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BASE STATION SWITCHING STRATEGY USING NORMALIZED RESIDUAL ENERGY IN GREEN HETEROGENEOUS CELLULAR NETWORKS

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Abstract-*The introduction of smart phones and other smart gadgets, which offers ubiquitous internet access and other diverse multimedia applications, has lead to the explosive growth of mobile data. However, this also increases the energy consumptions and carbon footprint of the mobile communications industry. The recent advancement in green telecommunication networks explores energy saving through dynamic base station (BS) switching algorithms. One such strategy is to entirely turn off some under-utilized BSs during low traffic periods. The decision metric for this switching strategy is the system load, however the system load doesn't always vary at the same rate over space. Residual energy can be used as a more reliable metric for switching and it is independent of traffic variations. Normalized residual energy based algorithm can be implemented effectively in both homogeneous and heterogeneous environment.*

Keywords*-green communication; cellular networks; energy saving; normalized residual energy*

I. INTRODUCTION

The continuously growing demand for ubiquitous information access triggers the rapid development of the information and communication technology (ICT) industry. In the last decade, there has been an explosion in mobile data, which is mainly driven by smart-phones. However, this also brings ever increasing energy consumptions and carbon footprint to the mobile communications industry. Responsible for 2% to 10% energy consumption in the world, ICT industry ranks among the top energy consumers and is expected to call for more in the future. In particular, the whole ICT sector has been estimated to contribute to about 2% of global CO_2 emissions, and about 1.5% of global CO_2 equivalent emissions in 2007. While the overall ICT footprint is estimated to be less than double between the year 2007 and 2020, the footprint of cellular networks is predicted to almost triple within the same period. With increasing awareness of the potential harmful effects to the environment caused by CO_2 emissions and the depletion of non-renewable energy sources, it is more critical than ever to come together to develop more energy-efficient systems in all industries and telecommunication systems is not an exception. From the economical perspective of cellular network operators, it is also important because a significant portion of their operational expenditure goes to pay the electricity bill. For infrastructured mobile access networks, the energy consumption comes from the data server, backhaul routers and the base stations (BSs). With the scarcity of spectrum resources and the high bandwidth demands from users, BSs will be more densely deployed, especially for the future 4G networks. Since the operators deploy their BSs to support the peak time traffic, it is inevitable that the BSs are under-utilized most of other times, especially, at night and on weekends. The large numbers of BSs contribute a significant portion of the whole network energy consumption. Therefore, it will be very valuable if the energy consumption of the BSs can be greatly reduced. When a BS is switched on, the energy consumption has a large floor level, i.e., by merely controlling the wireless resources (e.g., transmit power), the effect of energy saving is marginal, because the energy consumption of processing circuits and the air conditioner actually depends on the on-off states of the BS. Hence for significant reduction in energy consumption, we need to entirely switch off the base stations.

II. ENERGY CONSUMPTION IN BASE STATIONS

The energy consumption of a base station consists of two parts, modeled concurrently. The first part describes the static energy consumption, a power figure which is consumed already in an empty BS. Depending on the load situation, a dynamic energy consumption part adds to the static consumption. The items with the highest impact on a BS's energy consumption are the following: utilization of remote radio heads or ordinary power amplifiers with corresponding feeder losses, different kinds of cooling (air conditioning, air circulation, or free cooling), site sharing (especially regarding infrastructure), and number of carrier frequencies. It can be expected that the average energy consumption requirement per bit decreases in the following years due to new technologies. The energy consumption behavior of a base station is illustrated in Fig. 1.

The major sources of energy consumption can be listed as:

- *Power Amplifier including feeder*: The power amplifier (PA) is expected to work in a state in which the peak value of the signal corresponds with the possible peak power of the PA. Thus, the efficiency can be maximized.
- *Signal Processing*: UMTS signals are much more complex than GSM signals regarding the signal processing on transmitter and receiver side, whereas LTE signals are even more complex. Thus, the signal processing per link is substantially increased. An A/D converter consumes less than 5% of a macro base station's input power. Thus, it is assumed to be included in the signal processing part.
- *Feeder*: The feeder loss is about 3 dB in a macro base station. It is included in the link budget as well.
- *Power Supply and Battery Backup*: The loss within these two components is typically between 5% and 10% and depends mainly on the employed technology. By using 10%, an optimistic value is assumed.
- *Air Conditioning:* The cooling mainly depends on environmental conditions. Values between zero (free cooling) and 25% can be found.

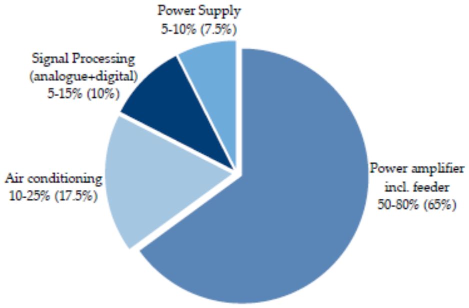

Fig. 1. Energy consumption distribution of a BS

III. EXISTING SYSTEM DESCRIPTION AND PROBLEM FORMULATION

A. Existing System Description

We consider a wireless cellular network where the set of BSs, denoted by B, lies in the two dimensional area A. Our focus is on downlink communication as that is a primary usage mode for the mobile Internet, i.e., from BSs to user equipments (UEs). The packet-based traffic model is used for the analysis and simulations. We assume the traffic arrival rate of UE located x at time t is modeled as an independent Poisson distribution with mean arrival rate $\lambda(x, t)$. Its average requested file size is assumed to be an exponentially distributed random variable with mean $1/\mu(x, t)$. The traffic load of UE, $\gamma(x, t)$ is then defined as:

