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Power Consumption Analysis in Femtocell Networks

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Abstract— **In this paper, the power consumption in a femtocell base station network is investigated using optimized heuristic algorithm and is compared with power consumption using heuristic algorithm for various bit rates, different user density, different base station density and different boundary areas. Furthermore, it is investigated to what extent the introduction of sleep modes can reduce the power consumption in femtocell networks. Reducing the power consumption of cellular wireless access networks is not only necessary for the global environment but also makes commercial sense for telecommunication operators. With the help of this optimized heuristic algorithm, a significant power saving is achieved, and the network becomes much 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— **Base station, femtocell , heuristic algorithm, sleep mode.**

I. INTRODUCTION

Today, almost each and everyone possess one or more mobile cell phones and thus the trend is projecting towards wireless devices. The Wireless World Research Forum (WWRF) [1] has a vision of 7 trillion wireless devices serving 7 billion users by 2017. These wireless devices are currently not only used in the outdoor environment, but are also used in indoor environments. Therefore, the operators and the manufacturers are looking for solutions to increase indoor coverage capacity. One such possibility is the introduction of femtocell base stations to increase indoor coverage capacity. A femtocell base station is rather cheap and can be installed by the end user. It communicates with the cellular network through a broadband connection such as DSL (Digital Subscriber Line) or cable modem, or through a separate RF (Radio Frequency) backhaul channel, thereby reducing the traffic on the cellular network.The power consumption of one femtocell base station is limited, however, when number of femtocell base station used in a network are increased, the power consumption can become significant.

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According to the Telecom Regulatory Authority of India (TRAI) [2] 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. As the wireless subscribers are increasing day by day, it results in increasing no. of deployment of base stations to provide service and coverage to more and more users. 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. With an increment in the number of base stations, it results in more power consumption. Also as the cost of resources such as coal, electricity are increasing day by day, the operational cost is also increasing in the same ratioo. Moreover the resources are becaming so scarce. Even though the operators like to cut down the operational cost and the resource utilization due to the uncontrolled user requirements but they cannot cancel out the already deployed base stations(BSs). One way to tackle the problem is to improve the efficiency or reduce the resource consumption. When optimizing a system for energy efficiency, the introduction of sleep modes in the base stations is one of the most commonly used approaches and is already well known in other wireless communication systems such as sensor networks.

There are different objectives for lowering the power consumption. The main reason is the financial cost. In mobile networks for instance, 90% of the overall power consumption is used by the operator's network, contributing to the operational expenditure of wireless carriers and only 10% is used in the user segment to power the mobile handsets of the cellular users. In fixed line networks on the other hand, because there are no base stations to power, energy only constitutes to 30% of an operator's operational expenditure. With rising fuel prices, power operational expenditure will only become a more important factor to be considered. Ecological considerations are a secondary factor. The main problem related to the environment is carbon-dioxide emissions due to increased level of power consumption which will worsen the quality of environment.

Thus, this paper focuses on maximization in energy conservation by increasing number of sleeping base stations i.e. to make the network more energy efficient and optimized through reduction in the power consumption of base stations (BSs) [9] by taking into account different scenarios like for various bit rates, different user density, different base station density and different boundary areas. Power reduction in base stations can be achieved in different ways: from hardware design (e.g., more energy efficient power amplifiers [8] and renewable energy resource for

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cooling [10]) to topological management (e.g., the deployment of small cells and cell zooming [7]) and so on.

The paper is organized as follows. In Section 2, characterization of the power consumption for mobile devices as well as for base station is described. In Section 3, the performance of the proposed algorithm is demonstrated for different scenarios to calculate the power consumption. Finally, the paper is concluded in Section 4, and future scope is discussed in Section 5.

II. CHARACTERIZING THE POWER CONSUMPTION

The power consumption of a typical cellular base station is related to the overall power efficiency of a mobile communication system. Power consumption is a significant cost factor for the operation. High power consumption results in additional construction costs (e.g. for fans) and space requirements so reduction in power consumption allows less battery backup, smaller and cheaper base-stations.Femtocell base station consists of several components a shown in the Fig. 2.1.

