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Performance Analysis of Cell Zooming Network

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Abstract- Cellular network is an inevitable part for human well being. Cell zooming deals with the concept of minimizing the energy consume by the mobile base stations. This paper describes the energy saving nature of cell zooming that can be implemented in the cellular network. The algorithms are designed such that the base stations can be switched in sleep mode under low traffic period and in normal mode under other traffic conditions. More the number of base stations sleeping; better the energy efficiency and leads to a concept of greener network.

Index Terms- Energy efficiency; Cellular network; Power Control; Base station cooperation; Cell zooming and Traffic density.

1. INTRODUCTION

As the world peeps into a situation of scarcity in the energy resources field, it is necessary to think of the need to save the energy produced. The energy consumption by the Information Communication and Technology is increasing day by day and a major part of the energy produced by each country is now utilized by the mobile cellular network. As the number of mobile subscribers has been explosively increased, each cellular operator tries their best to serve their users with a good quality of service. Apart from the voice information, now the usage data transfer increases and it overcomes the transfer of voice signals. Hence with the increase in the subscriber number and the data transaction, the operators try to tackle the situation by increasing the transmission power of the base station and it leads to the deployment of more number of base stations. As the number of base stations increases, automatically the energy consumed by base stations and the cellular network also increases.

When the base station is in its working mode whether it is lightly loaded or heavily loaded; it consumes the same transmission power all the time. Energy can be saved when the base station can be switched off during less traffic load or reduce the transmit power level of the base station. Switch off base station implies that the BS works in a sleeping mode. Cell zooming is a new technique which adaptively adjusts the cell size depending upon the traffic fluctuations.

The main objective is the need for energy efficiency due to increased no. of base stations, which in turn is due to the increased no. of cellular subscribers(i.e. increased demand), mainly due to data transfer(video streaming) through mobiles. Thus the increase in energy consumption in base station is the main problem. Cell zooming algorithms would help in achieving better energy efficiency during cell operation by controlling the base station energy consumption; at the same time blocking probability should be very small otherwise it affects the performance of the cellular network. Increased blocking probability is not tolerable for mobile users and hence it is a challenge to every operator to design its base station.

2. RELATED WORKS

Researches started working over the concept of green cellular networks after realising the desperate need for energy conservation. As the information technology is developing day by day, the issues regarding them are also increasing. Studies say that the communication system is responsible for about 3-10% of the global emission of CO2 and hence the power consumption by base station should be made under control [1]. Zhisheng Niu *et.al* proposed two zooming algorithms to switch the operation of base stations [2]. Balasubramaniam *et.al* described about three cell zooming techniques namely continuous, discrete and fuzzy. The techniques differ in the way the base stations adjust their transmit power level [3]. Sourjya Bhaumik *et.al* studied the relation between the consumed energy of the network and the cell sizes [4]. Eh Oh *et.al* studied about the switching strategies of base station by setting a threshold to switch off and switch on [5].

2.1 Base-station switching

A switching threshold ρ value is set and based on the threshold value the base station is switched ON and OFF. The energy saving depends upon the mean, variance of the traffic distribution and the number of neighboring base stations. Here, the base stations are completely switched off, when the traffic falls below the threshold. Since complete switching off creates delay in waking up the base station, the switching off

concept is replaced by sleeping modes and dimming networks [6]. It deals only with the switching of base station depending upon the threshold.

2.2 Cell zooming

Cell zooming is about traffic load balancing and reducing the energy consumption. During high traffic period, there can be a scenario where a base station is over loaded whereas the adjacent ones are lightly loaded. The concept of load balancing finds its application here. The technique of transferring the load from heavily loaded base station to the lightly loaded one is termed as load balancing. Cell zooming is commonly termed as the adaptive adjustment of the transmission power according to the traffic load. In practice cell zooming is made possible by usage of a cell zooming server. It is the server attached with the base stations take decision whether to zoom in or zoom out or go for sleep analysing the traffic density.

3. SYSTEM DESIGN

Cell zooming is designed to operate under low traffic period, when focusing on the energy efficiency factor. The transmitting power of the base station can be increased or decreased based on the concept of cell zooming. Increasing power refers to zooming out (the radius is increased) and decreasing power refers to zoom in (reducing the cell radius). Centralized algorithm and decentralized algorithm are commonly used to find the base stations that are lightly loaded [2]. But in practice it is not possible to simply increase the transmission power of base station. Interference may arise due to the power incrementing in the cell radius. When the power of one base station extends to the premises of another base station, then the powers may overlap and leads to interference in the cellular network. For every application in the mobile communication network, interference is always a limiting factor. So it is very essential to keep the interference in the cellular network under a particular level but at the same time quality of service and blocking probability and the energy efficiency need to be maintained.

