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Optimization of Power In Cellular Networks using Fuzzy Logic

Purnima Lala[1] , Prabhjot Kaur[2]

ECE Deptt, ITM University

Gurgaon, India

[1]purnima.lala@gmail.com , [2]prabhjotkaur@itmindia.edu

Abstract *:*

Power consumption at base stations in cellular networks has become an important issue as the increasing CO_2 *emissions at the base station sites have an adverse effect on the environment. In this regard dynamic deployment of cell sizes is believed to reduce the power consumption at some base stations for a given area depending on the traffic load conditions. A growing concept of cell zooming has been used in this paper wherein a cell adaptively adjusts its size depending on the subscriber load . This paper presents a fuzzy based cell zooming solution to reduce base station power consumption. Base station antenna height and its transmitted power are the antecedents of our proposed fuzzy system.*

Keywords- power consumption; BTS; cell zooming; fuzzy system

I. INTRODUCTION

Since the last decade it has been seen that power efficiency is becoming an inescapable issue for all communication layers from wired to wireless communications [1]. With the accession in number of users subscribing to wireless technologies, the world of telecommunication is facing a pensive challenge of world-wide CO_2 gas emissions. A number of network operators are putting their best efforts to meet the increasing user demands cost-efficiently. Energy-efficient wireless transmission techniques for reduced radiation and for reduced transmission power including optimization methods are being introduced by different network operators. A recent research report by Ericsson [2] suggests energy costs accounted for as much as half of a mobile operator's operating expenses. Therefore, cellular networks can have a direct and substantial impact on lowering power consumption and hence reducing CO_2 gas emissions.

The focus of this paper is on reducing the power consumption at base transreceiver station (BTS) sites as they are indicative for major amount of energy consumed in cellular networks, reported amount to about 60-80% [3]. From the point of view of total power used in any cellular system the BTS sites have been recorded to absorb a maximum portion of it [4]. Generally from the point of cell planning process, in the cellular networks the cell sizes are designed to be fixed depending on the estimated subscriber load. However the subscriber load can have significant variations, that can bring both threats and opportunities to the planning, designing and implementing of cellular networks. If the number of cells are planned based on the peak traffic load for each cell, there are always some cells with lighter load, while others are under heavier load. For such cases any fixed cell deployment will not be optimal due to traffic load inconsistency.

With the next generation cellular networks moving towards smaller cells such as microcells, pico-cells, and femto-cells, traffic load variations can be even more challenging which make the cell deployment even harder [8]. To conserve the power of the whole system, the unusual phenomenon of traffic load variation suggests that some BTSs can be put to sleep mode when the traffic load is light . In urban areas, the traffic load varies during the 24 hour cycle. Traffic load is high during the day time and low during the night time. This means there is no consistency in load in any particular cell. Also the power consumption at any BTS site does not vary proportionately with the varying load. Hence there arises need for conserving power at some sites.Power consumption is believed to be reduced with variable cell size deployment or extended cell mechanisms [6-7]. A new concept of cell zooming was introduced, that adaptively adjusts the cell size according to present user conditions as depicted in Fig. 1. The implementation of cell zooming has the probable effect of balancing the increasing subscriber load and hence reducing the power consumption at base stations. Cells can zoom in or out by a variety of techniques such as physical adjustment, BTS cooperation techniques and also relaying through low power relay stations [8].

