Advance in Electronic and Electric Engineering.
ISSN 2231-1297, Volume 3, Number 3 (2013), pp. 365-372

http://www.ripublication.com/aeee.htm

A Review on Impacts of Cell Size on Electromagnetic Pollution - A Comprehensive Step Towards Green Mobile Communication

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Abstract

The explosive growth of world population is exponentially increasing the density of mobile communication system. At the end of 2011, total worldwide mobile subscription have grown to 5.9 billion and mobile internet subscription to 2.5 billion over the worldwide population of 7 billion, and these are expected to increase up to two times within five years. The growth in mobile communication is directly coupled with the growth of base stations (BSs) and mobile stations (MSs) which are the cause of rising carbon foot print rate and electromagnetic pollution (EMP) in the biosphere. The rapidly growing electromagnetic radiation (EMR) and carbon foot print has given rise to increasing concerns about the unpropitious repercussion on human health, flora and fauna. The paper will acquaint a review of epidemiological and experimental studies performed by various international bodies and researchers. That, the impact of cell size on energy saving and system capacity and the effectiveness of small-cell based future mobile communication systems in terms of energy efficiency as well as the reduction of EMP in terms of electromagnetic pollution index (EPI) for 'True' Green Mobile Communications.

Keywords: Green Mobile Communications, Electromagnetic Radiation, Electromagnetic pollution, Electromagnetic Pollution Index, EPI, Reducing electromagnetic pollution.

1. Introduction

Fast and uninterrupted communication system is the most essential thing for human society. Because of this, communication technology is growing day by day, form 2G to 3G and 3G to 4G and 5G technology. Higher data rate requires more electrical power. To ensure uninterrupted power supply the use of diesel generators is essential, it increasing the greenhouse gas (GHG) emission and rational enhancement of the carbon footprint which has a deleterious impact on the biosphere.[9] Due to this the considerable rise in temperature is seed of the effects of global warming in the atmosphere. Many governments around the world, including India has taken steps in Kyoto Protocol in 1997 to reduce energy consumption and emissions of greenhouse gases by 5%, in between the year 1990 to the year 2012. India is dedicated to reduce carbon intensity by 20-25% between 2005 and 2020[4].

The information and communications technology (ICT) industry alone responsible for about 2% or 860 million tones of the world's greenhouse gas emissions. BSs and MSs contribute about 24% of the total emissions. The challenge for ICT and the government is to pursue growth in telecommunication networks, while insuring that the 2 % of global GHG emissions does not significantly exceed over the coming years. On the other hand the electromagnetic radiation (EMR) is also rapidly increasing with consecutive growth in BSs and MSs. The electromagnetic non-ionized radiation adversely affect on the human body and flora and fauna. It is categorized into thermal effects and biological effects. International Commission on Non-Ionizing Radiation Protection (ICNIRP) formulated guidelines, specifically ignored the potential long term biological effects such as increased risk of cancer [1]. As WHO classified on 31 May 2011[3], the RF exposure from mobile telephones "possibly carcinogenic to humans (Group 2B)". Also the biological effects on flora and fauna are synopsized by Committee on the Environment, Agriculture and Local and Regional Affairs [5]. The Council of Europe report explain that "EM fields from mobile telephony appear to have more or less potentially harmful, non-thermal, biological effects on plants, insects and animals, as well as the human body when exposed to levels that are below the official threshold values"[7] . The report of Government of India [6] recommended for radiations from mobile towers has to be recognized as a pollutant. This paper is the review of previous studies which are concerned with the problems which we have discoursed in this section. According to these studies these problem can be strongly minimized by deploying the BSs in the small-sized cell-based technology. This technology will reduce EMR as well as it will require less power supply for operation so that is well reducing power consumption consecutively will extend the battery life of the MSs.

2. Effects of Cell-Size on System Parameters

To achieve the required high data rate, efficient energy consumption and to minimize electromagnetic pollution for the future mobile communication system, it is significant to understand the effects of cell size on system parameters. And the parameters are

Energy conservation, system and user capacity, Per Energy Capacity, Electromagnetic pollution.

