International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 05, May-2015

Base Station Energy Performance Improvement with Optimum Switching Frequency based on the Concept of Cell Zooming

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***Abstract*— The concept of sleep mode is widely applicable in a cellular network in which the base station can be turned off if certain traffic and power conditions are met. So this technique is most often used for power saving. On the other hand, the concept of cell zooming is emerging as a very promising technology to reduce power consumption. In cell zooming, the original size of the cell can be changed according to the incoming or outgoing traffic load of that particular cell both for homogenous and heterogeneous networks. So, in this process the cell size is increased or decreased based on the traffic intensity of the cell. In this paper an algorithm is proposed which merges the concept of cell zooming and sleep mode together for significant power reduction in a cellular network. The algorithm is examined for three different traffic conditions to calculate the power saving.**

Keywords—Sleep Mode, Cell Zooming, Heterogenous network, HomogeneousNetwork, PowerEfficiency, SwithingFrequency

I. INTRODUCTION

With enormous growth in the communication sector, the overall power consumption has increased to a high level globally. Several researches are showing their concern over this increase in energy consumption, where the wireless communication sector plays a major role. Studies have also shown that base station power consumption provides most significant contribution in this regard. So, an economical solution is needed to solve this problem of high energy consumption by some suitable power reduction techniques. Sleep mode[1] is such an efficient power saving technique in which a base station can be made off under some constraints but for a particular time period. The quality of service provided to the user must be ensured. Sleep mode is broadly classified in to two broad categories: Semi Static sleep mode and Dynamic Sleep mode[2]. In the first case, the resources used in the network remain active for a long time period compared to the second case. Here, for a particular incoming traffic load the amount of network equipments that can be turned off is first identified so that reduction in power consumption while providing proper quality of service both can be achieved simultaneously. This procedure of activation and deactivation takes several hours rather than several minutes[3]. Dynamic Sleep Mode, provides option for activating components of a base station based on the user density in a cell for a particular time instant dynamically. For application of this first of all a limit is needed to be set. Ensuring the required quality of service, a particular resource component activated or deactivated around the limiting factors. This activation or deactivation normally observed in minutes based on mobility of the users into or out of the cell. The energy is saved while putting the base station in sleep mode and , it can be activated, sensing the user concentration, using any of the methods like prediction of user location, Reverse Channel Sensing or even both[2].

Cell zooming has emerged as a potential strategy to develop a green communication system in our society and it has become an essential research area of wireless communication. Cell zooming is the reduction or increment of cell size from its originally designed size in accordance with the traffic condition in a cell. The advantages offered by cell zooming concept are reduction of power consumption and solving traffic congestion problem[4]. For example, as illustrated in the following figure 1, the cell with light traffic load can zoom out to serve some of the users in two other cells. This reduces the traffic load in its neighboring cells and some cells can even go switch-off, which will result in energy saving.

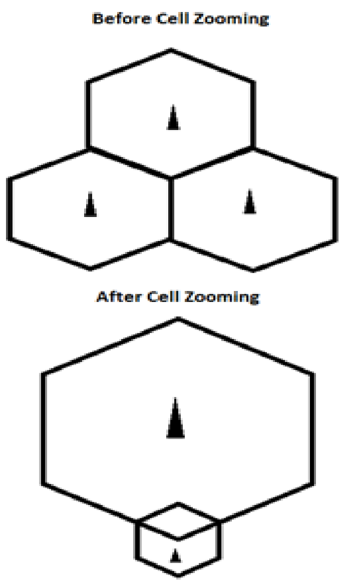

Figure 1:- Concept of Cell Zooming

The cell zooming algorithms can be grouped into two categories according to their basic similarity as discussed in [5]. These are regular or static switch-off algorithm and dynamic switch-off algorithm.

A. *Regular or static switch-off algorithm*

The regular switch-off algorithm provides an easier implementation than dynamic algorithm. Here, the cells i.e. base stations are turned off depending on a definite preset pattern. Such algorithm is applied for a definite time period where the arrival of traffic is low by network control server. The base stations which are active increases their transmission power or their antenna height so that they can also provide coverage to the switched off base stations region. In other approach, low traffic hours are defined by setting a specified traffic threshold. Since the daily traffic distribution is mostly considered as regular and uniform throughout the network, the switched-off cell pattern will not vary time by time during cell zooming period and also day by day. Thus it is seen as static algorithm. All the cells work at normal mode at out of cell zooming period. The main advantages of this type of algorithm are its easy application and noticeable power saving at night hours. On the other side, the limitation of this algorithm is that it cannot be applied for full-day operation in which time-dependent traffic fluctuation and traffic spatial distribution is high. Also, it is not useful for a location where traffic arrival pattern is not consistent day by day.

