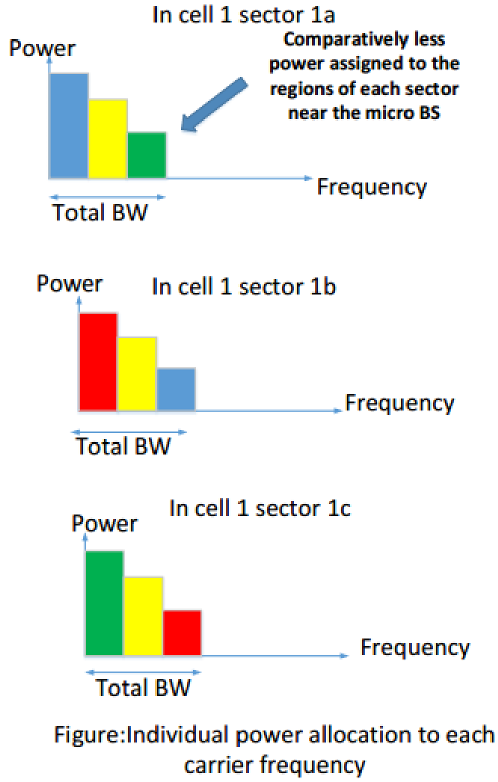

Fig 2: Individual power allocation to each carrier frequency

The interesting fact is that this power allocation scheme is totally dynamic. The pico cells deployed in the cell edge are to provide network coverage and overcome dead-zones. i.e. each cell has approximately the full system bandwidth that is, all the four set of carrier frequencies are utilized and designed using a different combination in each of the three sectors of each cell.

IV. Traffic Handoff Algorithm

Suppose there are 1,…, Micro UEs (MUEs) under the micro BS (mBS) and 1,…, Pico UEs (PUEs) under each pico BS (pBS) , the number of total pBSs are 1,…, . If the number of UEs for the micro cell increases beyond then we may consider that the traffic load is now beyond the maximum traffic that it can handle. The traffic load of the micro BS and neighboring pBSs are defined as and respectively. One of the important parameters that has to be considered is the number of maximum subcarriers allowable for a pico BS and the available subcarriers at each pBS at a certain time. When the traffic load is greater than the maximum traffic limit, means more user devices want to get the network coverage from that mBS but it is not able to provide so, then it should definitely handoff the traffic to neighboring pBS. The number of extra MUEs that want network coverage from the mBS is defined as 1,…, . In this algorithm we are providing scheme for micro to pico handoff within the same cell and considering only the downlink. We define as the set of the RSRP of the pico cells 1,…, and as the RSRP of the micro BS and as the maximum RSRP that any pico BS can provide to an UE. Then, the algorithm checks which neighboring pBSs can provide maximum amount of Reference Signal Receive Power (RSRP) than a certain threshold value ($RSRP_0$) and at the same time less amount of traffic than that of maximum traffic a pBS can maintain, they would be eligible to take over the work after handoff is done from micro BS. Under these conditions, a probability calculation is made by considering highest number of available subcarriers to a pBS and maximum RSRP it can provide. The pBS which can provide highest probability value (between 0 and 1) would be regarded as target pBS and be eligible for taking handoff responsibility from the micro BS. For selecting target pico the Traffic handoff algorithm is given in algorithm. Here x and y are priority factor for RSRP and available subcarrier respectively.

Algorithm 1: Algorithm for Traffic handoff

Define , , ;
find $\Phi_m = length(ava$
if)
for c =1 to do
= 0 ;
for t = 1 to do
find $rsrp_t = \max(R_k = r_1$;
If
< and $rsrp_t > RSRP_0$ and
then
$P(R_{mn}^{u}) = \frac{1}{2}[x.\frac{rsrp_t}{RSRP_{max}} +$
then handoff to
= ;
end
end
end
end

V. CLOUD OFFLOADING

Cloud Offloading:

For each work of mobile computation, the parameters that might be taken into account are the category of the work whether it may be offloaded to cloud or not; the amount of memory usage if the computation is performed in the mobile itself; the amount of the codes when the instructions are converted into machine language.

