The Effects of Cell Size on Total Power Consumption, Handover, User Density of a Base Station, and Outage Probability

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Abstract—**The green IT (information technology) issue is one of the important issues on the network department recently. Because the wireless access point has an amount of portion of network power consumption, reducing cell size is introduced to save the wireless network power consumption. In this paper, we investigate the effects of cell size in terms of total base station power consumption, handover rate, user density, and outage probability. Finally, as reducing the cell size, total power consumption and outage probability are decreased. However, the handover rate increase and the number of user in a cell decrease. Since, the multicast transmission scheme is good solution to reduce the bandwidth and delivering the same contents to user, we investigate the energy resource performance based on the multicast transmission system. Finally, these analyses can be helpful for energy efficient cell planning.**

Keywords-cell size; base station power consumption; handover; user population density; outage probability

I. INTRODUCTION

Over the last 5 years, the green IT issue is one of the most important issues on the electrical engineering department. During this period, many researches focused on reducing the power consumption. Moreover, it is also important issues to save energy and reduce the power consumption at network equipment. Especially for network department, wireless access point is the most important issue of green network because it has 40% of total power consumption at the access point in wireless networks [1]. Therefore, some technical issues such as network architecture, cell size, routing, etc., are researched to reduce energy consumption of the wireless access point [1].

Since the wireless access technology has been developed quickly and the number of users who requests various multimedia broadcasting and streaming such as IPTV increases, it is important to allocate resource efficiently [2]. To support quality of service (QoS) of users, wireless multicast transmission can be a good solution to reduce the resource waste for delivering the same contents to user. However, there is lack of consideration in energy efficiency of multicast transmission scheme, since it is just focused on some resource such as bandwidth, delay, capacity and so on. Therefore, we investigate the energy resource considering multicast transmission system. Moreover, Cell planning is main problem in the cellular mobile communication and also it is the key of reducing power consumption of base station. Previous cell planning technology for energy saving is focused on small-sized cell which has advantage of reducing base station power consumption [3].

In this paper, we focus on the cell planning technology for reducing the power consumption especially in wireless multicast environments. In detail, we analyze the base station power consumption and handover rates as varying the cell size. Moreover, we also analyze the multicast outage probability versus cell size. It is energy efficient way on behalf of the base station power consumption. However, a small-sized cell topology makes smaller coverage area and more frequent handover. The more handover causes latency and additional unnecessary power consumption. In addition, small-sized cell makes that the number of users per one base station is reduced. Therefore, our analysis shows the effects of cell size on total power consumption, handover, the number of user per base station, outage probability in this paper. This analysis can be efficient tool for cell planning by considering various points of view.

Moreover considering mobility, S.K. Lee et al. [4] already investigated the wireless access network based on WDM-PON for mobility support. They optimize the mobility management process between the corresponding node and the home agent. From their results, bandwidth waste and long end-to-end packet delay are reduced using their proposed scheme. However, power consumption and cell radius are not considered in their proposed scheme.

The remainder of the paper is organized as follow. Section Ⅱ briefly explains the related works. Section Ⅲ introduces the system model and performance. Section Ⅳ concludes the paper. Last, we present the future work which is to find the optimal solution in section Ⅴ.

II. RELATED WORKS

A. *Cell size*

Previous study, I. Hakki CAVDAR et al. [5] proposed an algorithm for the TDMA-FDMA mobile cellular communication system. They consider traffic and coverage analysis for procedure of cell planning. As the cell radius increases, transmitted power of base station (BS) and path loss are increased, however the capacity has better performance. They also consider three environment, urban

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area, suburban area, and rural area. In case of the urban environment, performance is worse than suburban and rural environment. Jayant Baliga et al. [6] present a comparison of energy consumption of access networks which are passive optical networks, fiber to the node, point-to-point optical systems and WiMAX. Their results show that the optical access technologies provide the most energy-efficient solutions than other access technologies.