B. *Dynamic switch-off algorithm*

When the overall traffic distribution for the day is not uniform and there is an irregular pattern observed in arrival of traffic, the static switch off algorithm is not reliable. The dynamic cell zooming algorithms are developed to overcome these drawbacks. Thus, it is relatively more complicated than static switch-off algorithm. In such algorithm, the traffic condition in each cell or a cluster cells is dynamically inspected. This traffic load information is exchanged among collaborative base stations themselves called as distributed plan or via central server called as in centralized plan. Then, the cell zooming decision is made depending on the traffic load condition in each cell. Thus, on/off cells are not statically defined. This dynamic algorithm can provide power saving and at the same time it can solve traffic congestion problem if it occurs. However, the challenge in dynamic switch-off algorithm is how to manage the requirement of massive information exchange among mobile users, base stations and control server. In addition, this type of algorithm is more acceptable for micro cells rather than in macro cells because reactivating time for switched-off macro cells is considerable to set them in fast dynamic on/off operation. The organization of the paper as follows, section I was about the introduction of the two concepts, section II deals with an overview of the proposed modified algorithm. In section III, the actual algorithm is described and section IV has the results and corresponding discussions.

II. OVERVIEW OF THE PROPOSED MODIFIED ALGORITHM

In this section, an overview or the main fundamental idea behind the algorithm is explained. Every Base station consist of these important components, such as, Air conditioning, Rectifier circuit, Power amplifier, feeder, digital signal processing unit etc. Out of which some components are independent of traffic load but some others depend on incoming load traffic. With this base constraints the algorithm has been developed.

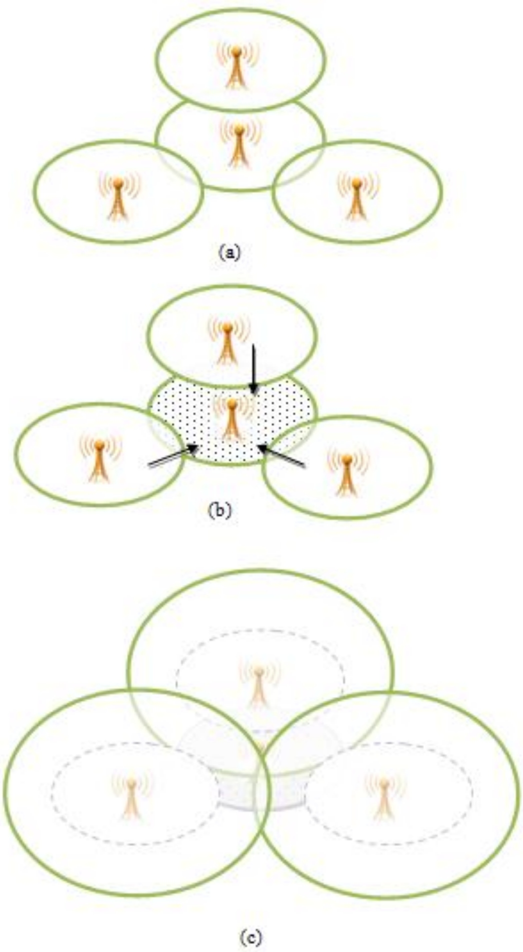

Figure 2: Actual representation of Proposed algorithm merging the concept of cell zooming and sleep mode: (a) For a network that is always on (b) Increasing the coverage of surrounding Base Stations and checking if BS can be put into sleep mode (c) Final configured network with switched off BS

The fundamental idea behind the proposed algorithm is given in figure 2. The initial situation is the always on network. For each and every Base Station in the network, it is evaluated if it is possible to put that Base station into sleep. But, it must be assured that when a particular Base Station is turned off the coverage area of it must be provided by other Base stations which are in active mode at that particular moment. After turning a particular Base Station off, the surrounding active Base stations coverage area is increased to some extent by increasing the antenna power. It can also be increased by increasing the antenna height. In the mentioned figure, the circle in the dotted format indicates previous coverage of the surrounding Base Stations. The traffic load of this switched off Base station will be divided between the neighboring Base Stations. We have set a minimum threshold power value which is termed as sleeping threshold power. If the total power consumption of a Base Station is below that pre-set value then only the base station can be considered for a switch off condition. When the sleep threshold is not obtained, the configuration is as shown in Figure 2(b) and when the sleeping power threshold is achieved, the final configuration is as shown in Figure 2(c).