If the computation, that is to be computed using cloud service, is divided into numbers of related modules (fragments), then it may be defined : the quantity of data during sending to cloud, the quantity of data during receiving from cloud and the total quantity of transferred data to and from cloud.

Let's presume there are numbers of fragments for offloading to cloud . This fragments have the properties described above. Let's presume that there are numbers of related fragments that could be offloaded. This individual fragments have length of sent data ; length of received data ; length of transferred data where {1,2 …. , } {1,2 …. , } and + = . We consider for fragment *j* as an indicator which notifies if the computation is performed either in the mobile device itself ( ) or in the cloud ( ).

The function to be expressed as :

$$\min_{\Psi_j \in \{0,1\}} (v_T \times w_T + v_M \times w_M + v_{CPU} \times w_{CPU})$$

Where,

;

, = Code length

$v_m = \sum$; , = Amount of memory usage

$v_{CPU} = \sum_{i=1}^{l} q_i >$; , transformation factor between Code length and CPU commands

load or weight of transfer costs (e.g. least transmission overhead)

load or weight of memory costs (e.g. least memory usage)

load or weight of processing power costs (e.g. least usage of processing power)

The three restrictions are stated as : least memory, energy and computational time consumption

Least usage of memory would follow the following condition :

The value or cost of memory that would be used for a computation cannot cross the limit of available amount of memory in the specific device.

$$v_m = \sum_{i=1}^{l} q_i \times (1 - \Psi_j) < \lambda_m \times \beta$$

is the amount of memory which is offered in a mobile which is obviously device specific

the factor deciding the memory usage limit, as an application or computation cannot access the total available memory of the mobile device though that free amount mayn't be used in any current computation

Least usage of energy would follow the following condition :

As our main target is to optimize the energy consumption, so it means that the computational tasks would be offloaded to cloud only if the amount of consumed energy is certainly less than the consumed energy if the task is performed in the device itself.

$\xi_d - \xi_{cl} > 0$

Where,

amount of consumed energy when computation performed in the device itself

amount of consumed energy when computation performed in the cloud

Again ,

$$\xi_d = \frac{PW_d \times \mathcal{I}_d}{\mathcal{S}_d}$$

amount of consumed power when the computation is performed in the device itself

= number of commands given when the computation is performed in the device itself

= the implementation speed when the computation is performed in the device itself

The value or cost of the energy consumed while performing the task in the cloud, is equal to the summation of the energy consumption while waiting idly for the final outcome, and the energy consumption in the time of transmission, and reception,

=

= $\mathcal{P}_s \times t_s + \mathcal{P}_{trans} \times t_{trans}$

Or, = – [+ +]

Here , waiting time of the device is nothing but the time of remote computation execution time in the cloud server.

= the implementation speed when the computation is performed in the cloud server

= total amount of sent data

= total amount of received data

= Bandwidth during sending data to the cloud

= Bandwidth during receiving data from the cloud

=

=

=

Where {0,1}

Least usage of computational time would follow the following condition :

Certainly, a very fast execution or implementation of the computation is desired when it is offloaded to cloud rather than the time taken in local execution.

$t_d - t_{cd} > 0$

Here, =

=

VI. NUMERICAL ANALYSIS

This section includes Monte Carlo simulation of the proposed Hetereogeneous wireless network. It has been assured that the cell radius of LTE is less than 1 kilometer, all the users use single antenna, channel fading model is Rayleigh, Channel State Information (CSI) are known to all receivers. The effect of SNIR on figure 3 shows capacity of FFR. It has been noticed that the performance of the prpposed system has been improved drastically due to FFR. figure 4 shows effect of of pico cell on performance improvement and on the offloading rate. The rate will improve energy of the wireless node. figure 5 shows the energy efficiency will increase with the maximum permitted delay of the LTE, when the delay increases the algorithm will force the users to offload traffic to cloud and thereby improve energy efficiency. In figure 4 When the deployment of effect of pico cell is lower then the node traffic will be handed over. In figure 5 When the max permitted delay for the data transmission is higher than a predefined threshold value,wireless node with HO the data traffic to cloud server for the further processing of data.This will save the energy of wireless node and thereby more load can be accommodated.

