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GA-based Dynamic Base Station Operation to Improve Energy Efficiency

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1 Introduction

Improving energy efficiency of communications network is a concern with regard to environmental and economical aspect. Referring to previous research, 3% of the world-wide electrical energy consumption is from the information and communication technology (ICT) infrastructure. Moreover it is estimated that the rate is increasing rapidly [1]. Regarding the expense, 20~30% of the network operation cost is from the electrical energy consumption [2].

Mobile telecommunication networks are usually designed to be able to treat peak-time traffic volume. Therefore, average traffic load for a day is usually much lower than the peak traffic. In a daily traffic pattern of a real-deployed base station (BS), the traffic volume is lower than the half of the peak traffic for about 12 hours a day (see Figure 1).

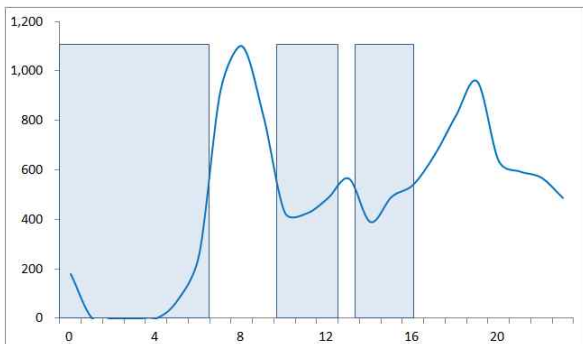


Figure 1. A daily data traffic pattern sample for a real 3G base station – a week day

In mobile networks, electrical energy consumption of BSs is estimated to take about 60~80% of the whole energy consumption of the network [3]. There are many technologies under study to improve energy efficiency of BS deployment and management [4]-[9]. Dynamic BS operation is one of them. Dynamic BS operation, in this paper, is turning off redundant BSs when traffic load is low and the adjacent BSs support the users, previously supported by the turned-off BSs, by extending their coverage with increased transmission power.

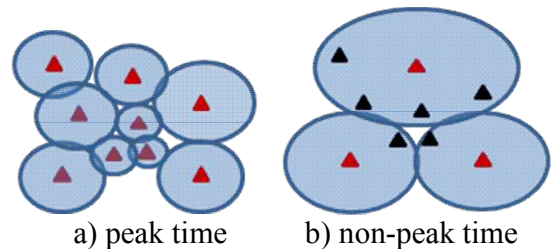


Figure 2. Dynamic BS operation, a) BS operation in peak time, b) BS operation in non-peak time

The structure of this paper is as follows. Chapter 2 introduces research trend for the area of green communications, especially on the technologies to improve energy efficiency of communications networks. Chapter 3 simulates energy saving of mobile networks using dynamic BS operation. For the simulation, genetic algorithm (GA) is used. The simulation also covers the relationship between energy saving and coverage hole.

2 Related research

Methodologies and techniques to improve energy efficiency of communications networks are under investigation by several organizations. *Green Touch* is a consortium composed of ICT industry, academic and non-governmental research experts. It was organized by Bell Labs in 2010. The purpose of Green Touch is to create 1,000-fold energy efficiency improvement by transforming Internet and telecommunications networks. It has five working group project: core optical networking and transmission working group projects, core switching and routing working group projects, mobile communications working group projects, wire-line access working group projects, and services, applications and trends committee projects. Especially in mobile communications working group projects, technologies for green transmission and large-scale antenna system are under investigation [10]. *EARTH* (Energy aware radio and network technologies) investigates energy efficiency of mobile communications systems. It has 15 members from European countries including Alcatel-lucent, Ericsson, ETSI, etc. It is composed of six work packages: project management (WP1), energy efficiency analysis, metrics and targets (WP2), green networks (WP3), green radios (WP4), proof of concepts and operator test plant (WP5), integrated solutions, standardization & dissemination (WP6) [11].

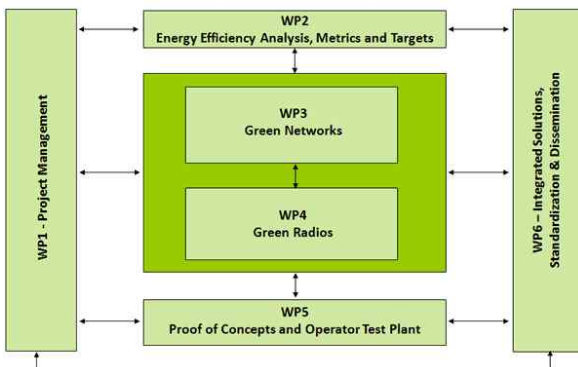


Figure 3. Work package structure of EARTH

There have been several academic events on green communications. *International workshop on green communications*, first held in 2009 in conjunction with IEEE ICC 2009, had its fourth event in 2011. IET Communications had special issue on “Green technologies for wireless communications and mobile computing” in 2011. *International conference on green computing (ICGREEN)*, *Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (ENERGY)*, and *ACM Sigcomm workshop on green networking* are also the events which has focus on green communications technologies.