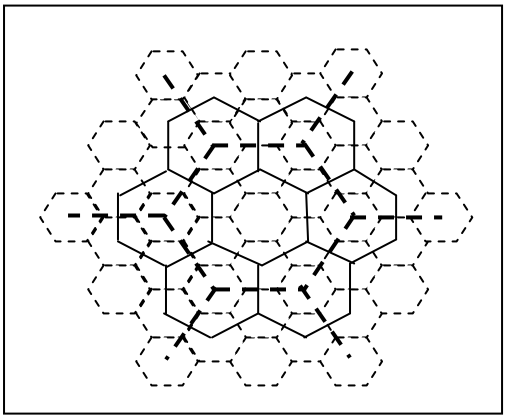


Figure 1. Cell Zooming Concept

Physical adjustment can be either be done by adjusting the antenna height at a BTS tower or by adjusting transmit power of a BTS. Antenna tilt have also been studied to assist zoom in or zoom out a cell. With BTS cooperation a number of BTSs can cooperatively transmit or receive from mobile users. Different cooperative algorithms have been proposed for future cellular networks e.g in [4]. Relay stations can also be employed for cell size adjustment by relaying traffic from a cell with heavy traffic to a cell in low traffic conditions [7-8-9]. In our model we have used different combinations of BTS antenna height and transmit powers to execute cell zooming. However, it is practically difficult to change antenna height at a BTS. As an alternative, as suggested in [10], two possible solutions could be electrically alterable heights or switching between two antennas co-located at different antenna heights of the same BTS tower can be considered.

In this paper we assume that BTS is capable of switching between active and sleep mode with no channel assignment and path loss issues. Our power model uses fuzzy logic to control some parameters according to active traffic and make decisions on cell zooming. As suggested in [11], in their future work for selection of a population threshold for switch-off decision which has also been considered in our proposed model. This logic needs to be installed at every BTS for a given area. A lot of study has been done to find out solutions for power consumption at BTS sites but less contribution has been made on how would these methods could be executed. Our system works on decision based algorithm for making the cell zooming concept execute in cellular networks.

Based on comparison of our work with [7] for similar parameters, specifications and concept but with a different logic, our results demonstrate better power consumption. A multi-layer cellular architecture with uniform hexagonal cell sizes has been considered for simulation purposes.

In the following sections of this paper, a brief introduction on fuzzy logic is presented in section II, followed by the BTS power model used for power saving in GSM cellular systems as given in section III. Simulations and Results depicting the analysis of this study are discussed in section IV. Lastly, conclusion and future work is stated in section V.

I. FUZZY LOGIC

Fuzzy logic is used for non-linear multivariate, uncertain systems that cannot be easily modelled. Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Fuzzy logic works out on mathematical imitation of human thinking system to deal with uncertainty[8]. Fuzzy deals with deterministic plausibility. It measures the degree of correctness to which a preposition is correct. The degree of truth of a statement in fuzzy logic can range between 0 and 1 and is not constrained to the two truth values {true, false} as in classic Boolean logic.

BTS Power model

Fig. 2 shows the power model that comprises of three sub fuzzy models that have been interfaced together to give a Hierarchical Fuzzy System. The first fuzzy sub model has Base station antenna height (BSH) and Power transmitted (PT) as its input parameters. The output parameter is the Cell Radius (R) . The parameters BSH and PT are important in determining the coverage area of a BTS tower and hence used for cell zooming concept in determining zoom in and zoom out cell radius depending on the active traffic load.

