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Reduction in number of active base Stations in femtocell networks using optimized heuristic algorithm

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***Abstract*— Reducing the energy consumption of cellular wireless access networks is not only necessary for the global environment but also makes commercial sense for telecommunication operators. Since access networks are designed to support peak time traffic, the Base Stations that are under-utilized during low traffic periods can be switch off because traffic profile is time varying. This paper proposes an optimized heuristic algorithm to put the base station in sleep mode i.e. decreasing the no. of active base station fraction percentage without sacrificing the required quality of service and maintaining the connectivity. With the help of this optimized algorithm, a significant power saving is achieved, and the network becomes more energy efficient. Introduction of sleep modes acts as an enabler for femtocell deployments. Simulation results shows that a lot of power saving is achieved with the help of optimized heuristic algorithm.**

***Index Terms*— Active mode, femtocell , heuristic algorithm, sleep mode.**

I. INTRODUCTION

According to the Telecom Regulatory Authority of India (TRAI) [1] the Indian telecom sector continued to register a remarkable growth in the year 2012-13. Over the past two decades the Indian telecom sector has seen a tremendous growth. The number of mobile phone subscriptions increased from 13 million in 2003 to 867.80 million by March 2013 while the wire line base recorded a decline from 41.48 million in 2003 to 30.21 million by March 2013. In the past, mobile access networks were mainly used for voice and text communication [2] but the increasing popularity of wireless access networks led to an increased traffic on wireless networks deployment. The increasing demand for higher data rates [5] and better quality of service due to the constant growth in the number of active wireless terminals corresponds tohigher number of base stations. Currently, the no. of base stations in India as on November 2012 are approximately 736654 so more than 50% cell-site operating expenditure is spent to power up base stations [9]. With an increment in the number of base stations, it results in more energy consumption. Also the level of carbon emission will be increased [6] which will degrade the quality of the environment because the large amount of pollution is generated from the communication network operation. One way to tackle the problem is the optimization of the base stations in order to make them more energy efficient. When optimizing a system for energy efficiency, the introduction of sleep modes in the base stations [10] is one of the most commonly used approaches and is already well known in other wireless communication systems such as sensor networks. With this the number of active base station will be decreased and the network becomes more energy efficient and also less harmful to environment as carbon emission footprints will also be reduced significantly [11] [12].

With an increase in awareness of the harmful effects to the environment caused by greenhouse gas emissions i.e. carbon-dioxide emissions [14] and the reduction in non-renewable energy sources [16], it is more critical than ever to come together to develop more energy-efficient systems in all industries [4] and telecommunication systems is not an exception in that case as a large amount of pollution is generated from the communication network operation. The pollution from the carbon emission increases the risk of many breathing problems like asthma etc.

Thus, the focus of this paper is to make the network more energy efficient and optimized by reducing the power consumption of base stations (BSs) [13] that accounts for heavy energy usage in cellular networks. Energy reduction in BSs can be achieved in many ways: from hardware design (e.g., more energy efficient power amplifiers [9] and renewable energy resource for cooling [17]) to topological management (e.g., the deployment of small cells and cell zooming [8]) and so on. In this paper, we concentrate on the switching based dynamic Base Station operation i.e. introduction of sleep modes in the base station for potential energy saving, which allows the system to entirely shut down some underutilized base stations during low traffic time.

The paper is organized as follows. In Section 2, introduction of sleep mode using proposed optimized heuristic algorithm is described. In Section 3, the performance of the proposed algorithm is demonstrated for different scenarios to calculate the active base station fraction. Finally, the paper is concluded in Section 4, and future scope is discussed in Section 5.

II. INTRODUCTION OF SLEEP MODE USING HEURISTIC ALGORITHM

According to CISCO Visual Networking Index (VNI) Global Mobile Forecast reports, 2013 -2018 [18],

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projecting future mobile data traffic over cellular networks (2G, 3G or 4G) and Wi-Fi offload traffic shows that by 2018, global mobile data traffic will reach 15.9 Exabyte per month or 190 Exabyte annually, increasing nearly 11-fold from 2013 to 2018. 190 Exabyte is equivalent to four trillion video clips or 42 trillion image. By 2018, there will be 4.9 billion mobile users from 4.1 billion in 2013. In 2013, nearly 58% of the world's population (7.2 billion people) were mobile users. By 2018, more than 64% of the world's population (7.6 billion people) will be mobile users. Thus, the number of users are rapidly increasing and currently responsible for the larger part of the data traffic on mobile access networks. With this user bit rate demand is increasing day by day. Since the higher bit rates are only available near the base stations but providing high bit rate to mobile access network appears unsustainable, we need to find a way to reduce the power consumption of these high bit rate access networks. One solution is optimization of the base stations by introducing sleep modes in it in such a way that the user bit rate demands are also fulfilled and at the same time network power consumption is also reduced. With this the network congestion will also be reduced and spectrum will become free to utilize it somewhere else. In this context, an optimized heuristic algorithm has been designed to find the best possible combination of base stations to be put to sleep mode in order to minimize power consumption. Deploying a mobile network for a certain bit rate depends on the range of the base station i.e. it varies depending on what bit rate is required. To determine the range of a base station, first the maximum allowable path loss PL_{max} to which a transmitted signal can be subjected while still being detectable at the receiver needs to be calculated [2] [3][19]. Based on maximum allowable path-loss PL_{max}, the range can be determined by using a propagation model which describes the relation between path loss and range. In this study, focus is on femtocell base stations. For the femtocell base station the ITU-R P.1238 model is used [20]. For the femtocell base stations a frequency of 2.6 GHz has been assumed as defined in the long term evolution standard. Also it has been assumed that the femtocells transmit at 21 dBm power.