When the power is increased leisurely, then more number of users can be served but at the same there is a chance for interference addition. So to keep the interference in the cell under a limit, the power cannot be increased beyond a limit. To beat the increase rising of the interference level inter-cell cooperation and power control can be included. If the base stations transmit at minimum power level by dynamically switching to the minimum cell radius then the interference can be controlled to an extent; where the minimum possible cell radius is chosen depending upon the location of the farthest mobile user under the base station coverage area.

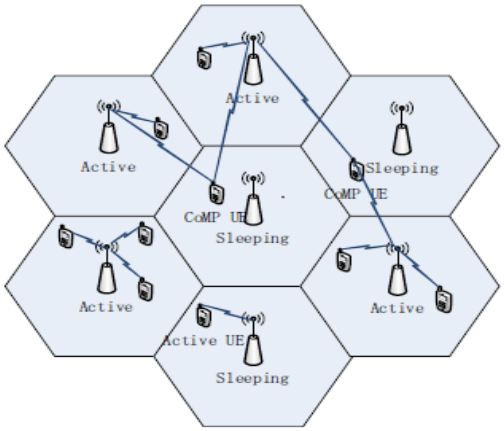

Fig.1. Cell zooming network with co-operation [7]

3.1 Inter-cell cooperation

Inter-cell cooperation aims at improving the coverage to the mobile users and thereby it helps in maximizing the energy efficiency of the cellular network. It is assumed that the total bandwidth for each base station is divided into several subcarriers. Each base station has same bandwidth and same number of subcarriers.

In the traditional system, a single user is served only by a single base station but with the concept of coordinated multi-point communication, a single user can be served by more than one base station (say B_h, B_c). With inter-cell cooperation, two base stations jointly try to serve a single user. Since two base stations are coordinated for serving a single user, the power received by the user is the summation of power received from both the base stations and by this technique users along the boundary or at remote end can be served; thereby reducing the blocking probability. By coordinated transmission interference level can also be reduced comparing with the traditional system. Figure 1 depicts cell zooming network with inter-cell cooperation.

$$P_r = P_b * G_b + P_n * G_n ; \qquad \text{Eq. (1)}$$

where P_r is the power received by the user when working under cooperation mode, P_h is the power received from home base station B_h with a channel gain of G_h over the subcarrier 'j'; Similarly, P_c is the power received from cooperative base station B_c with gain G_c over the same subcarrier 'j'.

Subcarrier allocation is done such that the inter-cell interference is minimized. Coordinated multi-point transmission can be exploited only when the base stations transmit over the same subcarrier. For maximizing the energy efficiency depending upon the user-base station distance, the base station can operate either in coordinated mode ($d > d_{th}$) or in non-coordinated mode ($d < d_{th}$). A threshold distance d_{th} is defined for mode selection.

When the user is served in the usual traditional way (no coordination employed), then the user will

experience interference from all base stations around it except its home base station.