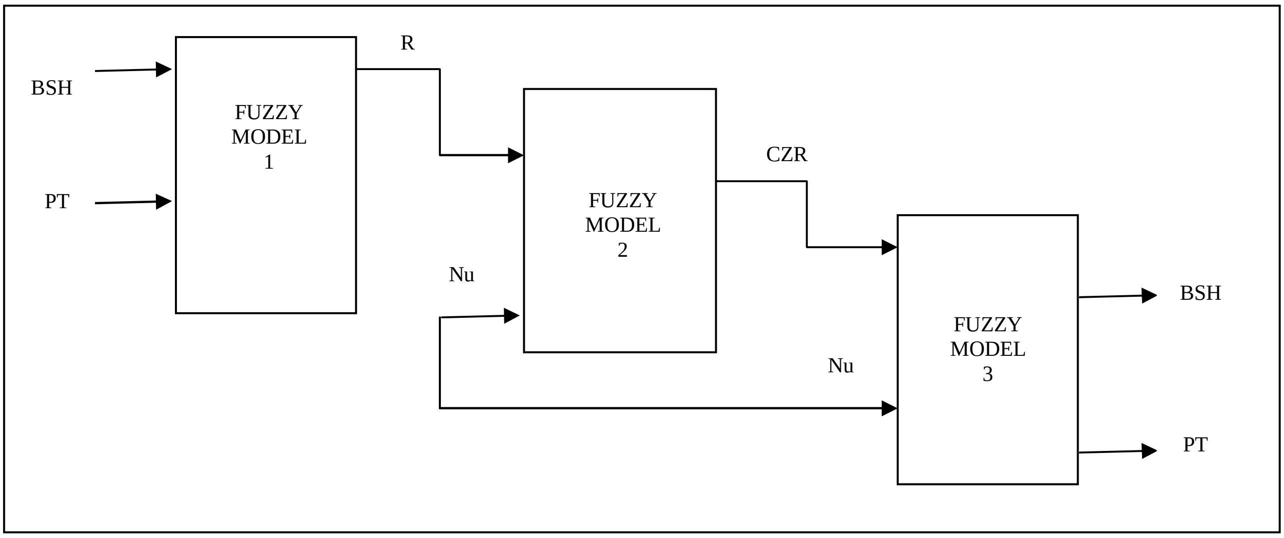


Figure 2. Block Diagram of BTS Power Model

The second fuzzy sub model has Cell Radius (R) derived from previous sub model as its input along with new parameter Number of active users (Nu) to be serviced by a BTS. The output of this model is Cell Zooming Radius (CZR). The fuzzy logic in this model decides the cell zooming radius depending on the initial input radius and variable parameter Nu.

The input parameters to the third fuzzy sub model is CZR derived from previous model and Nu which is also the input to the second fuzzy model. The output parameters of this sub model are BSH and PT. The new cell zooming radius along with Nu will decide the new BSH and corresponding PT which will be fed back to the first fuzzy sub model. Hence this model acts in an iterative manner and controls parameters depending on the active subscriber load in the cell. Figure 1 shows the block diagram of BTS Power Model.

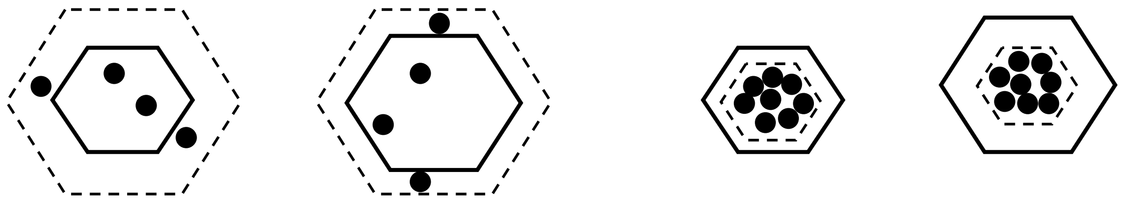
The power model has been formulated in Matlab Fuzzy Toolbox and interfaced using Simulink. Triangular membership functions are defined for all the parameters. There are four different important fuzzy inference methods. These are max-dot, min-max, tsukomato and takagi sugena. In this study, min-max fuzzy inference method is used.

Table I (a) depicts the rule table for first fuzzy sub model. Initially a fixed value of BSH and PT will be given to the model depending on the initial deployment of BTS antenna height and its transmitted power for a given hexagonal area to give the fixed radius for initial cell deployment.

Table I (b) depicts the rule table for second fuzzy sub model in which the initial radius and current traffic load will determine the new cell zoomed radius. For low traffic the cells will zoom out , but this zooming out will depend on the initial cell radius and on number users in it. If the value of R is less, zooming out will be more. If the value of R is more, zooming out will be less. This zooming out concept for low traffic will result in less number of cells that is less number of BTS sites will be running and rest will be put to sleep. The active BTS sites will cover the area of their adjacent BTS sites that have been put on to the sleep mode in order to compensate the load that they were supposed to service in their active mode. For this the transmission power of each BTS site needs to be increased with increase in antenna height at the BTS tower depending on load conditions

