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Distance Aware Energy Efficient Cellular Mobile Network using Semi Adaptive Clustering Algorithm

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Abstract:
This paper explores the energy efficiency maximization of cellular mobile network using user based clustering scheme. We developed a clustering algorithm that automatically draws a number of concentric circles and so that the transmit power is adjusted adaptively based on the maximum radius at which the threshold value of user density is attained. As a result the transmit power of the BS linearly changes with the size of the outermost concentric circles and the number of mobile stations as well. The numerical result indicated that from 10 sample scans of the 2 km radius BS(BS) an average of 6% of the maximum transmit power has been saved and this brings a valuable return on the environmental effect and energy consumption costs of the operators.

Keywords: *BS, clustering, distance aware, energy efficiency*

1. Introduction

ENERGY-efficient design of wireless networks has received significant attention for decades with emphasis on prolonging battery life-time for sensor nodes and mobile terminals [C. E. Jones et al. (2001)]. More recently, there has been a renewed focus on energy-efficiency in wireless networks from the different perspectives of reducing the potential harms to the environment caused by CO2 emissions (e.g., global warming) and the depletion of non-renewable energy resources. Reducing energy consumption has also economic impact on revenue, e.g., the wireless network operators are estimated to spend more than10 billion dollars for electricity [E. Oh, B. Krishnamachari, june 2001], a significant portion of their operational expenditure (OPEX). Energy consumed by ICT (Information and Communication Technology) industry is rising at 15-20% per year, doubling every five years [G. Fettweis and E. Zimmermann, 2008]. Pushed by such needs of energy reduction, the operators have been seeking ways to improve energy-efficiency in all available dimensions and all components across BSs (BSs), mobile terminals (MTs) [H. Kim,et al. 2009]–[G.-W. Miao et al. apr. 2009], and backhaul networks [L. Chiaraviglio et al. 2009].

So far many research works have been conducted on different aspects of energy efficient cellular communication systems, a short summary of some highly related works as below are summarized as below.

Europe's climate and energy package", EC press release Dec. 2008 proposed a new perspective on green wireless networking. Without turning off BSs they deployed small cells to offload traffic from macro cell base stations to achieve power saving. The work also studied the MC-BAPS problem for multi-cell scenarios. But the proposed scheme doesn't emphasize power saving mechanisms for a single base station. Anna Ferrer Bosch,2008, evaluated increasing energy-efficiency in hierarchical communication protocols using different approaches that use distance parameter to distribute the energy load uniformly throughout the sensor network. It has never mentioned anything about adaptive clustering approach and user distribution.

In this paper, the Semi Adaptive clustering concept is implemented for reducing the overall power consumption of a single cell macro cellular network. An algorithm has been developed to cluster or divide the coverage of the BS to a number of concentric circles based on the traffic statistics. The BS counts the number of users and calculates the specific density. The density of the users at that track is compared to the average density, which is obtained from the total cell coverage area and total number of users. In this case, the average density is taken as threshold value. If the specific density is below the threshold, the radius of the BS is dynamically adjusted to the radius of the next concentric circle and does the same till greater or equal to the threshold value. Since the transmit power is directly related to the distance, it linearly reduces with the distance. However, those users at that specific track or concentric circle are automatically marginalized or out of service area and the transmit power is saved.

The rest of the paper is organized as follows. Section II introduces the system model and Section III gives the power model and problem definition. In Section IV simulation results are presented based on numerical values considered. Finally, Section V concludes this paper.

2. System Model

The proposed system model consists of one serving base station and multiple mobile users, which create point to multipoint system at the base station. The base station transmits with Omni directional antenna and total transmit power is shared by all users. The cell is divided by a number of concentric circles which are drawn based on user density. The users in the cell are randomly distributed and their position adaptively changes from time to time. The power model of the system estimates and calculates the total power where our focus is on the downlink communication, i.e., from BS to MS (Mobile Station).

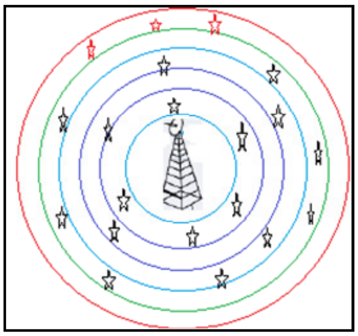

Figure 1.a: BS with Full Coverage

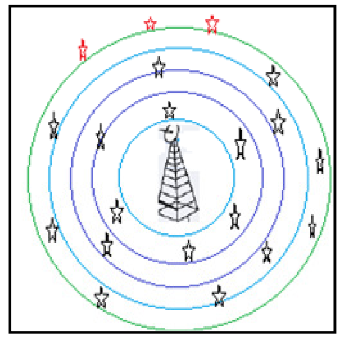

Figure 1.b: BS with Reduced Distance

From figure 1a and 1b, if the number of users at the last track is less than the threshold value, then the radius shrinks to the second outermost track as shown on fig. 1b and the transmit power is adjusted based on that reduced distance.