An important parameter when determining the bit rate at which we want to evaluate the range is the receiver signal-to-noise ratio (SNR) which represents the SNR at the receiver for a certain Bit Error Rate (BER) and depends on the modulation scheme and coding rate use. Higher the coding rate scheme and higher the modulation scheme, higher the bit rate, but also higher the receiver signal to noise ratio (SNR) and thus lower the range becomes.

Another important parameter that influences the bit rate and the range is the channel bandwidth. Lower the channel bandwidth, lower the bit rate, but higher the range. The relation between bit rate and BS range is given in Table 2.1, together with the corresponding Modulation and Coding Scheme (MCS) for LTE femtocells at a channel bandwidth of 5 MHz. This relation between bit rate and range is also shown in Fig. 2.1.

Table 2.1 Bit rate versus range for a femtocell

Bit Rate (Mbps)	Range (m)	MCS
2.8	187.3	1/3 QPSK
4.2	129.3	1/2 QPSK
5.7	69.8	2/3 QPSK
8.5	52.3	1/2 16-QAM
11.3	34.7	2/3 16-QAM
13.6	25	1/2 64-QAM
16.9	14.8	2/3 64-QAM

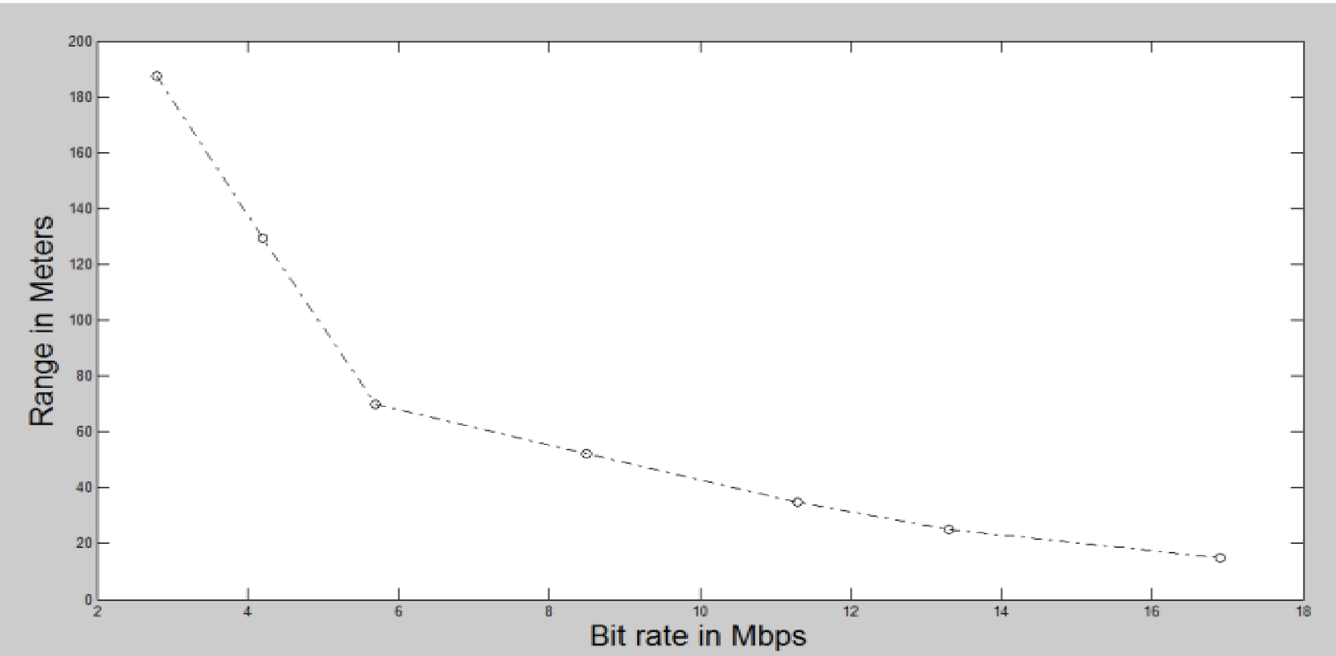

Fig. 2.1 Bit rate versus range for femtocell

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Assume the number of users as 'm' and the number of base stations as 'n'.The coordinates of users and base stations are taken as random because the predetermination of the location of users and the location of femto-cell base stations is not possible as these base stations are user deployed. As different user require different bit rates, so to distribute users according to different bit rates an exponential probability distribution η for different bit rates is taken. This distribution shows the probability of bit rate required by the user as shown in Fig.. 2.2. In this the preference for lower and higher bit rates is determined by β. When β< 0 then there are larger chances of higher bit rates, at β >0 there are larger chances of low bit rates and at β=0 there is a uniform distribution of bit rates. Higher bit rates correspond to video traffic and lower bit rates correspond to voice traffic.

$$\eta(BR) \propto \frac{1}{BR^{\beta}}$$

The probability distribution is normalized:-

$$\sum_{BR} \eta(BR) = 1$$

The vector **U** contains the coordinates of the users. The vector **R** contains the required range of the users. It is calculated based on the bit rate requirement of the user which is then mapped on the corresponding base station range. The matrix **B** contains the coordinates of the base stations. We now construct m × n matrix '**T**'.