TABLE I RULE TABLE FOR FUZZY SUB MODELS

(a) Fuzzy Model 1				(b)Fuzzy Model 2				(c)Fuzzy Model 3				
Rule No.	*R*	*Nu*	*CZR*	*Rule No.*	*BSH*	*PT*	*R*	*Rule No.*	*CZR*	*Nu*	*BSH*	*PT*
1	Low	Low	Zoom Out More	1	Low	Low	Low	1	Low	Low	Low	Low
2	Low	High	Zoom In Less	2	Low	High	Medium	2	Low	High	Low	High
3	High	Low	Zoom Out Less	3	High	Low	Medium	3	High	Low	High	Low
4	High	High	Zoom In More	4	High	High	High	4	High	High	High	High



(a) (b) (c) (d)

Figure 3. Cell Zooming Concept

For high traffic, the cells will zoom in less for low values of R and zoom in more for high values of R. This zooming in concept for high traffic will result in more number of cells to be formed. This will require more number of BTS sites to be working with decreased transmission power and antenna height. Low Power Relay Stations can also be employed in this case instead of installing a complete BTS tower.

The power consumption for low traffic that is at night time will be quite less as few BTS sites will be working In high traffic period that is in day time, more BTS sites will be working but with less transmission power .Power consumption at each BTS site is less than its initial deployment. Though the number sites working will be more but the total area power consumption will be reduced.

Fig. 3 shows how the zooming takes place depending on the number of users present in a given cell. In low traffic period as depicted by Rule number 1 and 3, the cell zooms out more for low radius values as shown in Fig. 3(a) and zooms out less for high radius values shown in Fig. 3(b). In high traffic period as depicted by Rule number 2 and 4, the cell zooms in less for low radius values as shown in Fig. 3(c) and zooms in more for high radius values shown in Fig. 3(d).

Table I (c) depicts the rule table for third fuzzy sub model. The new zoomed radius and the current traffic load will determine the new antenna height and its corresponding transmission power. The newly configured BTS site will now work according to the present traffic load. These values will be fed back to the first model to determine the next radius to be zoomed out or in when the traffic load changes.

II. SIMULATIONS AND RESULTS

We consider a multi cellular environment with uniform hexagonal cells with uniformly distributed traffic. Each cell consists of a BTS tower at center with omni-directional antenna. Let A be the total area of the network with N_t number of active users. The area of the hexagonal cell A_C can be calculated as $A_c = (3\sqrt{3}/2) \times r^2$, where r is the cell radius. The total number of cells $N_c = A/A_c$. Also the number of active users per cell can be calculated as $N_u = N_t / N_c$.

We have followed the parameters and specifications from [7] and applied on to our BTS power model. We started our simulation with initial parameters (TABLE III) for the multi cellular environment. These values are fed as the starting parameters to the model and the cell zooming is determined depending on the current traffic load using the hourly traffic model. Then the new BSH and PT are determined for the new cell zoomed radius .

The initial values of BTS and PT are set to give the value of cell radius as 0.48 Km that has been defined for the network area initially. The initial cell radius can be visualized with seven medium sized cells in Fig. 1.This cell radius (R) value and current number of users (Nu) per cell are then fed into the system to determine the new zoomed in or zoomed out radius (CZR). The cells with new zoomed in radius can be visualized with small dashed cells in Fig. 1. Similarly the cells with new zoomed out radius can be visualized with the dark big dashed cell. With new CZR and current Nu, new BSH and PT are determined and are fed back as next inputs to the system. This system runs iteratively for different values of number of users and rest of the parameters are controlled by the fuzzy system depending on the rules given to it.

The simulation of the network using the BTS power model is performed using hourly traffic model as shown in Fig. 4 based on urban specifications (TABLE II) and is given in [8]. The traffic model suggests there is high traffic in day time particularly in evening and very low traffic during night time. With our simulation using cell zooming concept it was found that power consumption per BTS is less during day time (8 a.m. to 8 p.m.) that is when number of users are more. The number of BTSs working are more due to formation of more cells. During night time (8 p.m. to 8 a.m.), that is when number of users are less, very few BTSs are working but consuming more power per site as shown in Fig. 5.