3. Power Model and Problem Formulation

The problem formulation for the overall system goes through the following procedures:

- Count and add the number of users till greater than or equal to the threshold value(Th) from outer to inner tracks. N=N1+N2+N3+…+Nx,
- If N=0 at the beginning, then the base station sleeps (uses minimum power) and no need of clustering.
- The base station wakes up immediately when the users enter to the zone(radius)
- Find the number of users N_x at each track
- If the number of users of a track N_x at the far distance from the base station is instantly falls below the threshold value, then R decreases to R_{m-1}(to the radius of the next concentric circle) and the new path loss will be calculated using Okumura Hatta models based on R_{m-1} such that $L=247.41+35.22*\log(R_{m-1})$ and the new transmit power, P_T will change since it depends on the path loss effect. We the parameters in table 3 to obtain this reduced path loss model.

$$P_T=P_R*L \quad (4.1)$$

Where P_T = transmitted power

P_R=Minimum Received Power, L=Path loss $L=247.41+35.22*\log(R_m)$, from Okumura Hatta Where R_m= Radius the mobile user, m is nth concentric circle and n is a natural number.

2.1. Semi Adaptive Algorithm

In this technique, the mobile equipments which are nearly within the range of radius from the base station are grouped together and make a cluster. In practice, the possibility of many users to be exactly at equal distance from a base station is very rare. At least there is a fraction of distance between them and some rounding has to be done to cluster. Otherwise the number of concentric circles drawn and the users will be equal. information. Figure 2 shows the semi adaptive algorithm where R_{xn}, R_m, U_o, U_{xn}, R_i radius of of nth concentric circle, maximum radius, the number of users to be ignored, number of users between two consecutive concentric circles and minimum radius respectively. The algorithm is stated as below:

i. Initialize
ii. $R_x=R_m$,Uo=0 , where R_x , R_m and Uo are radius of nth concentric circle , maximum radius and users to be marginalized initially respectively
iii. Calculate change in radius between two consecutive concentric circles
iv. Count number of users at the change in radius of 3rd step
v. $U_n= U_n +U_o$ where U_x is the number of users in the nth concentric circle.
vi. Compare U_n to the threshold value. If greater then go to step 2, if less then $U_o= U_n+U_o$
vii. Move to the next inner concentric circle and assign the transmit power based on the radius

viii. Compare this concentric circle to the innermost one
ix. If equal, then go to step 2 after some t time interval, if not then go to step3.

If the smart base station is equipped with the modern scanners, it can continuously scan the coverage 390 times per second [12]. The base station is triggered as the user equipments send request and responds based on the channel state information.
From the simulation result shown on table 1 below, it has been found that almost all user equipments at each scan have distinct distance(in kilometers) from the two kilometer radius base station.

1st scan	2nd scan	3rd scan
0.1360	0.1054	0.0450
0.1816	0.2560	0.2155
0.3073	0.3422	0.3230
0.4814	0.3563	0.3575
0.5329	0.5382	0.5036
0.5620	0.6029	0.5215
0.5781	0.8355	0.5306
0.8469	0.8457	0.5809
0.8802	1.0783	0.6254
0.9148	1.0957	0.6878
1.0361	1.3327	0.8505
1.0543	1.3331	1.1681
1.2754	1.3962	1.1887
1.3436	1.4022	1.2342
1.3522	1.4757	1.4605
1.3903	1.8407	1.6355
1.5576	1.8855	1.6488
1.7507	1.9033	1.7593
1.8872	1.9661	1.8126
1.9154	1.9982	1.9653
1.9159	1.9983	1.9657

Table 1: Distance of User Equipments (Mobile Stations) From a Base Station at Three Scans

By rounding off these distances to one decimal places, we can cluster those users which are at the new rounded distances as shown in table and as a result the size and number of concentric circles adaptively change.