Based on this overview an algorithm has been developed. The proposed algorithm for a HSPA network which gives us an overview of when to turn off the base station during sleep mode. Based on that when a particular base station is consuming less power we can turn it off provided surrounding base stations are providing coverage to its area. This condition holds for static condition, i.e. when no calls are in progress and the traffic load is relatively very small. The regular switch-off algorithm[8] is simpler compared to dynamic algorithm. In such algorithm, the cells are switched off in predefined pattern by network control server during a predefined time period when low traffic arrival is expected. The active cells are managed to zoom out by increasing transmitted power or antenna height to cover the convergence umbrella over the switched-off cells. In other approach, low traffic hours are defined by setting a specified traffic threshold[9]. Since the daily traffic distribution is mostly considered as regular and uniform throughout the network, the switched-off cell pattern will not vary time by time during cell zooming period and also day by day. Thus it is seen as static algorithm. All the cells work at normal mode at out of cell zooming period. The main advantages of this type of algorithm are simplicity and noticeable power saving at night hours[11]. On the other side, the limitation of this algorithm is that it cannot be applied for total-day operation in which time-dependent traffic fluctuation and traffic intensity variation comes into picture.

III. PROPOSED MODIFIED CELL ZOOMING ALGORITHM ALONG WITH THE CONCEPT OF SLEEP MODE

In this section the algorithm is discussed. The algorithm is applicable for a network where the traffic distribution is considered to be uniform throughout the day. Also the algorithm is applicable for a HSPA network configuration. The algorithm can be described in the following steps.

- start: calculate normalized value of the voice calls(V) which lies between 0 and 1.
- If its value lies between 0 and 0.6,
  - i. Calculate the load factor using the formula L=0.6*V+0.2.
  - ii. Determine the maximum switching frequency Mmax i.e. how many number of times we can turn off a power amplifier.
  - iii. Calculate the minimum power(Pmin) consumed by the base station at the maximum switching frequency(Mmax).
- If this value of P_{min} is below a certain level called as sleeping power threshold(S_{th}).
  - i. Determine 3 closest base station of the active station in consideration.
  - ii. Increase the coverage of this base station by increasing the transmission power of them.
- If the coverage is achieved and the total power increased by this three base station <Pmin, then we can turn off the base station off.
- If any of the above mentioned conditions fails then it is not possible to turn off the base station.

IV. RESULTS AND DISCUSSION

For evaluating this previously mentioned algorithm, several parameters are required out of which two attributes has been identified i.e. cell load factor (L) and normalized value of the voice calls(V). The following simulation results reflects this conditions well. For required simulation the parameter values we have taken is noted down. For the evaluation two new parameters have been added. The parameters we have used for the simulation purpose is listed below in the table format.

TABLE I: PARAMETERS REQUIRED FOR SIMULATION

Parameter	Symbol	Value
Avg. bits per packet	S	100
Avg. transmission rate	R	1000
Times the number of packets/ second	Λ	{2,5,8}
Avg. energy needed for 1 packet transmission	E_{tx}	20 J
Feeder Efficiency	η_F	0.5
Avg power consumption for PA idle state	P_{idle}	100W
Avg. time being turned off	T_{off}	0.4sec
Avg. power consumption for PA in off state	P_{off}	3.5W
Switching frequency	M	0---1.6Hz
Normalised value of number of Voice calls	V	0<V<1
Cell Load Factor	L	0.6*V+0.2

Power Saving percentage(%):-

The following figure illustrates the amount of power saving obtained by application of this algorithm.

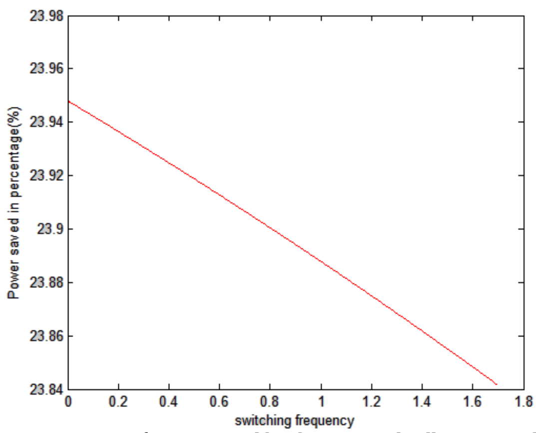

Figure 3: Percentage of power saved by the proposed cell zooming algorithm in 20% traffic condition

As seen from figure 2, almost 23.94% power is saved by using the cell zooming algorithm when the traffic load is as low as 20% only. As the switching frequency i.e. how many time we can turn off the power amplifier, increases the power saving percentage decreases.