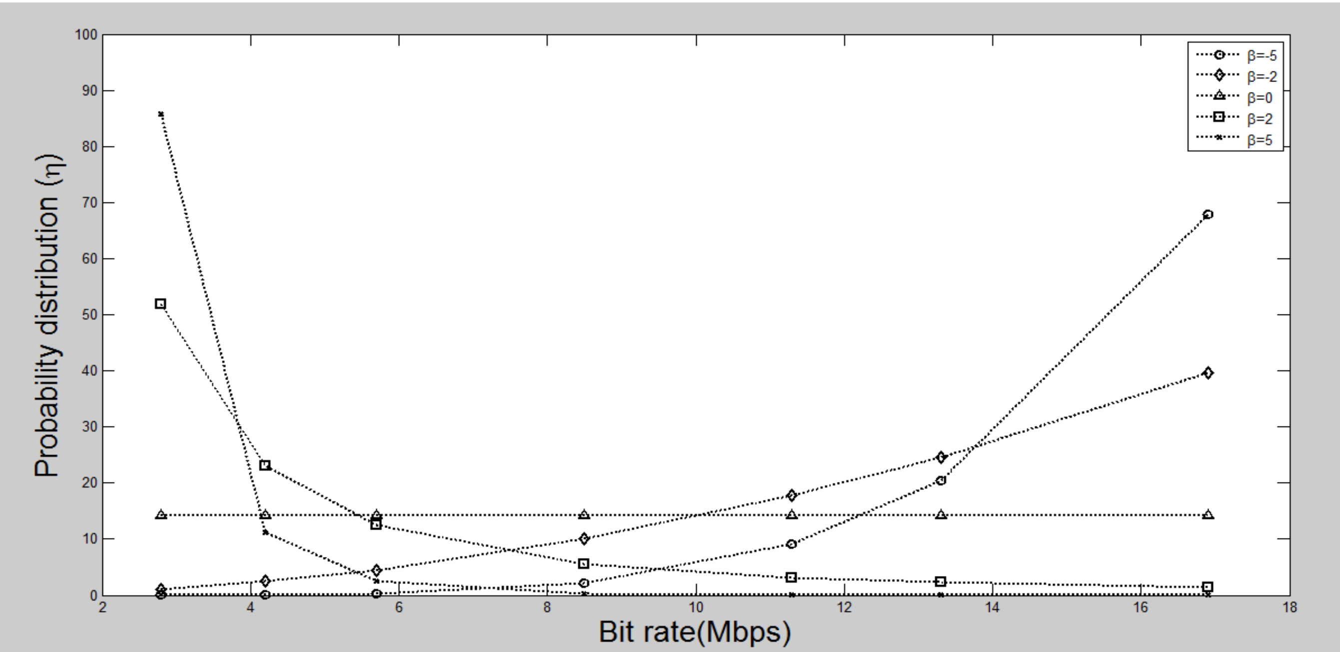

Fig. 2.2 Probability distribution of bit rates in function of beta

$$T_{ij} = \begin{cases} 1 \ if \ | Bj - Ui | \leq Ri \ ; \\ 0 \ if \ | Bj - Ui | > Ri \ ; \end{cases}$$

This matrix represents the possibilities to provide a user with a suitable connection. In case a row of the matrix R contains only zeroes, this implies that no user is in range of base station. Since nothing can be done to serve those users it's better to keep them out of the equation. Based on the matrix T, we can now construct two vectors

$$G^u : G_i^u = \sum_{j=1}^{n} Tij$$

$$G^b : G_j^b = \sum_{i=1}^{m} Tij$$

Where G^u is a 'm' dimensional vector whose every indices shows that a users is connected to how many number of base stations. G^b is a 'n' dimensional vector whose every indices shows that a base station can serve how many number of user according to the bit rate requirement of the user.

Strategy to put base stations in sleep mode using optimized heuristic algorithm is as follows

(a) Select a user which is connected to minimum no. of base stations.
(b) From these base stations select a base station to which maximum users can connect.
(c) Switch on this base station.
(d) Check the users which can connect to this base station according to their bit rate requirement by taking a assumption that a base station can support any no. of users.
(e) Remove the connections of these users from other base stations after the users get connection to the selected base station which is switched on.

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(f) And remove these users from the heuristic and start over.

User and base station distribution is random so every time algorithm will give different result, so to approximate this, the average over 5 repetition of the process are taken. In this work assumption is taken that a base station can support any number of users, this assumption is taken by keeping in mind the capacity that the futuristic base stations will offer that can support a large number of users. As the technology is developing and new techniques are coming in to picture such as massive MIMO, VAMOS, asynchronous transmissions, large bandwidth and high frequency transmissions etc that are increasing the capacity of base stations in terms of bit rate and the capacity in terms of increasing the number of users a base station can support. In the algorithm given below a ‘n’ dimensional all zero vector S is taken where n is the number of base stations in which we change a zero to one each time to switch on a base station. Each time in loop only a single base station is turned on.

Optimized heuristic algorithm:-

G^u : $G_i^u = \sum_{j=1}^{n} T$ij
G^b : $G_j^b = \sum_{i=1}^{m} Tij$
[Val, Ind]=Min(G^u);
While Val==0
    G^u (Ind) =10000;
    [Val, Ind]=Min(G^u);
end
G^b = G^b.*T(Ind,:);
[Val, Index]=Max(G^b);

S(Index)=1;

N=find(P(:,Index));
P(N,:)=0;
until $\sum_{i,j} T(i,j) = 0$

In the algorithm minimum value G^u index is selected not to switch on a base station for a single user in last and maximum value G^b index is selected to serve maximum number of users by switching on a base station. In each iteration only one base station gets switched on, users removed which can get service from the switched on base station and the connection of these users from other base stations also removed. Active base station fraction is calculated by dividing the active umber of base stations after heuristic with the total number of BS. Lower values for active base station fraction implies more base stations are switched off and thus power consumption is reduced

III. SIMULATION AND RESULTS

Simulation is done for femto cells at bandwidth 5 MHz and frequency 2.6 GHz. Every time simulation gives different result for active number of base stations. This is taken care during the simulation for comparison between optimized heuristic algorithm and heuristic algorithm [2] by taking same user density distribution and base station density distribution.