3 Simulation on energy saving by dynamic BS operation

3.1 Energy saving and coverage hole

Although dynamic BS operation is able to improve energy efficiency of mobile networks, there are several challenging issues, e.g., coverage holes, deterioration of service performance, etc. When there are coverage holes while turning off BSs, techniques such as relay transmission, CoMP (coordinated multipoint) need to be applied to cover the hole. This paper first investigates the effect of dynamic BS operation on energy saving. It also simulates the relation between energy saving and coverage hole, when the coverage hole is 0%, 5%, 10%, 15%, and 20%. The traffic pattern of each BS, location of BSs, and the BS capacity is set referring to real operation data of one of Korean ISPs.

3.2 Experimental design

The experimental field is 16km² (4km x 4km) area, which is composed of 40 x 40 unit blocks, a square area of 100m x 100m. There are 37 BSs in the field and locations of BSs are given (see figure 4). The capacity of each

BS is set 1,577 Erlang. The max coverage radius of a BS is set 2km. A BS of coverage r covers the unit blocks within a circle with radius r . Coverage overlap between BSs is not allowed. When there are several nearest BSs for a unit block, the unit block is randomly allocated

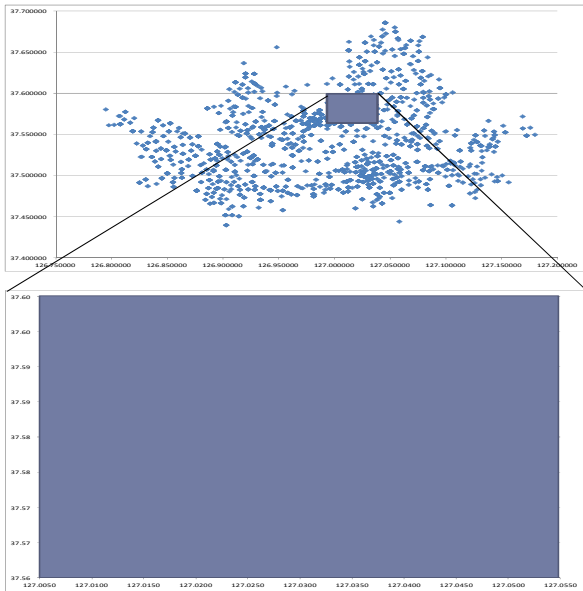


Figure 4. Selection of experimental field and locations of BSs

Traffic pattern of each BS is set according to the real traffic pattern of the corresponding BSs for a certain week day. Figure 5 shows traffic patterns of sample BSs among them for day. As can be seen from the figure, each BS has different traffic pattern.

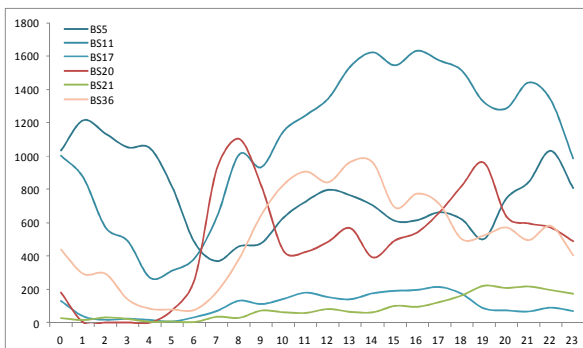


Figure 5. Example of traffic pattern of BSs for a certain week day

3.3 GA modeling

In the proposed mechanism, turning on and off the BSs based on traffic volume is determined hourly. We use genetic algorithm to determine which BSs to turn on and off at each time. For the algorithm, binary tournament method is used. Regarding the experimental parameters, population size is 200, number of generations is 200, one-point crossover probability is 0.9, and probability of mutation is 0.1.