TABLE II URBAN SPECIFICATIONS

Parameter	GSM 900
Downlink Frequency	935 MHz
Channel Bandwidth	200 KHz
Bit rate per user	13 kbps
Receiver Sensitivity	−104 dbm
Antenna Feeder Loss	3 dB
Transmitter Gain	10 dB
Power Amplifier Efficiency	50%
Pathloss Model	Cost 231

TABLE III SIMULATION PARAMETERS

Parameter	Value
Network Area	100 sq. Km
Initial Cell Radius	0.48 Km
Total Number of active users	20000
BTS Antenna Height	(40,50)m
MS Antenna Height	1.5 m
Transmission Power	(10,20)W

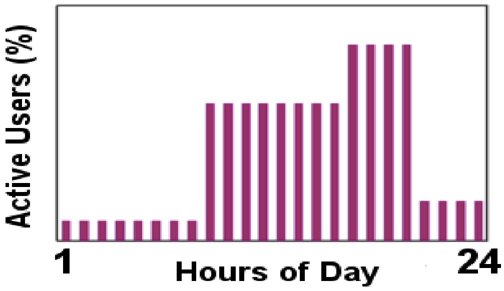


Figure 4. Hourly Traffic Model in [8]

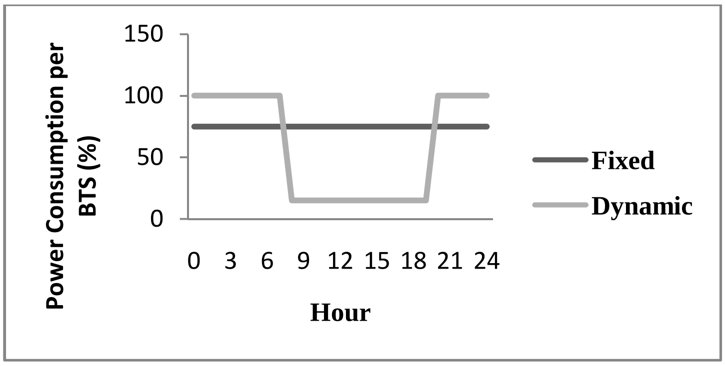


Figure 5. BTS Power Consumption for a day

Fig. 6 illustrates the total power consumption on hourly basis corresponding to number of BTSs working per hour. The graph shows 100% power consumption for fixed cell deployment of radius 0.48 Km. The number of BTSs working are same for every hour irrespective of varying load. With our simulation it was seen that total power consumption during night time (8 p.m. to 8 a.m.) is significantly less. This is due to the fact that number of BTSs working during this time are quite less to service the less amount of users. During day time(8 a.m. to p.m.) the number of BTSs working are more to service more number of users. As these BTSs are consuming less power site the total power consumption is still less. The total network area power consumption on the basis of number of BTS sites working in both the cases comes out to be lesser than that consumed with the fixed deployment case. Considering the fact that the inactive BTSs will have to be working for paging throughout the day and consuming some amount of power while in sleep mode, our BTS power model for the multi cellular environment achieved about 35.6% power savings as compared to 29% power saving as given in [7].

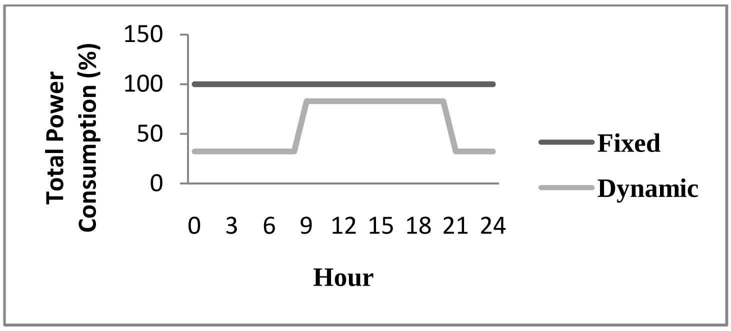


Figure 6. Total Power Consumption of a day

III. CONCLUSION AND FUTURE WORK

Our BTS power model is a Fuzzy based hierarchical system that makes decisions depending on the rules stored in it and on the input values alongwith their membership functions. The model makes decision on how much to zoom in or zoom out the radius of the cell depending on current traffic load. The BTS antenna height and transmission power are adjusted accordingly. About 35.6% power savings were observed for urban 24 hr cycle.