The users are randomly distributed with a user density D_u of 500 users per 1.1 km^2 for β = 5 shown in Fig. 3.1 and for β= -5 as shown in a Fig. 3.2 in a femto-cell access network operating for a channel bandwidth of 5 MHz. In both figures red and green color squares shows high bit rate and low bit rate users respectively, solid blue and hollow blue circles shows active base stations and switch off base stations respectively. β = 5 shows users will have the preference for lower bit rates whereas β= -5 shows that users will have preference for higher bit rates. In the access network there are 1951 base stations, covering an area of approximately 1.1 km^2. Of these base stations, some need to be active in order to provide all users with a connection. This leads to an active base station fraction of 1.43 & 14.09 for β=5 and β=-5 respectively.

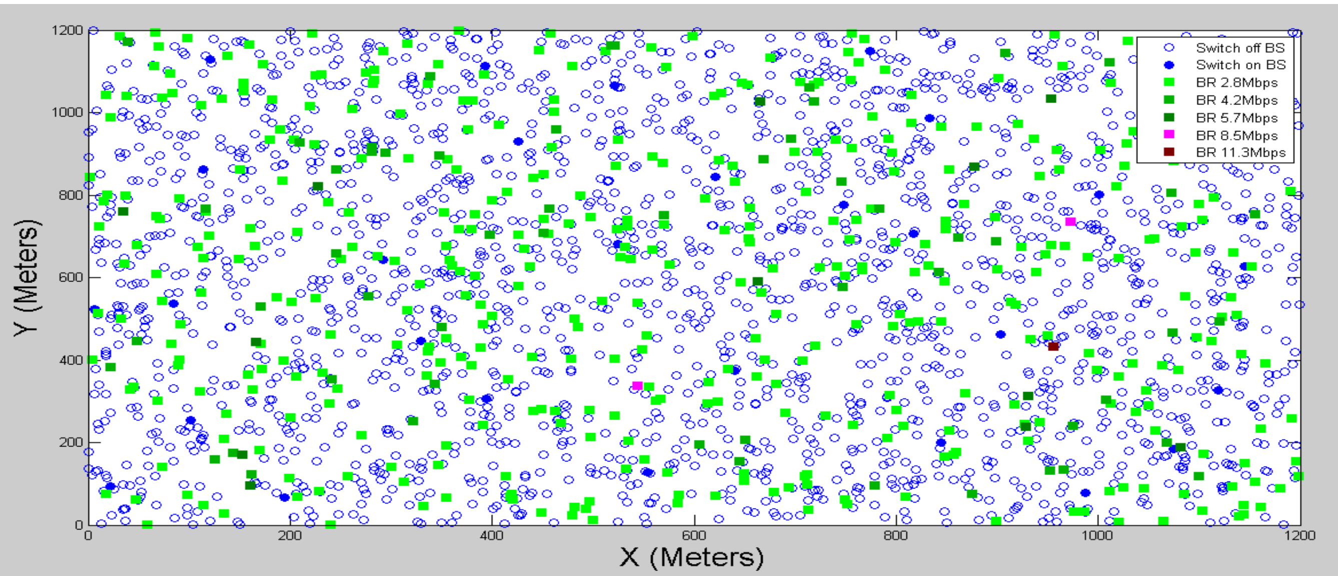

Fig. 3.1 Distribution of users for β =5

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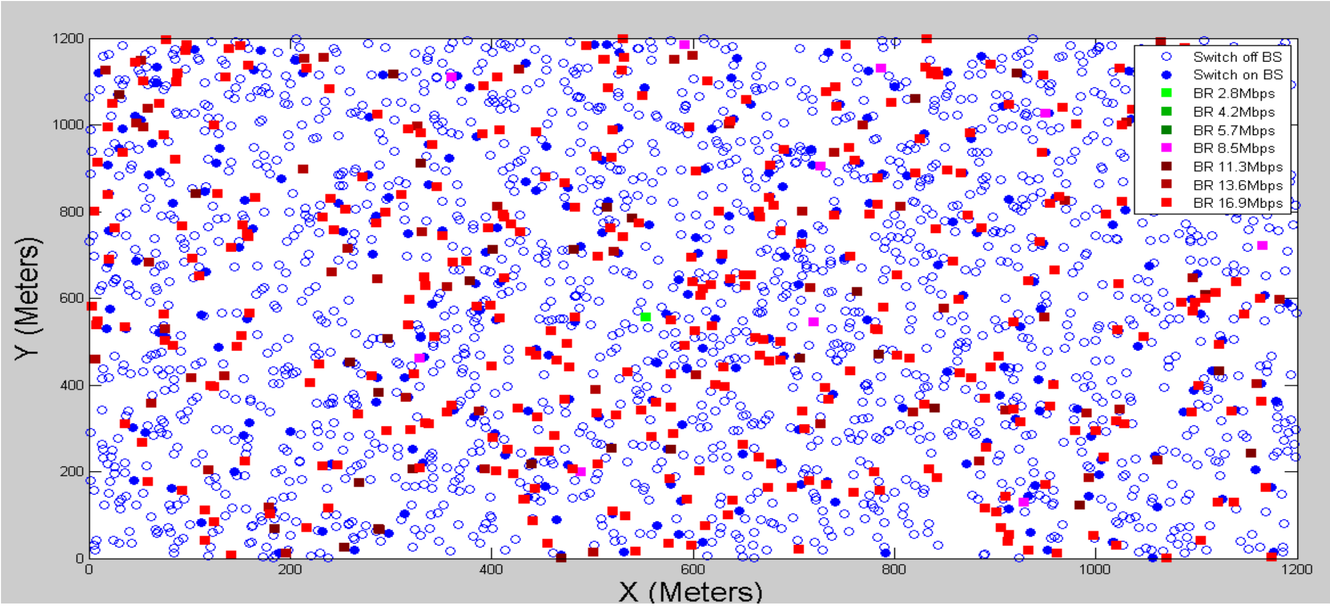

Fig. 3.2 Distribution of users for β = -5

A. INFLUENCE OF BETA ON THE ACTIVE BASE STATION FRACTION

Users operating at low bit rates can connect to base stations at longer distances. Therefore, lower active base station fractions will be possible.