B. Handover

Daehyung Hong et al. [7] investigate the performance of cellular mobile radio telephone systems with handoff procedures. They consider the cellular structure, frequency reuse, and handoff for mobile radio telephone systems. In their paper, they also analyze the probability distribution of residing time in a cell and derive the handoff probability when mobile node resides in a cell to which its call is handed off. One of their results shows that mean channel holding time in a cell is increased as the cell radius is increase. Hyun-ho Choi et al. [8] propose the new vertical concept, *Takeover*, which enables a neighbor node to process requests of a mobile node. Their proposed handover scheme has better performance in terms of average handover latency, packet loss and power consumption. In their results, energy consumption per a mobile node is increased if the speed of mobile node is lager.

C. The User Population Density

In [5], they present the power consumption per a user and energy per bit versus average access rate for typical access networks. Power consumption per a user and energy per bit are important factor on energy resource point of view. In their results, power consumption per a user is increased if the average access rate is larger. However, they only consider the maximum average access rates that each technology can achieve at user population densities.

D. The Outage Probability

S.Y. Baek et al. [9] investigate the adaptive transmission scheme for mixed multicast and unicast traffic. They proposed a novel hybrid scheduling scheme which is consider some threshold SNR values for multicast transmission. For users have less than threshold SNR, they transmit the data using unicast transmission scheme not the multicast transmission scheme. They evaluate the system performance of multicast and unicast transmission schemes in terms of system capacity, worst average channel user's capacity, and outage probability for varying cell environments. According to their results, the outage probability of the multicast transmission increases as the cell radius increases. Moreover using their novel hybrid scheduling scheme, multicast capacity improves than conventional scheme. However in this paper, the power consumption is not also considered in this paper.

III. SYSTEM MODELING AND PERFORMANCE

We first describe a system with a typical urban macro-cell model which has cell radius about 1.5km to 3.5km. Each

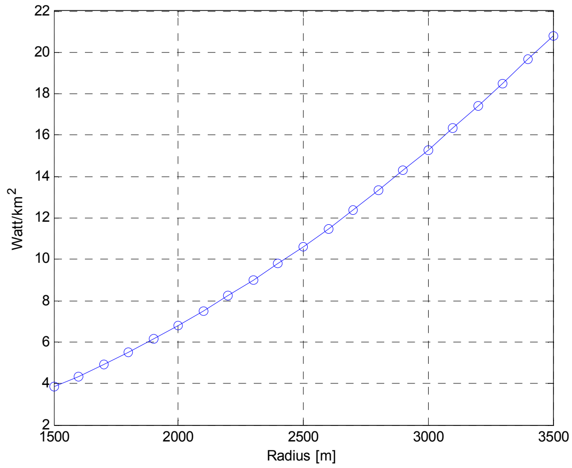

Figure 1. Area power consumption versus cell size

base station consisted of hexagonal cell and one hexagonal cell area has $A_c = \frac{\sqrt{3}}{2}R^2$ value where the cell radius is R. We assume the traffic density has uniformly distribution. Also, we assume the user popular density of total area is fixed and we only consider the base station's transmission power not mobile node's transmission power. Because the multicast transmission scheme is more efficient way of reducing resource waste, we assume that this system provides the multicast transmission scheme. In multicast system, even though the worst channel user should be guaranteed quality of service.

A. Base Station Transmit Power

Consider the propagation model [10] without shadowing, we can define the transmitted power of BS where the signal level is at least P_{min} follows

$$\mathrm{P_{tx}} = \frac{\mathrm{P_{min}}}{\mathrm{K}}\mathrm{R}^{\lambda}, \tag{1}$$

where P_{tx}, P_{min}, and λ denote transmit power, minimum transmit power at the cell boundary, and path loss exponent, respectively. In multicast service environment, the power at the cell boundary has minimum requirement power value because multicast service should provide the requirement data rate to worst channel user. Therefore, we fix the minimum power value at the cell boundary to guarantee the data rate. In macro cell environment, the effective propagation parameters are supported as path loss and the factor K, 4.00 and 2.2751, respectively.

Figure 1 shows the area power consumption as radius of BS is increased. The transmit power of BS is proportional to cell radius and also area power consumption, which is power consumption in unit area not a base station's transmit power, is increased when cell radius is increased.