1st scan		2nd scan		3rd scan	
Distance from base station	**Number of MS**	**Distance from base station**	**Number of MS**	**Distance from base station**	**Number of MS**
0.1000	1.0000	0.1000	1.0000	0.1000	1.0000
0.2000	3.0000	0.3000	1.0000	0.2000	2.0000
0.4000	1.0000	0.4000	1.0000	0.3000	3.0000
0.5000	1.0000	0.5000	3.0000	0.4000	2.0000
0.6000	1.0000	0.7000	3.0000	0.6000	1.0000
1.0000	2.0000	0.8000	1.0000	0.8000	1.0000
1.1000	3.0000	0.9000	2.0000	1.0000	3.0000
1.2000	1.0000	1.2000	1.0000	1.1000	1.0000
1.3000	3.0000	1.4000	1.0000	1.2000	1.0000
1.4000	1.0000	1.5000	1.0000	1.4000	1.0000
1.7000	1.0000	1.6000	1.0000	1.5000	2.0000
1.9000	3.0000	1.7100	1.0000	1.6000	1.0000
		1.7400	1.0000	1.9200	2.0000
		1.8330	1.0000		
		1.8200	1.0000		

Table 2: Clustering Based on New Rounding

In this technique, different number of irregular shaped virtual concentric circle is tactically drawn at each of the three scans as shown on the Table 2. At the first scan there are 12 concentric circles with different sizes. At 2nd scan there are 15 virtual concentric circles but the number of users is still the same to other scans. The basic difference in here is that as the number users change their position, the clustering pattern will change adaptively. From the simulation result shown at Figure 2a and b for different scan time, there are different types of concentric circles that are adaptively changing with time.

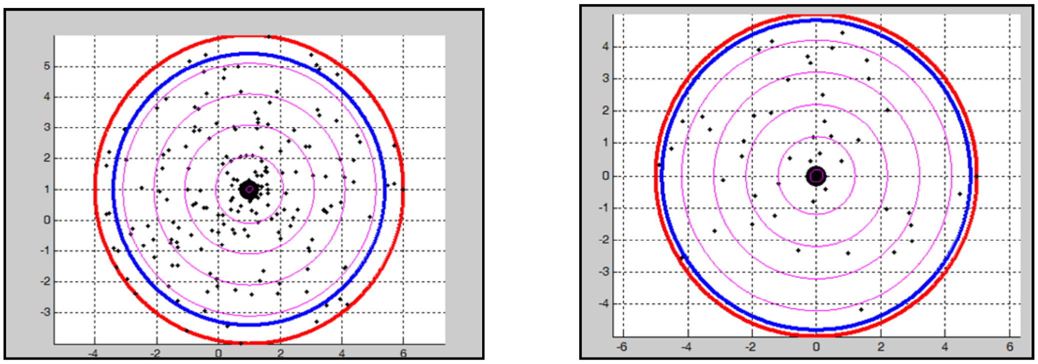

Figure 2.a. Figure 2.b.

Figure 2: Semi Adaptive Clustering Concentric Circles

The red colored or bold track shows that the number of users at that track is below the threshold value and the distance is automatically minimized to the blue colored track where the proportion is fair. This radius is what we call it the maximum reduced radius.

3. Simulation Results

Parameters	Symbol	Value (if any)
Maximum Distance	R	2km,3km,5km
frequency	f	900 Mhz
Basestation Antenna Height	h_{te}	200 meter
Mobile Station Antenna Height	h_{re}	30 meter
Wave length	λ	Depends on frequency
Antenna gain at the transmitter	G_{te}	-
Speed of light	C	$3*10^8$ m/s
Antenna gain at the receiver	G_{Area}	1
Environment gain	G_{AREA}	1
Number of users	N	adaptive
Received power	p_r	100 dBm
User threshold	thr	-

Table 3: Simulation Parameters

As we have seen the relationship between the transmit power and distance so far, area also has a direct relationship with the transmit power. As area increases the path loss also increases and to compensate this reaction the proportional transmit power is allocated.Fig.3 below shows this relation and our proposed smart base station adjusts the transmit power by sensing the user distances and area based on traffic statistics.