In order to evaluate this, we simulated user distributions of 500 users per 1.1 km^2 with 1951 base stations with varying β and a channel bandwidth of 5 MHz. We performed 5 simulations of which we display the average result and the standard deviation, represented by error bars. The result is shown in Fig. 3.3 for heuristic algorithm [2] and optimized heuristic algorithm. When using femto-cells even in cases with a large preference for high bit rates (β = -5) the fraction of active base stations is very much low and same is the case for high values of β. It is also important to note the standard deviation on the simulations. Depending on the user distribution the result may vary 3 to 6%. This indicates that the actual fraction of active base stations is difficult to predict.

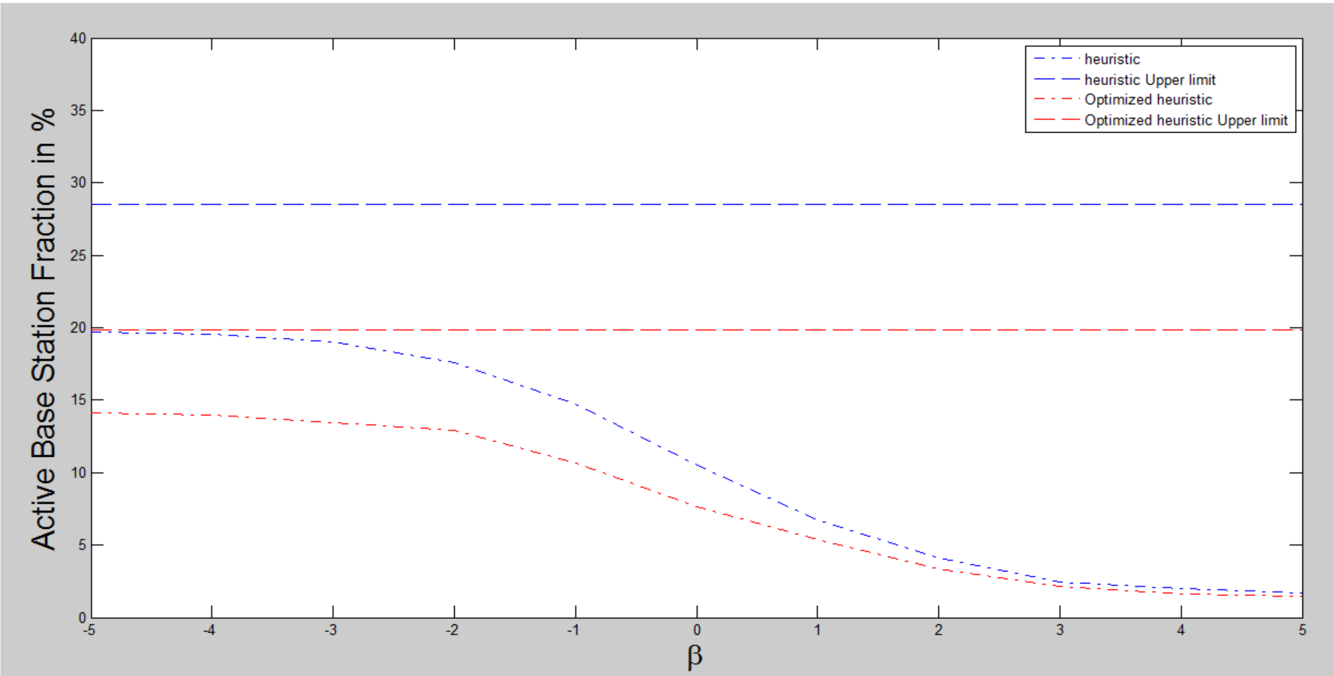

Fig. 3.3 Influence of beta on active base station fraction

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B. INFLUENCE OF USER DENSITY ON THE ACTIVE BASE STATION FRACTION

The influence of the user density on the active base station fraction is as shown in Figure 3.4 for heuristic algorithm [2] and optimized heuristic algorithm. The result obtained is for 5 simulations per case for varying user densities and channel bandwidth is 5 MHz when using femtocells with β = 3. With increasing user density, the simulations result in a slower increase of active base stations.