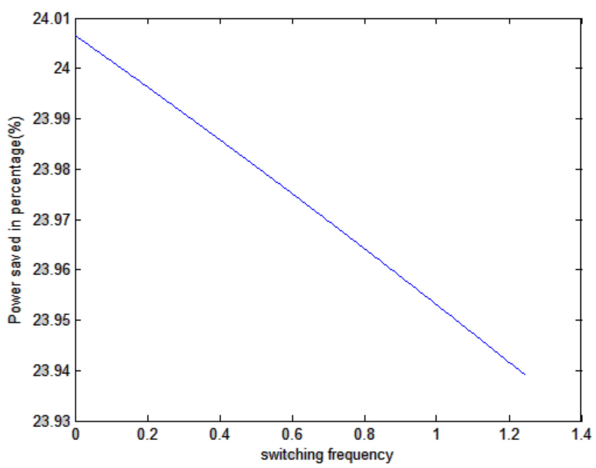

Figure 4: Percentage of power saved by the proposed cell zooming algorithm in 50% traffic condition

As seen from the previous figure, almost 24% power is saved by using the cell zooming algorithm when the traffic load is 50% .

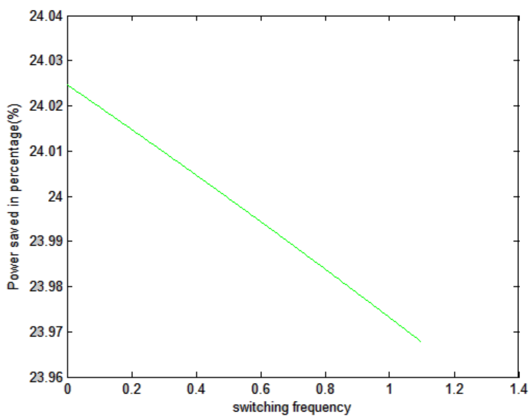

Figure 5: Percentage of power saved by the proposed cell zooming algorithm in 60% traffic condition

In this case also, as the load traffic is almost similar to the previous one, 24.02% or can be said 24% power has been saved by this proposed algorithm. Here the load traffic condition is assumed to be 60%.

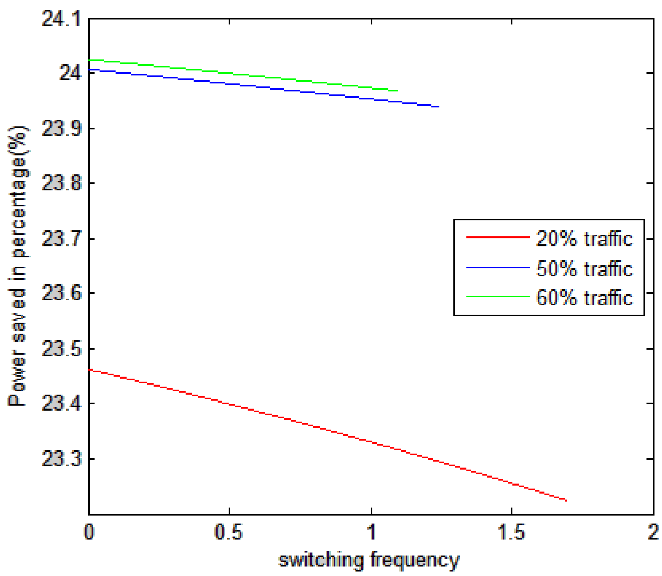

Figure 6: Percentage of power saved by the proposed cell zooming algorithm in different traffic conditions

So in the above figure 6 a comparative view of the amount of power saving has been shown. The traffic conditions are taken as 20%, 50% and 60% respectively. It can be shown that slightly more power is saved for 60% traffic condition after application of the algorithm.

CONCLUSION

The concept of sleep mode introduced in wireless network, seems to be good enough for managing low power consumption. In this study the simulation of the power model along with the newly identified parameters, the concept of cell zooming and sleep mode have been introduced in a wireless base station under varied traffic conditions and signifying the energy saving for lower traffic conditions. The proposed algorithm for a HSPA network provides the optimal solution strategy of when to turn off the base station during sleep mode. Based on that when a particular base station is consuming less power it can be turned off provided surrounding base stations are providing coverage to its foot print. This strategy holds for static condition, i.e. when no calls are in progress and the traffic load is relatively very small with uniformly distributed traffic intensity. This algorithm performs well for low to medium traffic conditions for a normalised value of voice traffic between 0<V<0.6. During 20% traffic condition a significant gain of 23.94% is achieved. During 50% traffic condition a gain of 24% is achieved. During 60% traffic condition a gain of 24.02% is achieved. The proposed algorithm can be considered as the primary algorithm for base station and the network optimal power utilization and further improvements and precise investigations are needed for applications with different wireless channel conditions.

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