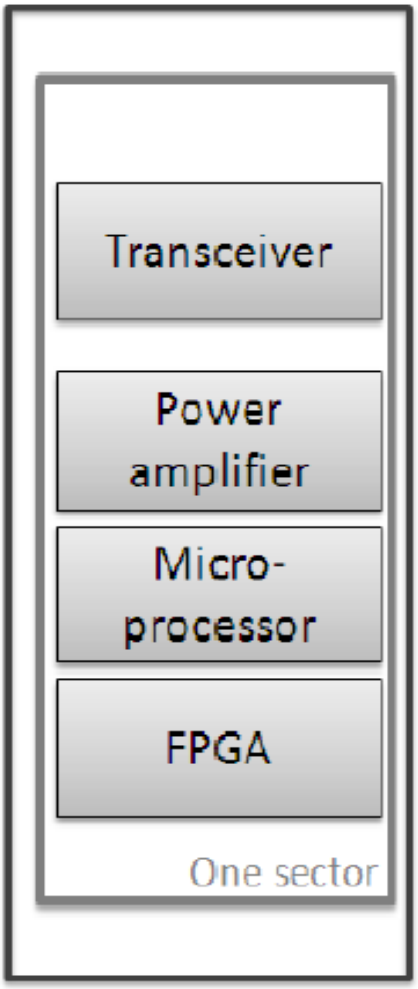

Fig. 2.1 Components of femtocell base station

The femtocell base station consists of a microprocessor, a FPGA (Field-Programmable Gate Array), a transceiver and a power amplifier. The microprocessor is responsible for implementing and managing the standardized radio protocol stack and the baseband processing and also takes care of the communication with the backhaul network. The FPGA is responsible for a number of features such as data encryption, hardware authentication, etc. Transceiver is responsible for transmitting and receiving the signals. Power amplifier converts the DC input power into a significant radio-frequent (RF) signal. The power consumption of these components is listed in Table 2.1.

Table 2.1 Power consumption of femtocell base station

COMPONENT	POWER CONSUMPTION
Digital signal processing	7.9 W (Microprocessor + FPGA)
Power amplifier	2.4 W
Transceiver	1.8 W

III. SIMULATION AND RESULTS

In the next generation networks the control signaling overhead is increasing to make network more adaptive and intelligent so the power consumption in these type of network increases. To reduce the power consumption in next generation networks , an optimized heuristic algorithm was proposed [4] which showed how we can reduce active number of base stations in a highly dense base station network, for that optimized heuristic algorithm power consumption analysis is done to check how much power can be reduced in a highly dense base station network without missing a single user.

Base stations can operate in two modes : active mode and sleep mode. When the femtocell base station is in active mode, the power consumed will be P_{act} while when the femtocell base station is in sleep mode, the power consumed will be P_S. To evaluate the power consumption of the access network, the average power consumption of a femtocell base station is multiplied by the number of femtocell base stations in the network. Thus, the power consumption density D_P is

$$D_P = D_B \left[P_S + F_A \left(P_{act} - P_S \right) \right]$$

Where F_A and D_B are the average active base station fraction of the access network and the base station density, respectively.

A. INFLUENCE OF BETA ON THE POWER CONSUMPTION

Users operating at low bit rates can connect to base stations at longer distances. Therefore, lower power consumption will be possible. In order to calculate this, we simulated user distributions of 500 users per 1.1 km^2 with 1951 base stations with varying β [4] and a channel bandwidth of 5 MHz. The result is shown in Fig. 3.1 for heuristic algorithm [3] and optimized heuristic algorithm [4]. When using femto-cells even in cases with a large preference for high bit rates (β = -5) the power consumption is very much low and same is the case for high values of β. Depending on the user distribution the result may vary 3 to 6%.