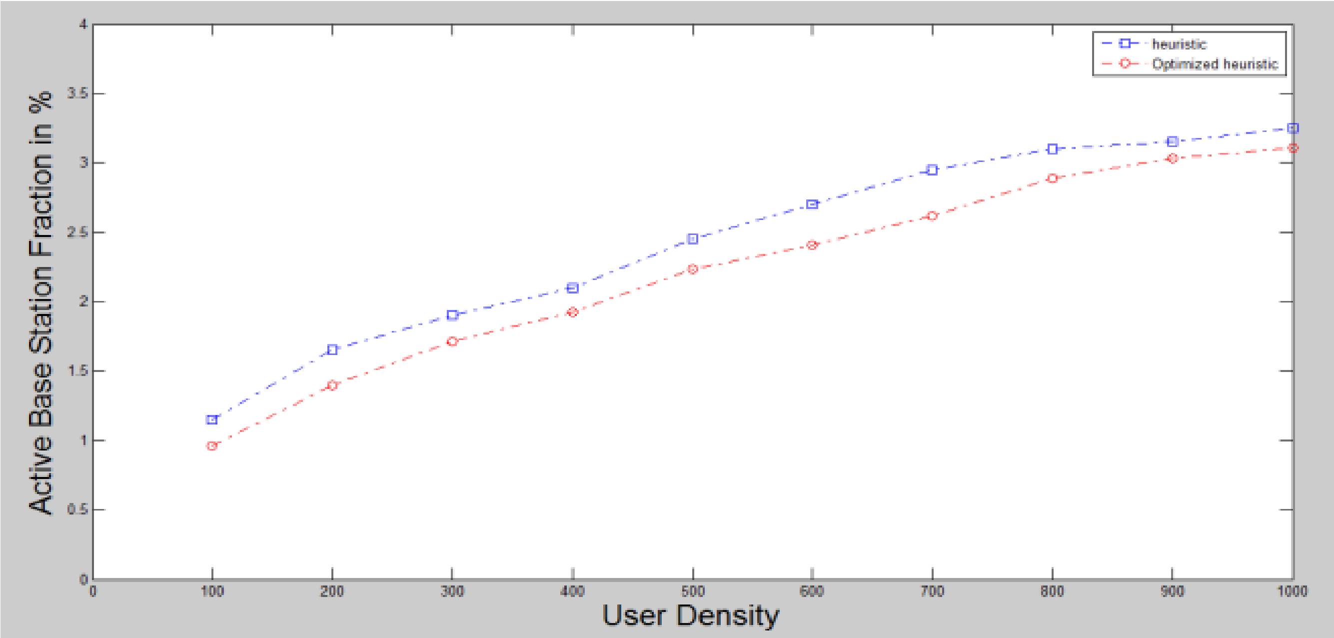

Fig. 3.4 Influence of user density on active base station fraction

C. INFLUENCE OF BS DENSITY ON THE ACTIVE BASE STATION FRACTION

The influence of user density on the active base station is as shown in Fig. 3.5 for heuristic algorithm [2] and optimized heuristic algorithm. It clearly shows that with the increase in the no. of base stations active base station fraction will decrease.

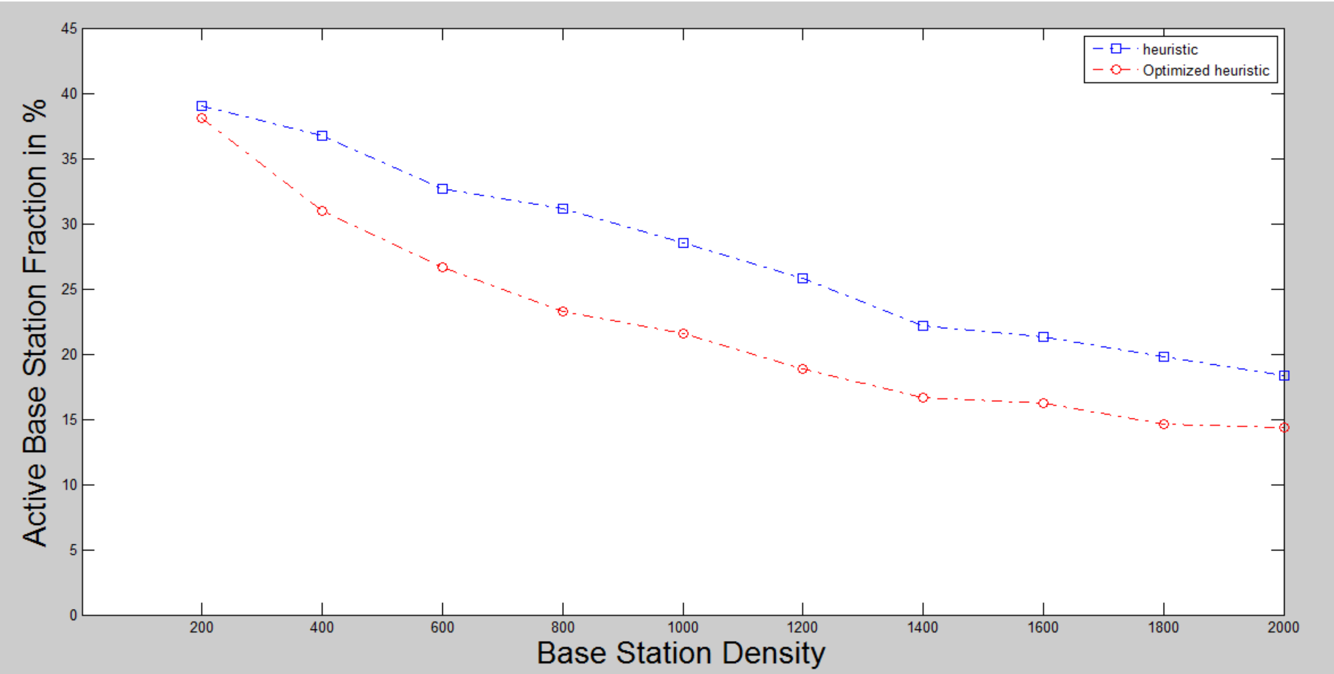

Fig. 3.5 Influence of base station density on active base station fraction

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D. VARIATION OF ACTIVE BASE STATION FRACTION WITH BIT RATE

Variation of active base station fraction with respect to bit rate is as shown in Fig. 3.6 for heuristic algorithm [2] and optimized heuristic algorithm. It shows that at high bit rates active base station fraction percentage will be more because more power is consumed for providing high bit rates to users as compare to providing low bit rates due to low range of signal for high bit rates.