3. Effects on Energy Conservation

To evaluate the energy conservation of BSc and MSs either Fixed Power Strategy or Power Control Strategy can be used. In Fixed Power Strategy the downlink and uplink power transmission is fix and the energy conservation is evaluating corresponding with the varing cell radius, on the other hand in Power Control Strategy downlink and uplink power transmission is varing according to the cell radius with maintaining the signal to noise ratio constant. By using both strategies it is obtained that the ratio of total system transmit power in a given area $A_1$is expressed as for downlink transmission[2]

$$\frac{S_k^{BS}}{S_1^{BS}} = \frac{P_k}{P_1} \cdot \frac{A_1}{A_k} = \left(\frac{R_k}{R_1}\right)^{n-2}, \text{ k=2,3,4} \quad (1)$$

and uplink transmission is expressed as

$$\frac{S_k^{MS}}{S_1^{MS}} = \frac{P_k^u}{P_1^u} = \left(\frac{R_k}{R_1}\right)^{n}, \text{ k=2,3,4} \quad (2)$$

The above equation (1) of downlink and equation (2) of uplink transmission shows the ratio of total power consumption for varying path-loss exponents. The cell-level power consumption ratio of the system decreases as the path-loss exponent and the parameter k value increases. As power consumption for BS and MS decreases,the emission of CO_2 will also decrease. In a year if the cell radius is 1km, 500m, 100m and 10m, the amount of CO_2 emission of one BS transmitter becomes approximately 181kg, 1.81kg and 18.1g, respectively. Hence, by using a small-size cell-based topology we can also reduce the CO_2 emission.

4. Effects on System and User Capacity

To evaluate the system and user capacity of BSc and MSs either Fixed Power Strategy or Power Control Strategy can be used. In Fixed Power Strategy the downlink and uplink power transmission is fix and the system and user capacity is evaluating corresponding with the varing cell radius, on the other hand in Power Control Strategy downlink and uplink power transmission is varing according to the cell radius with maintaining the signal to noise ratio constant. By using both strategies it is obtained that the ratio of system and user capacity in downlink transmission[2]

$$\frac{C_k^{BS}}{C_1^{BS}} = \left(\frac{R_1}{R_k}\right)^2, \text{ k=2,3,4} \quad (3)$$

and uplink transmission is expressed as

$$\frac{C_k^{MS}}{C_1^{MS}} = \left(\frac{R_1}{R_k}\right)^2, \text{ k=2,3,4} \quad (4)$$

The above equation (3) of downlink and equation (4) of uplink transmission shows the ratio of total system capacity for varying path-loss exponents. The cell-level capacity ratio of the system increases as the path-loss exponent and the parameter k value increases. If we compare macro-cell radius 1km with micro-cell radius 500m, pico-cell radius 100m and femto-cell radius 10m, the system capacity increases from 4 to 100 and 1000, respectively in area A_1. Hence, significant capacity in proportion to the number of BSs can be obtained by deploying small-size cell-based topology.

5. Effects on Per-Energy Capacity

We enumerate system capacity per energy consumption by using parameters of system capacity and energy consumption at BS and MS at cell type k.System capacity per energy consumption is the ratio of system capacity and energy consumption. It is obtained that the per energy capacity of downlink transmission can be expressed as[2].

$$\frac{U_k^{BS}}{U_1^{BS}} = \left(\frac{R_1}{R_k}\right)^n, \text{ k=2,3,4} \quad (5)$$

and uplink transmission can be expressed as

$$\frac{U_k^{MS}}{U_1^{MS}} = \left(\frac{R_1}{R_k}\right)^{n+2}, \text{ k=2,3,4} \quad (6)$$

By the above equations (5) and (6) it is observed that the ratio of per-energy capacity in downlink is smaller than uplink, and the per-energy capacity ratio of the system increases as the path-loss exponent and the parameter k value increases.