B. INFLUENCE OF USER DENSITY ON THE POWER CONSUMPTION

The influence of the user density on the power consumption is as shown in Fig. 3.2 for heuristic algorithm [3] and optimized heuristic algorithm [4]. As the user density increases more number of base station will become active and the overall system will consume more power but the use of optimized heuristic algorithm reduces power consumption in comparison to heuristic algorithm.

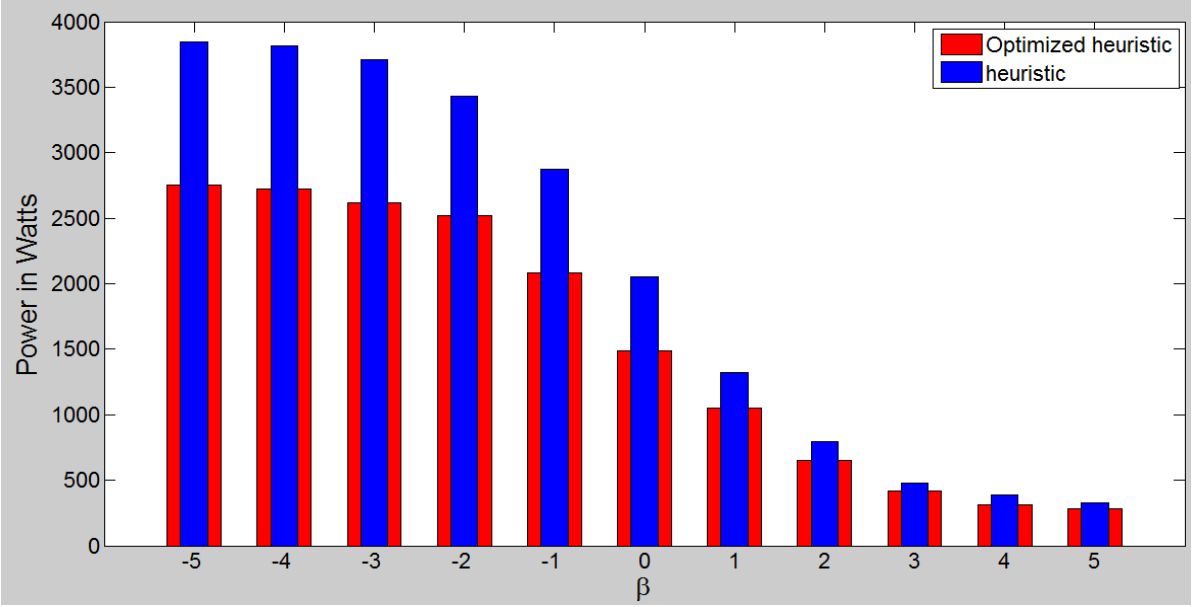

Fig. 3.1 Influence of beta on the power consumption

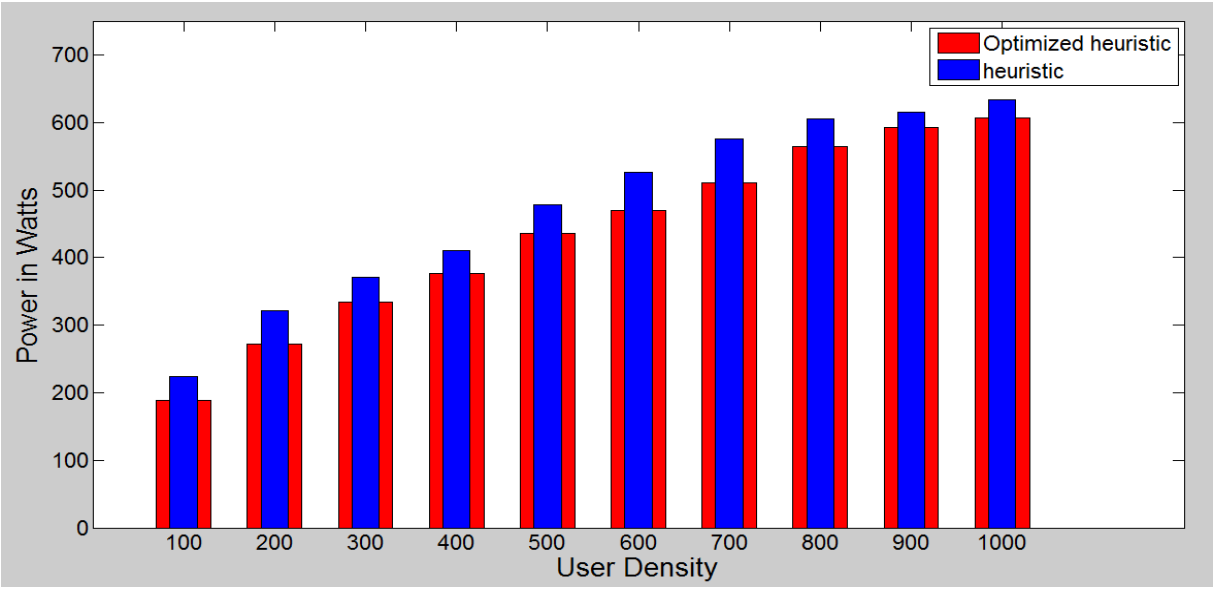

Fig. 3.2 Influence of user density on the power consumption

C. INFLUENCE OF BASE STATION DENSITY ON THE POWER CONSUMPTION

The influence of base station density on the power consumption is as shown in Fig. 3.3 for heuristic algorithm [3] and optimized heuristic algorithm [4]. As the

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network become more dense due to decrease in cell sizes , more overlapped cells will be there so due to redundancy more base stations can be switched off due to which power consumption reduces in comparison to all on base station network.

D. VARIATION OF THE POWER CONSUMPTION WITH BIT RATE

Variation of power consumption with respect to bit rate is as shown in Fig. 3.4 for heuristic algorithm [3] and optimized heuristic algorithm [4]. As the requirement of bit rate increases , the power consumption also increases due to shorter distance support to users with high bit rate