B. Handover Rate

We take into account the handover rate to increase cell size. In more frequent handover environment, user's mobility

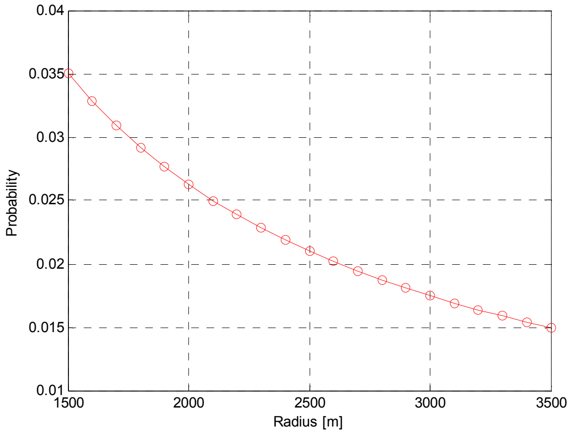

Figure 2. Probability of handover reside time versus radius

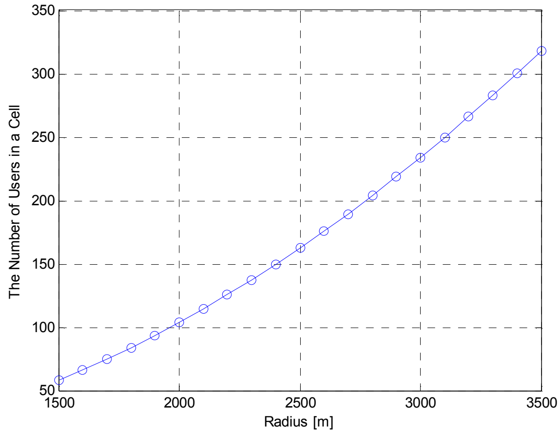

Figure 3. The number of users in a cell versus cell size

could not be guaranteed. Therefore, the handover rate is important factor in wireless system supporting mobility. In [7], the probability of the time, T_h, a mobile resides in a cell to which its call is handed off is defined as

$$P_{T_h} = \begin{cases} \frac{2}{\pi}\arcsin\left(\frac{V_{max}t}{2R_{eq}}\right) - \frac{4}{3\pi}\tan\left[\frac{1}{2}\arcsin\left(\frac{V_{max}t}{2R_{eq}}\right)\right] + \\ \frac{1}{3\pi}\sin\left[2arcsin\left(\frac{V_{max}t}{2R_{eq}}\right)\right], \quad for\ 0 \le t \le \frac{2R_{eq}}{V_{max}}, \\ 1 - \frac{8R_{eq}}{3\pi V_{max}}\frac{1}{t}, \quad for\ t \ge \frac{2R_{eq}}{V_{max}} \end{cases} \tag{2}$$

where V_{max}, and R_{eq} are maximum speed of mobile terminal and radius of approximation circle, respectively. In this model, we set the speed is 30km/h. Also, we assume the maximum handoff time is fixed and then we can find the probability of handover varying cell radius.

Figure 2 shows the probability of the handover which a mobile node resides in a cell when its call is handed off and maximum handover time is fixed. The probability of that is decreased when cell radius is increased. Following this results, the handover is occurred more frequently when the cell radius goes to smaller. The probability is 0.035 when the cell radius is 1.5km and the probability goes to 0.015 when cell radius goes to 3.5km. However, the effect of cell radius for handover is very small. Therefore, we can ignore the effects of the handover rate by reducing cell size not considering the handover latency in macro cell environment.

C. *The Number of Users per One Base Station*

The number of users per one BS is lower when the cell size is decreased. When the cell size is decreased, coverage of a BS is also decreased. In this paper, we consider the number of users per one BS and the transmit power of BS per the number of user in a cell.

First, we investigate the number of users in a cell versus cell size. We assume that there are 10 users in $1km^2$ and users are uniformly distributed. Therefore, the number of users in a cell is expressed as

$$N_{BS\_user} = N_{sample\_user} \times \frac{A_{BS}}{A_{sample}}, \tag{3}$$

where $A_{BS}$is the area of BS and A_{sample} is the sample area. It is proportional to R^2 because the BS coverage is proportional to R^2 and the other terms are constant value. Figure 3 shows its result so that the number of users in a cell is increased when the cell size is increased.