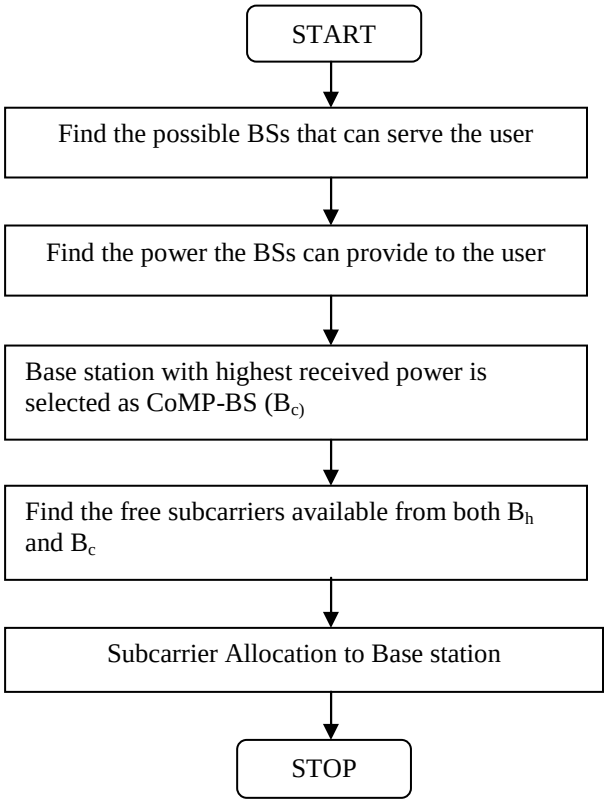

Fig.2. Flow chart for Inter-cell cooperation

With the implementation of inter-cell coordination, the interference experienced by the user is reduced since one more base station is there to serve the user and interference will be from base stations around it, other than home and coordinated base station. Inter-cell cooperation algorithm is executed under CoMP mode.

3.2 Power control

Power can be utilized efficiently by controlling the coverage only upto the farthest user. Power control made use of this concept, where the transmission power of the base station is limited according to the distance between the user and base station. Different threshold distances have been defined and depending upon the range of the distance the power amount is chosen. Let P_m be the maximum transmitted power, d is the distance between the user and the base station and d_1, d_2 be two threshold distances.

$P_{t1}= P_m *a1$; if $d<d_1$
$P_{t2}= P_m *a2$; if $d_1 \leq d< d_2$
$P_{t3}= P_m *a3$; if $d \geq d_2$; Eq. (2)

where 'a' defines the adjusting factor, which can be defined in the range $0 \leq a \leq 1$ and d_1 is set less than the value of d_2.

This technique helps in saving the power and mitigates interference. If all the users are located within the radius of d_1 then only a fraction of power has to be transmitted.

3.3 Mixing the algorithms

The above explained concepts are combined resulting algorithm with Coordinated Multi Point(CoMP) and power control [7]. Find the number of users under each base station coverage area, the one with maximum number of user coverage is considered first. The power need to be transmitted depending on the distance of the nearest user and the achievable rate is calculated. If rate is not met, depending on the distance; it works either in CoMP mode or in traditional mode. Rate is calculated in each subcarrier allocation. The process repeats until the required rate is achieved.

$$R= \log_2(1+ (P_r/(P_i + n_o))) ; \quad \text{Eq.(3)}$$

where P_r is the received power, P_i is the interference power, n_o is the noise power.

P_a be active power, N_a be number of active base stations, N_s be number of sleeping base stations, P_s be sleeping power, B_{total} be total number of base stations.

Energy saving ratio= $(P_a-P_s)*N_s /(P_a*B_{total})$ Eq.(4)
Power consumption= $P_a *N_a + N_s *P_s$ Eq.(5)

The whole algorithm terminates when all users are served or when no base station remains. Since low traffic is assumed, usually the latter happens and the remaining ones in the set define the number of sleeping base stations.

3.4 Centralized algorithm

Centralized algorithm[2] is mainly about allocation and reallocation of users. Traffic load is used as a parameter which measures the amount of traffic at each base station. The traffic intensity or the traffic load L, is defined at the ratio of summation of the user bandwidths b_{ij} to the total bandwidth of the base station, B_j.

$$L_j = \sum_{i \in \mu j} \frac{bij}{Bj} ; \quad \text{Eq. (6)}$$

where L_j denotes the traffic load at the BS 'j'.

User allocation matrix is defined such that $X=[x_{ij}]$, where $x_{ij}=1$, when a user i, is allocated to the base station'j' and $x_{ij}=0$, when the user is not allocated under the base station j. The amount of bandwidth in each base station for user allocation is $idleB_j = (1- \alpha_j)*B_j$, where α_j is the reservation factor. For each mobile user the constraint $L_j*B_j + b_{ij} \leq idleB_j$ should be checked. User re-allocation is done for the users under the base station that is going to serve in sleeping mode. The base station with the least $\frac{LjBj}{idleBj}$ ratio is selected for sleeping. The first step includes checking for bandwidth constraint. Depending upon the spectral efficiency of the base stations, the users

are allocated to the base station with highest spectral efficiency (N: Number of users).