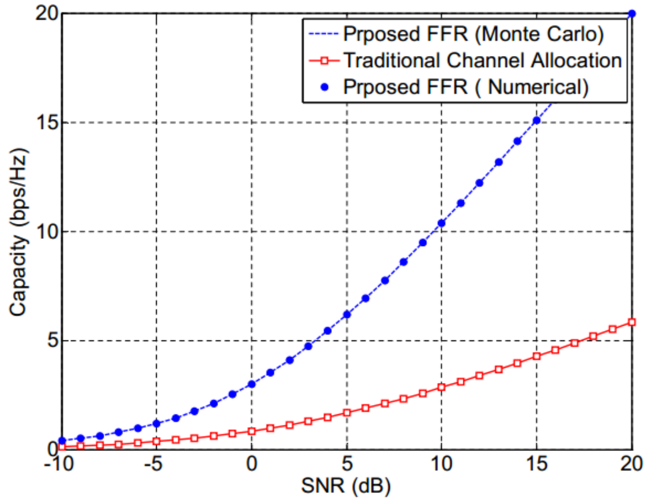

Fig. 3. Capacity comparison between proposed system with FFR and traditional system

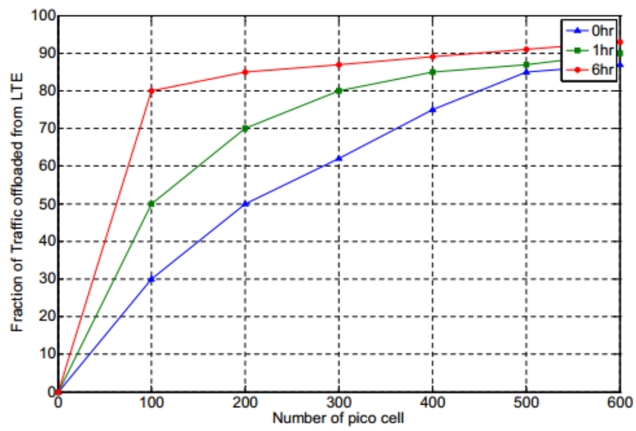

Fig. 4. Effect of pico cell on fraction of traffic offloaded from traffic LTE

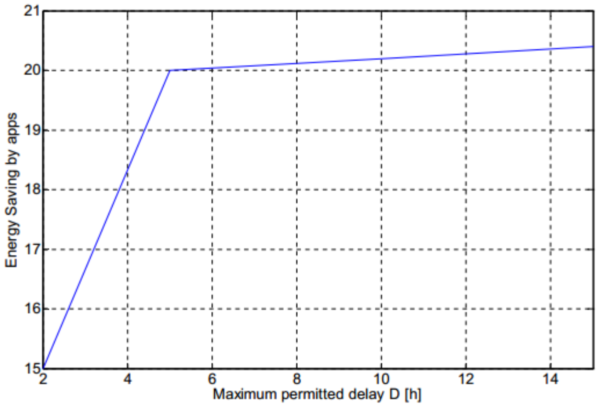

Fig. 5. Effect of maximum permitted delay of wireless data transmission on node energy saving

VII. CONCLUSION

In this work, we have proposed load balancing and handoff algorithm for heterogeneous warless network where the channel and power allocation have been done using fractional frequency reuse. The Monte Carlo simulation results show that the proposed algorithms have improved the overall capacity and reduce the energy consumption compared to the traditional LTE network. Adaptive modulation and network coding along with multiple input-multiple output will further improve the overall performance which we left for the future work.

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