Next, we investigate the power per one user in a cell. It is important factor considering energy resource management. We can say that the energy efficiency is low when the power consumption per user is low even though the total power consumption is large. Therefore, we also consider the transmit power of BS per users in a cell and it is defined as

$$P_{user} = \frac{P_{tx}}{N_{BS\_user}}. \tag{4}$$

Figure 4 shows the transmit power of BS per the number of users in a cell. Even though the number of users in a cell is increased when the cell radius is increased, the transmit power of BS per the number of users in a cell is increased. Therefore, reducing cell size is more energy efficient way than others in terms of allocated amount power for one user.

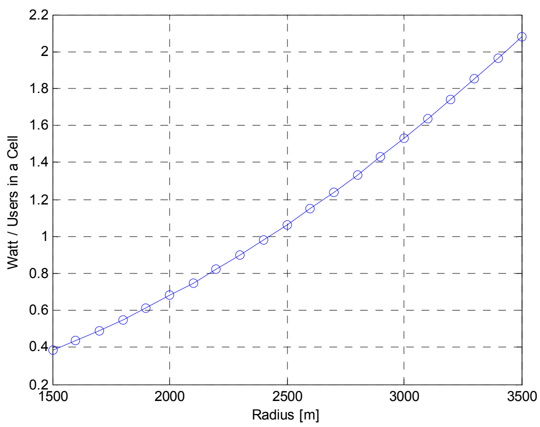

Figure 4. Base Station Transmit Power per Users in a Cell

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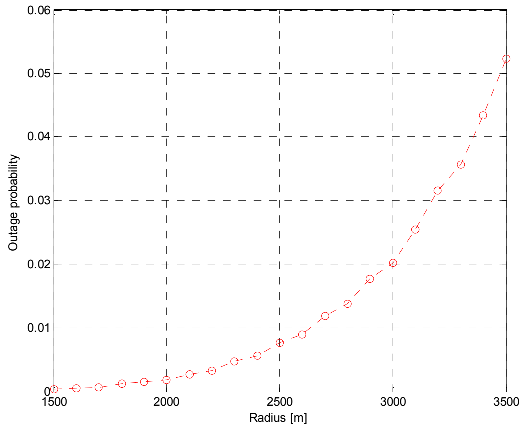

Figure 5. The outage probability versus cell size

D. *The outage probability*

In this paper, we consider the multicast transmission system. In multicast transmission, the outage probability is increased as the cell radius increases. From [8], the conditional pdf of selected users' SNR value is expressed as

$$f_{z|i}(z|i) = L\left(\frac{2\rho_0^{\frac{2}{n}}}{nR^2}\right)^L z^{-\frac{2L}{n}-1}\gamma\left(\frac{2}{n}+1, \frac{R^n z}{\rho_0}\right)$$

$$\times\left[\gamma\left(\frac{2}{n}, \frac{R^n z}{\rho_0}\right)\right]^{L-1}. \quad (5)$$

The parameter L means the number of users in a cell and R is the cell radius. We can calculate the number of users in a cell using ratio of BS coverage and sample area. Then, the outage probability of the multicast transmission scheme is expressed as

$$\Pr\{Z \le \Gamma\} = \int_0^\Gamma f_{z|i}(z|i)dz. \quad (6)$$

Figure 5 shows that the outage probability is increased when the cell radius is increased. The outage probability is 4.312×10^{-4} when the cell size is 1km and the outage probability is 0.0522 when the cell size is 3.5km. Therefore, there is advantage of reducing cell size in the aspect of outage probability.

IV. CONCLUSION

In this paper, we focus on the total base station power consumption, handover rate, the allocated power per user in a cell, and outage probability as varying cell size. Our analyses show that the power consumption and outage probability are proportional to the cell size. However, the handover probability and the number of users in a cell are inversely proportional to the cell size. Therefore considering energy efficiency, reducing the cell size is the most energy saving way in the aspect of base station power consumption. However in terms of handover, reducing the cell size does not guarantee the user's QoS or mobility. Finally, these two different aspects have trade-off relationship. Therefore, it is helpful for cell planning because our analyses show that these aspects should be considered.

On the contrary, the total power consumption will be increased from some point when the frequent handover is occurred because of the handover signaling. In addition, more base stations can consume more power consumption because of the initial power consumption of BS.

In future work, we will investigate the some optimal energy efficient point based on WDM-PON for HMIPv6 mobility support and also base station's power consumption.

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