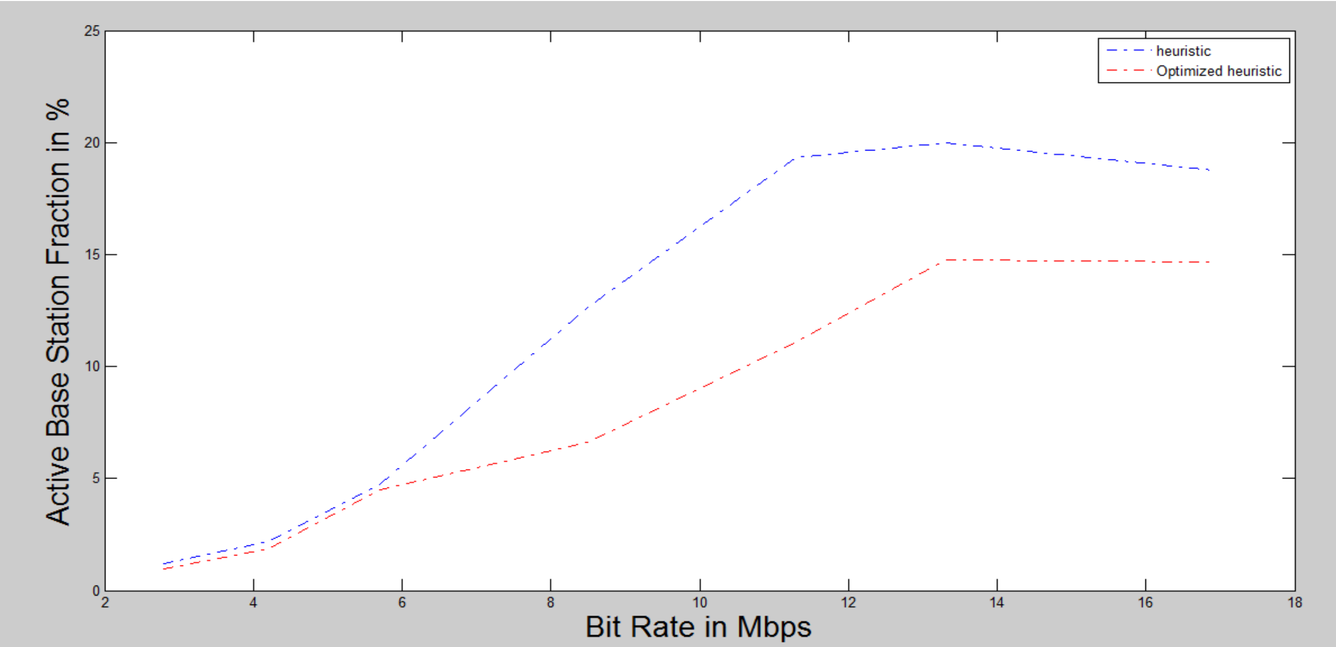

Fig. 3.6 Variation of active base station fraction with bit rate

E. VARIATION OF ACTIVE BASE STATION FRACTION WITH BOUNDARY

Variation of active base station with respect to boundary is as shown in Fig. 3.7 for heuristic algorithm [2] and optimized heuristic algorithm. It shows that as the area increases active base station fraction will decrease, it is because number of users decrease in the coverage of cell as boundary increases so active base station fraction decreases.

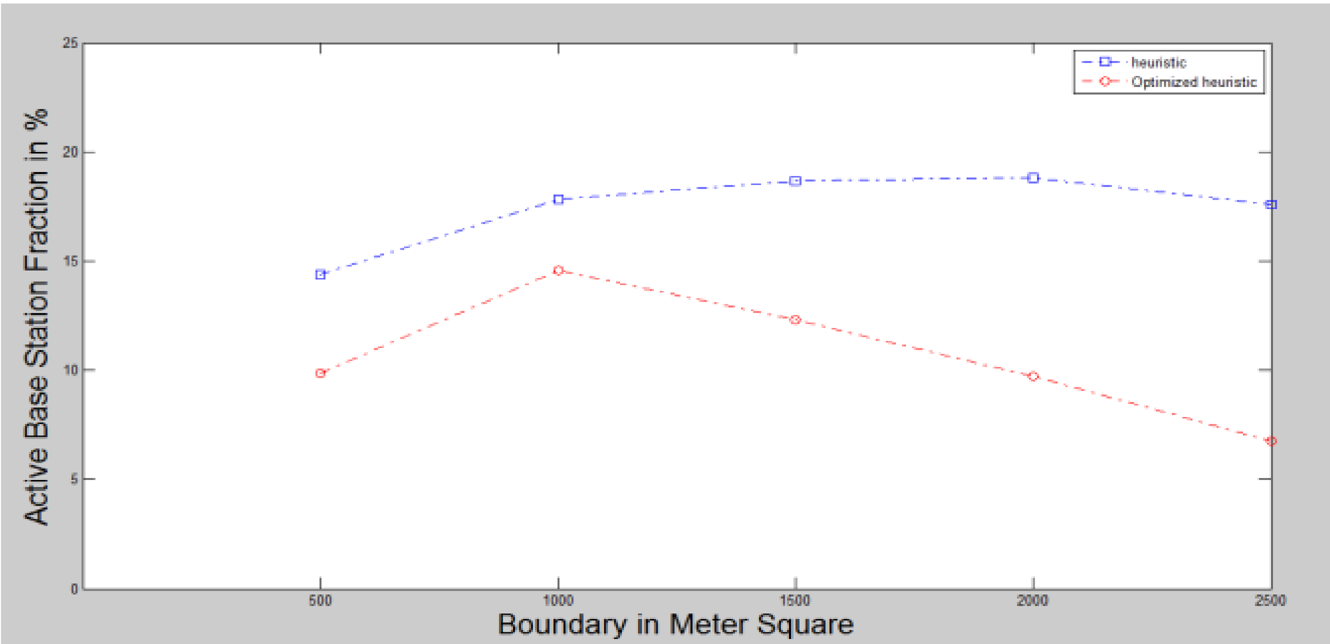

Fig. 3.7 Variation of active base station fraction with boundary

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IV. CONCLUSION

In this paper, the focus is on the problem of base station switching off through introduction of sleep modes for energy savings in wireless cellular networks. In particular, an optimized heuristic algorithm has been proposed for decreasing the active base station fraction by removing the redundant connections from base stations. The results achieved are far much better than heuristic algorithm [2].