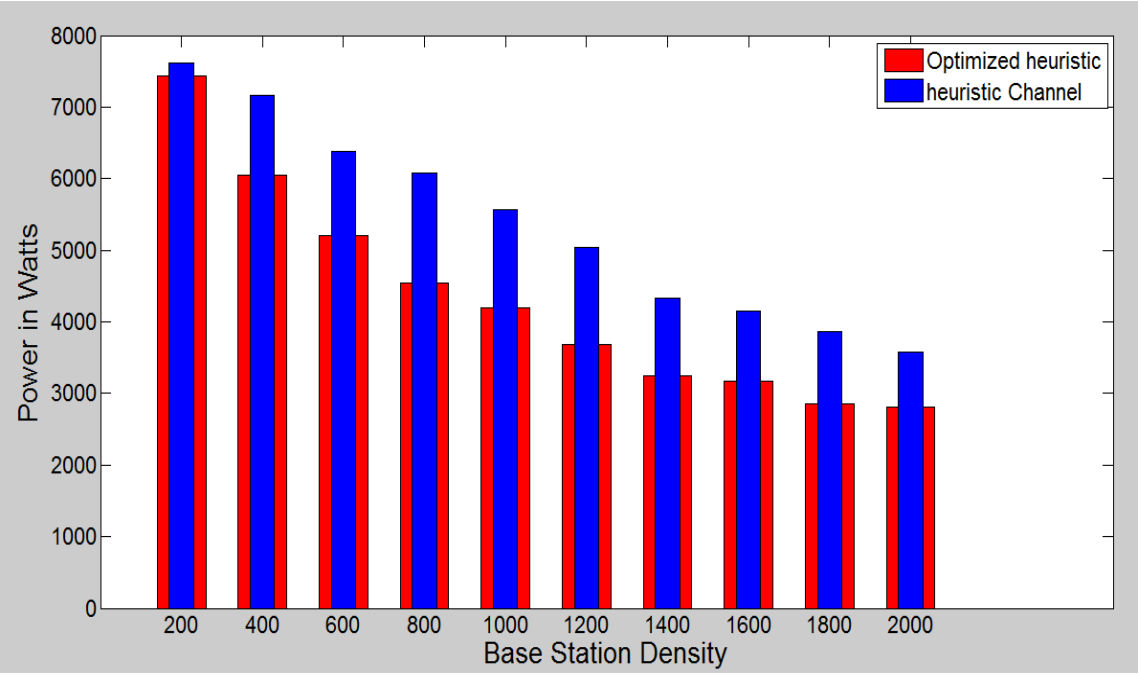

Fig. 3.3 Influence of base station density on the power consumption

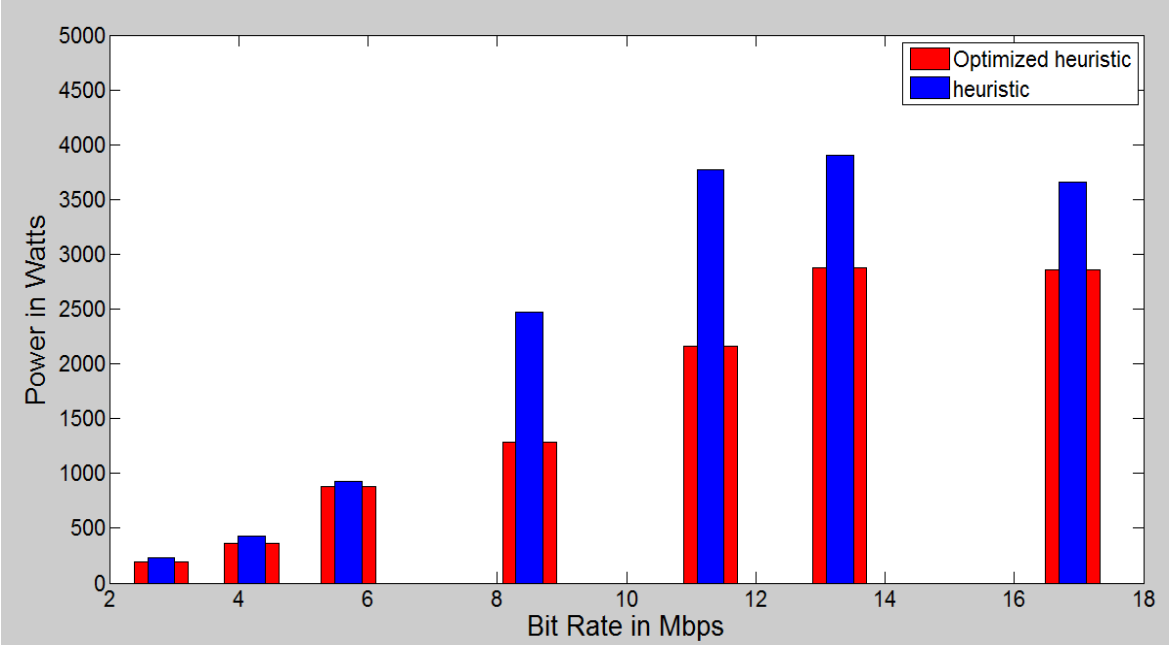

Fig. 3.4 Variation of power consumption with bit rate

E. VARIATION OF THE POWER CONSUMPTION WITH BOUNDARY

Variation of power consumption with respect to boundary is as shown in Fig. 3.5 for heuristic algorithm [3] and optimized heuristic algorithm [4]. As the area in which base stations are spreaded increases, the distances between base stations also increases due to which only the users which

are in proximity will get the service, all other users will get no service.So, less number of base stations required to be active due to which less power will be consumed.