Each chromosome is composed of 37 genes, of which the value represents coverage radius of each BS. A chromosome is expressed as $c_i = (p_{1,i}, p_{2,i}, \dots, p_{j,i}, p_{37,i})$, where i is the generation number, and j is ID of a BS. Each gene has an integer value $p_{j,i}$ ($0 \leq p_{j,i} \leq 20$), which means that the max coverage radius is 20 (2km). The probability of selecting '0' for each r in initialization is set 10%. The value 0 of a chromosome means the corresponding BS is turned off. Fitness value is calculated considering the number of BSs which are turned off and the coverage of each BS.

$$f_i = (\# \text{ of '0's in a chromosome}) \times 5,000 - p_{j,i}^2.$$

In the fitness function, the number of '0's in a chromosome is multiplied by 5,000, a big value, since energy saving by turning off a BS is generally greater than the increased energy consumption of adjacent BSs which increases their coverage to cover the area of turned-off BS. Proportional part of energy consumption of each BS is assumed to be proportional to the square of the coverage r .

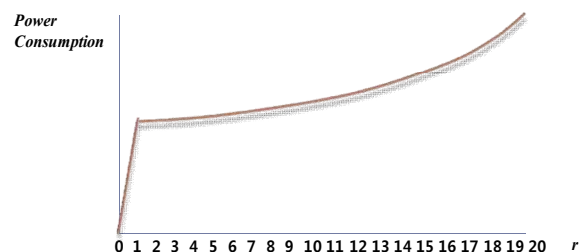


Figure 6. Fitness function

3.4 Results

The simulation result shows close relation between average traffic load of all BSs and the number of BSs on operation when coverage hole is not allowed. The less the traffic load the fewer the number of BSs on operation (see Figure 7).

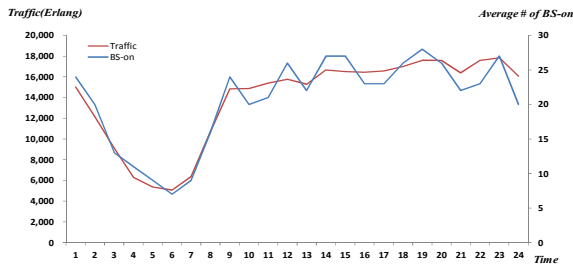


Figure 7. Relation between average traffic load and the number of BSs on operation when coverage hole is not allowed

Average number of BSs on operation with no coverage hole is 20.6, meaning that average rate of BS operation is 56%. Therefore 44% energy saving can be achieved by turning off redundant BSs when the traffic load is low.

The result also shows that the portion of the allowed coverage hole has effect on the average number of BSs on operation: the bigger the allowed coverage-hole rate, the less the average number of BSs on operation. Comparing two cases, when allowed coverage rates are 0% and 20%, the average number of BSs on operation is 20.6 and 17.2 respectively, meaning energy saving ratio increases from 44.3% to 53.5%.

Table1. Relation between coverage hole and BSs on operation

% of allowing coverage rate	Average # of BS-on	Average rate of BS-off
0%	20.6	44.3
5%	19.2	48.1
10%	18.1	51.1
15%	17.7	52.2
20%	17.2	53.5

4 Discussion

The simulation result of the proposed mechanism shows that dynamic BS operation can work as an efficient way to improve energy efficiency of mobile networks. Besides the BS operation technique, there are various areas to be studied by academic experts for energy efficient network operation.

Deployment of small size cells. Many studies show that treating fluctuating traffic only by macro cells is not efficient. Techniques for joint deployment of small-sized cells such as micro cell and femto cell with regular macro cells for energy efficient network operation requires more investigation.

Maintaining coverage. Maintaining full coverage by covering holes caused by cell breathing or turning off BSs is essential. There are various methods which can be used to extend coverage including power control, multi-hop relay, CoMP, etc. More sophisticated research is needed for the deployment of the abovementioned techniques.

Network cooperation. In real mobile environment, there exist several mobile networks in an area such as WCDMA, WiMAX. Therefore cooperation among them can help improve energy efficiency of mobile networks.

Deployment of these techniques into commercial networks by operators needs more sophisticated investigations. The study results may need to be adjusted considering real service environment, such as actual spatial and temporal traffic fluctuation, QoS policy, geographic characteristics, service user behaviors, etc. For example, guaranteeing service performance is one of the most important things for operators. Therefore, operators need to find sophisticated methods to adopt green communications solutions not to deteriorate service quality or appropriate trade-off point between energy saving and service performance degrade.

The government has its role to motivate academic and industry part to investigate and deploy energy efficient network solutions for environmental aspect.

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