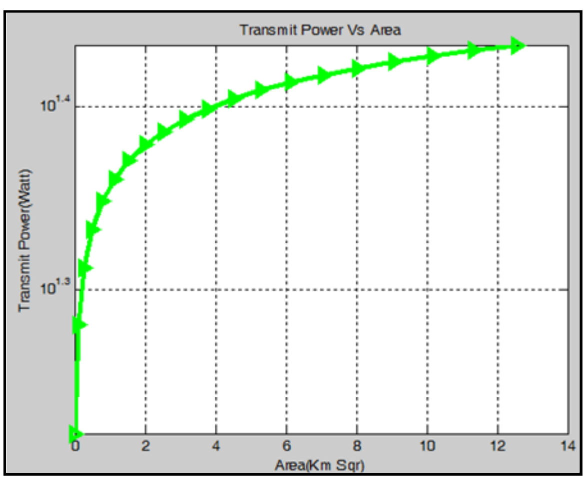

Figure 3: Transmit Power Vs Area

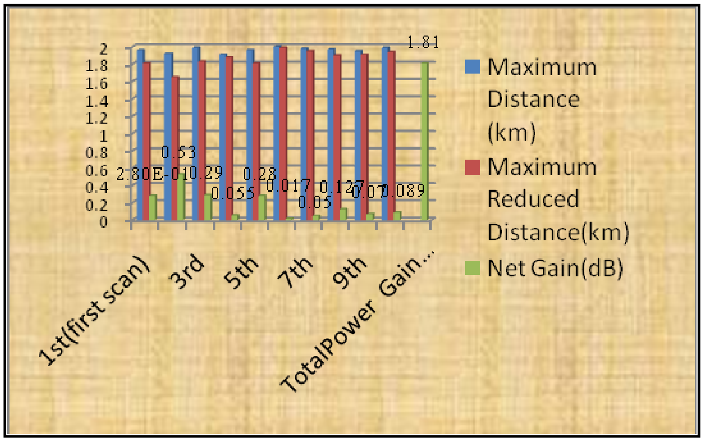

Figure 4: Net Power gain for ten sample scans

It has been observed that from 10 sample scans, there is different saved power value at each reduced distance. From the chart by reducing 0.15 km or 150 meters from the maximum distance of the coverage, the transmitted power dropped to 26.8 dB from 27.1 dB (from Table 4) and 0.28dB saved. For the total of 10 scans we have saved 1.8 dB powers.

The total net gain on the table shows that an average of 0.18 unit power which is 0.6% of the maximum power is saved in 1 scan time. The scan time and frequency depends on the scanner installed on the base station. If a base station scans 100 times in a second this value boosts to an average of 18 watt, which is 66% of the maximum power.

Maximum Power at each Scan, assuming the maximum received received power is 100mW						
Max.power in dB and t in micro second						
time	Users under threshold value at the max radius	Maximum Distance	Maximum Reduced Distance	Maximum Power	Maximum Power For Reduced Distance	Net Gain
1st(first scan)	1	1.96	1.81	2.71E+01	2.68E+01	2.80E-01
2nd	1	1.92	1.65	2.70E+01	2.65E+01	5.34E-01
3rd	2	1.99	1.83	2.72E+01	2.69E+01	2.95E-01
4th	1	1.91	1.88	2.70E+01	2.70E+01	5.58E-02
5th	3	1.96	1.81	2.71E+01	2.68E+01	2.80E-01
6th	2	2	1.99	2.72E+01	2.72E+01	1.77E-02
7th	1	1.98	1.95	2.71E+01	2.71E+01	5.38E-02
8th	2	1.97	1.9	2.71E+01	2.70E+01	1.27E-01
9th	2	1.95	1.91	2.71E+01	2.70E+01	7.30E-02
10th	1	1.99	1.94	27.1646	27.075	8.96E-02
Total Gain						1.81E+00

Table 4: Power Statistics of 10 Sample Scans
Note: 2.E+01=2x10^1

Table 3 shows the simulation result of 10 sample scans of a base station. At the first scan, the maximum distance that the signal travels to trigger the base station or UE was 1.9km. Between 1.96 km and 1.81 km, there is only one user even though the Omni directional antenna emits power up to that point. Therefore, in order to save this wastage of power, we tactically reduce the distance to the point where the number of users is above the threshold value. As the distance reduces, the transmitted power automatically reduces. The probability that the operation may affect the quality of service or grade of service is much less because this operation takes very small microseconds.

4. Conclusion

In this thesis, we studied the energy consumption problem. We proposed a smart strategy in order to minimize the energy consumption in a given network, without significant effect on quality of service. We introduced distance-aware energy efficient algorithm that achieves a significant reduction in power consumption. The result shows 66% of the total transmit power has been saved by tactically reducing the radius of the base station at the area of low traffic load for 100 sample scans using this algorithm. Hence it is worth to implement it in cellular systems.

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