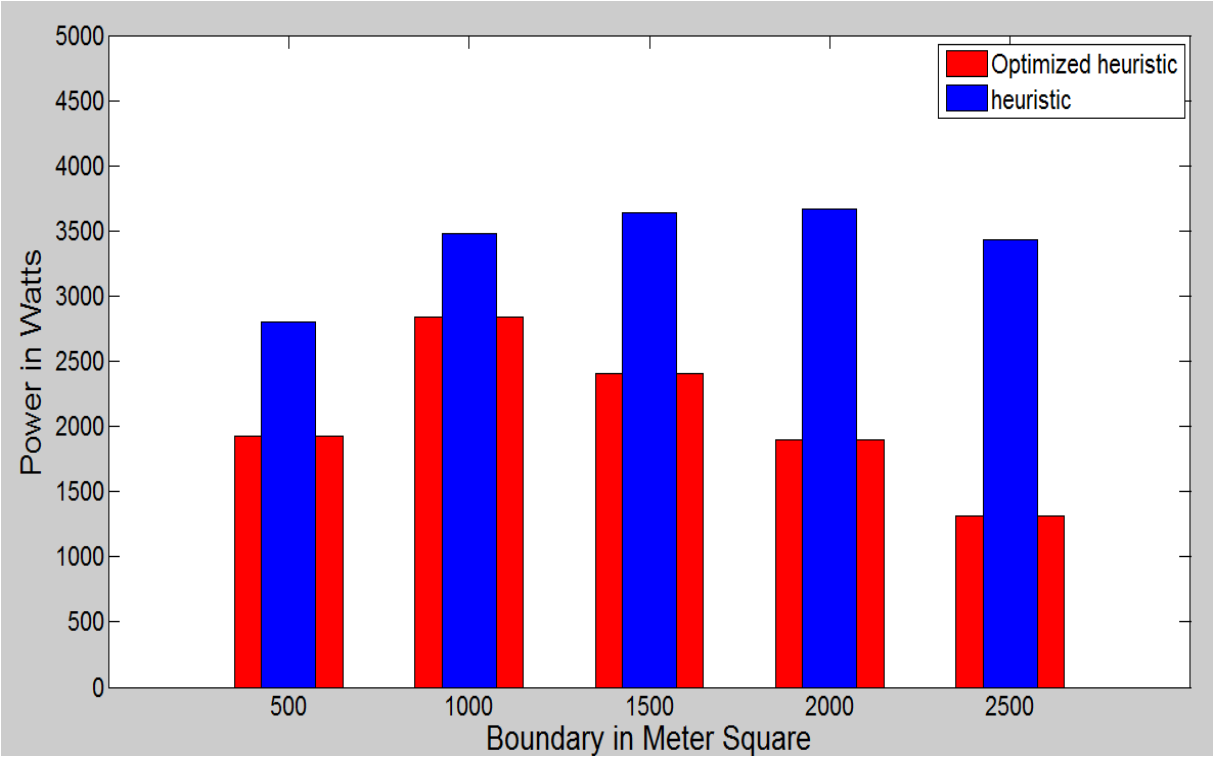

Fig. 3.5 Variation of power consumption with boundary

IV. CONCLUSION

This paper presents an analysis about reduction in power consumption through the introduction of sleep modes in base stations using optimized heuristic algorithm[4] and compared it with heuristic algorithm [3], also quantifying the potential of such a feature for different scenarios like for various bit rates, different user density, different base station density and different boundary areas.

V. FUTURE SCOPE

Low power consumption and energy efficiency is an important characteristic requirement of current and future telecommunication systems. It is therefore important both from the base station perspective, where electricity costs and thermal problems are major reasons to look for low power solutions as well as from a mobile terminal perspective, where the lifetime on a single battery charge is an important figure of merit. Moreover, low-power communication can potentially contribute to ameliorate public concerns about health issues related to mobile communication.Therefore, future research includes combination of the sleep modes with an advanced management algorithm that will have a positive influence on the power consumption and energy efficiency.

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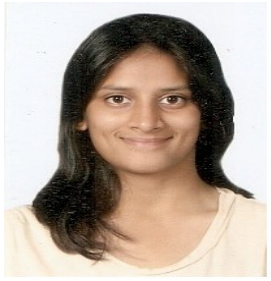

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