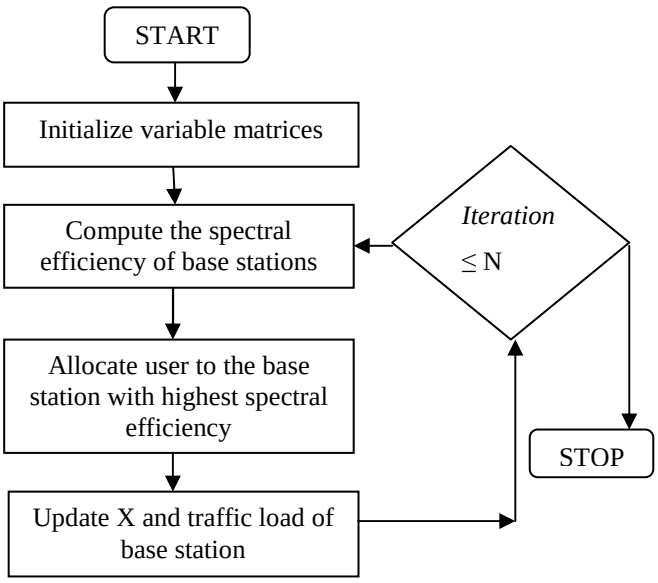

Fig.3. Flow chart for user allocation in Centralized Algorithm

4. RESULTS AND DISCUSSION

The simulation is performed with the help of MATLAB software. Number of sleeping base stations, energy saving ratio and power consumption are considered for the performance evaluation.

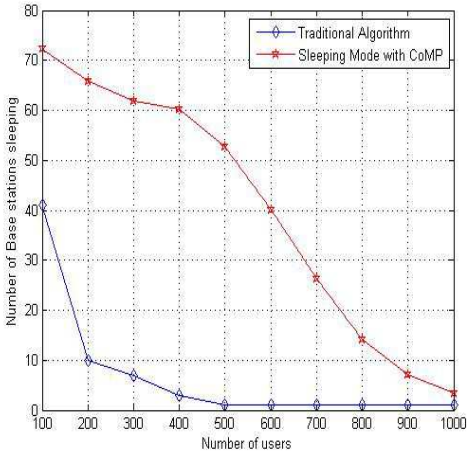

Fig.4. User number Vs Sleeping BSs number

The basic algorithm checks the traffic load of each base station and those with lesser loads are switched to sleep mode and doesn't make use of cooperation. Traditional algorithm performance deteriorates with the increase in user number. As the number of users increases; there occurs a decrease in the number of sleeping base stations. Whereas in the novel approach; a sequential allocation method is implemented along with power control, thereby finding the base stations to be switched to sleep mode.

Analyzing the spatial and temporal fluctuations in the traffic profile, the base station power transmission is altered and leads to a greener communication system. Depending to the traffic profile the base stations transmission power is varied. By including power control, the power is adjusted by determining the distance of the farthest user.

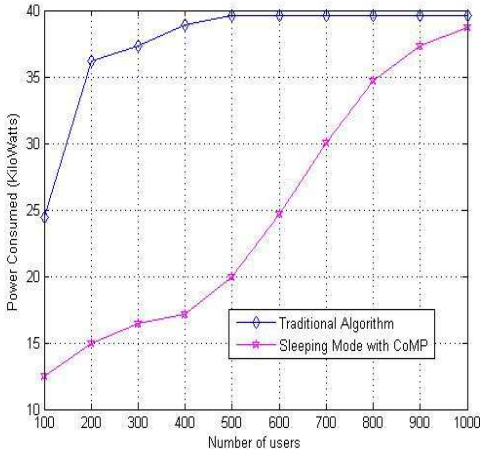

Fig.5. Base station power consumption with number of users

As the figure depicts the novel algorithm with cooperation performs far better than the traditional centralized scheme. The decrease in the number of base stations sleeping with the user will reflect in the power consumption of base station too. Since the base station number decreases the power consumption increases with the increment in the user number. With the incorporation of power control and coordination between base stations the power consumption can be reduced significantly. This corresponds to increase in the number of sleeping base stations and hence maximizes energy efficiency.

5. CONCLUSION

Cell zooming is a latest technique used to implement a greener cellular network. Greener cellular communication always aims at reducing the energy consumption of cellular system.

By considering power control technique more number of base stations can be switched off(not completely switching off, it will be in sleeping mode); whereas in normal zooming technique since the distance factor is not considered; the number of base stations that can be switched off completely depends upon the user requirement. As a future scope more work can be concentrated in the field of interference mitigation; that may arise due to the power variation (increasing power than the standard value).

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