Although uniform hexagonal cells and uniformly distributed traffic has been assumed for the simulation but the model can be used for realistic scenarios and real time traffic just by changing the ranges of parameters and also the rules stored in it. The model can be used with different path loss models as well as for different RF planning techniques and for different networks. We can employ this model on selected BTS sites also. Cells that are unable to zoom in/out or if the load conditions are such that may not require them to install such a logic can go to sleep mode to reduce power consumption, while the neighboring cells can zoom out to serve the mobile users cooperatively. Intelligent cell deployment strategies and sleeping mechanisms as suggested e.g in [12-13-14] can also be performed using this fuzzy system.

REFERENCES

1. Quittek, J., Christensen, K. and Nordman B," Energy-efficient networks [Guest Editorial],"Network IEEE, Vol. 25,No. 2,pp 4-5,March 2011

2. Ericsson Press, June 2008,

   http://www.ericsson.com/ericsson/press/facts_figures/doc/energy_efficiency.pdf

3. Kyuho S., Hongseok K., Yung Y. and Bhaskar K., "Base station operation and user association mechanisms for energy-delay trade offs in green cellular networks," IEEE Journal on selected areas in communications, Vol. 29, No. 8,Sept 2011

4. Hasan, Z., Hamidreza B. and Vijay K., " Green Cellular Networks: A Survey, Some Research Issues and Challenges,"Communications surveys and tutorials,IEEE ,Vol. 13 ,pp 524-540,Nov 2011

5. Md. Farhad Hossain, Kumudu S. Munasinghe and Abbas Jamalipour," A Protocooperation-based Sleep-Wake Architecture for Next Generation Green Cellular Access Networks,"IEEE ICSPCS International Conference,pp. 1-8, Dec 2010

6. J. T. Louhi, "Energy efficiency of modern cellular base stations," Proceedings of IEEE International Telecommunications Energy Conference (INTELEC), Italy, pp. 475 – 476, September 2007.

7. S Bhaumik ,G Narlikar,S Chattopadhyay,S Kanugovi,"Breathe to Stay Cool:Adjusting Cell Sizes to Reduce Energy Consumption", Sigcomm Conference,2010

8. Zhisheng N., Yiqun W., Jie G., Zexi Y., " Cell Zooming for Cost-Efficient Green Cellular Networks",Communications Magazine IEEE,Vol . 48 ,pp 74-79,Nov 2010

9. Jie Xu , Ling Qiu ,"Area Power Consumption in a Single Cell Assistedby Relays."IEEE GreenCom,pp. 460-465, Dec 2010

10. Priyangshu Ghosh, Suvra Sekhar Das, Swetha Naravaram, Prabhu Chandhar, “Energy Saving in OFDMA Cellular Systems Using Base-Station Sleep Mode: 3GPP-LTE a Case Study,” National Conference on Communications, Feb 2012, in press
11. Ziaul Haq Abbas and Frank Y. Li,” A system-level power saving approach for cellular networks with microcells/picocells,” IEEE Wireless VITAE, pp 1-5,Feb-March 2011.
12. Fred Richter, Albrecht J. Fehske, and Gerhard P. Fettweis,” Energy Efficiency Aspects of Base Station Deployment Strategies for Cellular Networks,” IEEE Vehicular Technology Conference,pp. 1-5,Sept 2009
13. Fred Richter, Gerhard Fettweis, Markus Gruber, Oliver Blume,” Micro Base Stations in Load Constrained Cellular Mobile Radio Networks,” IEEE PMIRC International Workshop ,pp. 357-362,Sept 2010
14. Lin Xiang, Francesco Pantisano, Roberto Verdone, Xiaohu Ge, Min Chen,“ Adaptive Traffic Load-Balancing for Green Cellular Networks,” IEEE PIMRC , pp. 41-45, Sept 2011