In the current wireless access networks, the bit rate that is to be available to the users is the determining factor in the power consumption of the network. The higher the available bit rate in the entire area covered by the network, the more base stations (BS) need to deploy and the higher the power consumption of the network becomes. Furthermore, a higher bit rate corresponds with a lower power efficiency of the base station (BS). This consumes a lot of power which will degrade the quality of the environment and also increases the level of pollution as a large amount of pollution is generated from the communication network operation. The pollution from the carbon emission increases the risk of many breathing problems like asthma etc. With the introduction of sleep modes power consumed and carbon emissions can be reduced to large extent. Thus, sleep modes are a very promising solution for power reduction especially for the femtocell base stations.

V. FUTURE SCOPE

Nowadays, wireless access networks consume high amount of power and are thus large contributors to greenhouse gas emissions. In the future, more devices are equipped with wireless interfaces, new services, small cell base stations will also increase to fulfill the increasing needs of users for high bit rates so existing networks need expansion. Thus, the future wireless access networks need advanced power saving designs and powerful algorithms like optimized algorithms to save power. So, low power consuming circuits and powerful algorithms should be designed to save power and to reduce harmful emissions.

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REFERENCES

[1] The website of Telecom Regulatory Authority of India available from*: http://www.trai.gov.in* .

[2] Willem Vereecken, Margot Deruyck, Didier Colle, Wout Joseph, Mario Pickavet, Luc Martens and Piet Demeester "Evaluation of the potential for energy saving in macrocell and femtocell networks using a heuristic introducing sleep modes in base stations*", EURASIP Journal on Wireless Communications and Networking*, Vol. 2012, No. 170, pp. 1-14, 2012.

[3] M. Deruyck, W. Vereecken, W. Joseph, B. Lannoo, M. Pickavet and L. Martens 2012 "Reducing the power consumption in wireless access networks: overview and recommendations", *Progress in electromagnetics research*, Vol. 132, pp. 255-274,2012.

[4] Eunsung Oh, Kyuho Son and Bhaskar Krishnamachari "Dynamic Base Station Switching-on/off Strategies for Green Cellular Networks", *IEEE Transactions on Wireless Communications*, Vol. XX, No. XX, pp. 1-11 ,2013.

[5] V. Chandrasekhar, J. G. Andrews and A. Gatherer "Femtocell Networks: A Survey", *IEEE Communication Magazine*, Vol. 46, No. 9, pp. 59-67, 2008.

[6] G Schmitt "The Green Base Station", *4th International Conference on Telecommunication - Energy Special Conference (TELESCON),* Vol. 4, pp. 1–6, 2009.

[7] M Marsan, L Chiaraviglio, D Ciullo, M Meo "Optimal Energy Savings in Cellular Access Networks" *IEEE International Conference*, Vol. 44, pp. 1-5, 2009.

[8] Z Niu, Yiqun Wu, Jie Gong and Zexi Yang "Cell Zooming for Cost-Efficient Green Cellular Networks" *IEEE Communication Magazine*, Vol. 48, No. 11, pp. 74-79, 2010.

[9] Luis M. Correia, D Zeller, O Blume, D Ferling, Y Jading, I Godor, G Auer and L Van der Perre "Challenges and Enabling Technologies for Energy Aware Mobile Radio Networks" , *IEEE Communication Magazine*, Vol. 48, No. 11, pp. 66-72, 2010.

[10] L Saker, S.E. Elayoubi, T Chahed "Minimizing Energy Consumption via Sleep Mode in Green Base Station" *IEEE WCN Conference*, Vol. 12, pp. 1-6, 2010.

[11] K Samdanis, D Kutscher, M Brunner "Self-organized energy efficient cellular networks" *IEEE 21st International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC)*, Vol. 21, pp. 1665–1670, 2010.

[12] D Valerdi, Q Zhu, K Exadaktylos, S Xia, M Arranz, R Liu and D Xu , "Intelligent energy managed service for green base stations", *IEEE GLOBECOM Workshops (GC Wkshps) on Green Communication*, Vol. 29, pp. 1453–1457, 2010 .

[13] Eunsung Oh, Bhaskar Krishnamachari "Energy Savings through Dynamic Base Station Switching in Cellular Wireless Access Networks" *IEEE Global Telecommunication Conference,* Vol. 29 , pp. 1-5, 2010.

[14] Vincenzo Mancuso and Sara Alouf "Reducing Costs and Pollution in Cellular Networks" *IEEE Communication Magazine*, Vol. 49, No. 8, pp. 63-71, 2011.

ISSN: 2278 – 909X

[15] Imran Ashraf, Federico Boccardi and Lester Ho "Sleep Mode Techniques for Small Cell Deployments", *IEEE Communication Magazine*, Vol. 49, No. 8, pp. 72-79, 2011.

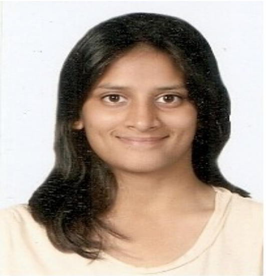
[16] Satnam Singh, Amit Kumar and Dr. Sawtantar Singh Khurmi "Green Base Stations: A Sustainable Approach in Wireless Communication Networks", *International Journal of Education and Applied Research (IJEAR),* Vol. 2, No. 1, pp. 9-14, 2012.

[17] Sanjay kumar, Jaya diptilal and S.V charhate "Green cooperative communication network using renewable energy sources", *IOSR Journal of Electronics and Communication Engineering (IOSR-JECE),* Vol. 9, No. 2, pp. 14-21, 2014.

[18] M Deruyck, E Tanghe, W Joseph, L Martens, "Modelling and optimization of power consumption in wireless access networks" *Elsevier Computer Communications*, Vol. 34, No. 17, pp. 2036–2046, 2010.

[19] Cisco Visual Networking Index (VNI) Mobile, Global Mobile Data Traffic Forecast Update 2013 – 2018, Tech report Cisco.

[20] Recommendation ITU-R P1238-2, Propagation data and prediction methods for the planning of indoor radio-communication systems and radio local area networks in the frequency range 900 MHz to 100 GHz. (1997–2001).



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