6. Effects on Electromagnetic Pollution

In any BSs and MSs the EMP can be evaluated by Electromagnatic Pollution Index (EPI) which is the product of the normalized polluted area and polluting energy, which is shown in equation (7). Where normalized polluted area is the ratio of sum of area of all packets of pollution (POP) and Area of cell, and polluting energy is the Sum of eneargy of all POP.[8]

$$\text{EPI} \trianglelefteq \left(\frac{\text{Sum of area of all POP}}{\text{Area of cell}}\right) * (\text{Sum of eneargy of all POP}) \quad (7)$$

A simplifed model of EPI is established under considerations free space propagation, no power control and isotropic antennas for the transmission

$$\text{EPI}= \left(\frac{1}{A}\right)\left(a_{BTS}+ \sum a_j\right)P_{min}R_{max}^2\left(\frac{4\pi}{\lambda^2}\right)\left(\sum_1^{uv} \tau_i\right)+\left(\sum_1^{M} T_j\right) \tag{8}$$

If all the channel are engaged for all the time then EPI will reach up to its maximum value. In this case EMP from MS will equal to the BS. If a large cell-size is splited in to 7 equal cell-size, then the ratio of EPI form larg cell-size and small cell-size is expressed in equation (9)

$$\frac{EPI_{max}}{Epi_{max}} = \frac{vR_1}{r_1} \tag{9}$$

Here upper case is used for larger cell-size and lower case of smaller cell-size. Epi_{max} form MS is almost equal to the BS EPI_{max}, hence it is observed that the EPI form MS can be eliminated by reducing cell density and call duration. Smaller cell-size provides the negligible EPI and it leads to reduce EMP.

7. Conclusion

Energy effeciency and high data rate is the major requirement for future mobile communication. In this paper we have reviewed the impacts of cell size on electromagnetic pollution as well as impacts on energy effeciency, system capacity and per-energy capacity. Both electromagnetic and greenhouse gases (GHG) like CO_2 emission can be mitigated by using the small cell-sized topology. which are the roots of atmospheric imbalance and the adverse effects on human health, flora and fauna. it is observed that as the cell size reduced, we can increase system and user capacity and energy efficiency as well it reduces electromagnetic pollution (EMP). Therefore, by deploying small cell-size topology BSs we can significantly minimize energy consumption and EMP and significantly increase system capacity and MSs battery life. Small-cell based topology is strongly recommended as effective solution for the green mobile communication.

8. Acknowledgements

The authors would like to express their sincere gratitude to the HOD of Electronics and Communication Engineering of BIT, Bhopal Dr. Ashutosh Sharma, HOD of Electronics and Communication Engineering of SATI, Vidisha Dr. S. N. Sharma and HOD of Electronics and Communication Engineering of TIT, Bhopal Prof. Vikas Gupta for their everlasting support and encouragement for research work and the research team.

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Appendix: Equation Parameter Discription

- S_k^{BS} = BS transmit power in cell type k
- S_k^{MS} = MS transmit power in cell type k
- C_k^{BS} = BS total system capacity in cell type k
- C_k^{MS} = MS total system capacity in cell type k
- U_k^{BS} = BS capacity per unit energy in cell type k
- U_k^{MS} = MS capacity per unit energy in cell type k
- A_k = Area of BS and MS transmit power in cell type k
- P_k = Tranmitted power of BS and MS in cell type k
- R_k = Radius of cell type k
- n = the path-loss exponent
- k denotes the cell type such as
- k=1 for macro-cell with radius of 1km

- k=2 for micro-cell with radius of 500m
- k=3 for pico-cell with radius of 100m
- k=4 for femto-cell with radius of 10m
- A = Area of the cell
- a_{BTS} = Area of POP because of BS
- A_j = Area of POP because of MS
- P_{min} = Required minimum signal at maximum distance
- R_{max} = maximun possible distance between BS and MS
- u = Number of channels per Transceiver
- v = Number of Transceiver
- τ_i = Average transmit time for i^{th} channel of BS
- T_j = Average transmit time for j^{th} MS
- M = Number of nodes