$$\gamma(x, t) = \lambda(x, t)/\mu(x, t) \text{ [in bps]} \qquad (1)$$

Assuming the physical capacity is modeled as Shannon capacity, the service rate of UE at location x from BS b at time t is calculated as:

$$s_b(x, t) = BW * \log_2 (1 + SNR_b(x, t)) \qquad (2)$$

where BW denote the system bandwidth. In order to guarantee the QoS of UE, a BS should assign a certain amount of resource (e.g., time or frequency) depending on user's traffic load as well as its service rate. The $SNR_{b(x, t)}$ is the received signal to noise ratio at location x from BS b at time t. From the perspective of system, the system load of BS b at time t is defined as the fraction of resource to serve the total traffic load in its coverage is defined as:

$$\rho_{b(t)} = \int_{A_b} (\gamma(x, t)/\, s_b(x, t))\, dx \qquad (3)$$

where A_b represents BS b's coverage (i.e., the set of UEs locations served by BS b). The system load denotes the fraction of time required to serve the total traffic load in his coverage.

In the most simplest form of base station switching off, compare the $\rho_{b(t)}$ values of all the base stations in the set of BSs B. For energy saving at low traffic period, switch off the BS with the lowest system load value[1].

B. Problem Formulation

The existing switching strategy works efficiently only when the traffic pattern varies at the same rate over space. In real time situations, traffic patterns don't vary uniformly. Switching decision metric, system load depends heavily on the traffic and file size. The system load in turns depends on the traffic arrival rate $\lambda(x, t)$ and average file size $1/\mu(x, t)$. Hence the packet drops experienced during the transmissions will affect the system load values. This can lead to incorrect switching of BSs, i.e., when there is a heavy packet drop, the BSs which doesn't have the lowest value for the system loads gets switched off. The existing switching strategy is employed only for homogeneous cellular networks. There is no mention about the performance of this switching on/off strategy in heterogeneous networks.

IV. PROPOSED NORMALIZED ALGORITHM

Instead of considering system load as the metric for switching on/off of BSs, the remaining energy or residual energy in BSs can be taken as a more as a more reliable metric for the switching procedure. The BS with less energy consumption should be switched off first. This corresponds to the under-utilized BS. The switching strategy can be simulated in a heterogeneous network like micro cell and macro cells, which have different transmission powers. A microcell is a cell served by a low power cellular BS, covering a limited area such as a mall, a hotel etc. A microcell uses power control to limit the radius of its coverage area. A macrocell is a cell that provides radio coverage served by a high power cellular BS. Generally, macrocells provide coverage larger than microcell. The antennas for macrocells are mounted on ground-based masts, rooftops and other existing structures. Macrocell BSs have power outputs of typically tens of watts.

A. Algorithm Description

The algorithm uses normalized values of residual/remaining energy for the implementation of switching on/off of BSs. We are now considering a heterogeneous setup, i.e., now there are macro and micro cells in the simulation. Hence the initial energy of micro BSs will be less than that of macro BSs. To bring the energy values to a common scale, it's necessary to normalize the residual energy values by dividing with its corresponding initial values. Hence the algorithm is named as Normalized Residual Energy based Base station Switching (NREBS).

TABLE I. NREBS ALGORITHM

NREBS ALGORITHM

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1. if node is a BS, obtain residual energy
    2. if a macro BS, normalize by dividing with $E_{initial,macro}$
3. else a micro BS, normalize by dividing with $E_{initial\ ,micro}$
4. for i= 0; i<=no. of BSs
       $\mathcal{E}_i$ ← sort normalized residual energy in ascending order
5. Switch off the BS $b_i$ corresponding to highest $\mathcal{E}_i$
6. Switch on BS $b_i$ after $t$ seconds
7. go to step 1
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V. SIMULATION RESULTS

The simulation is performed in ns2 with 50 nodes in which 5 nodes are deployed as BSs. The simulation setup consists of a total of five cells with 3 macro BSs and two micro BSs. The simulation result shows that BS switching with NREBS algorithm has less energy consumption than with the algorithm of existing system.

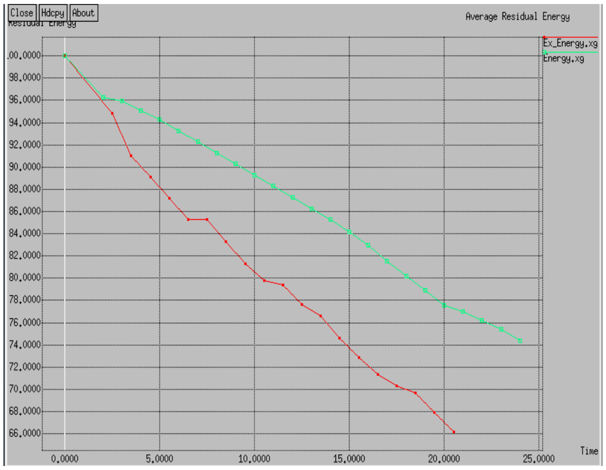

Fig. 2. Comparison graph of average residual energy

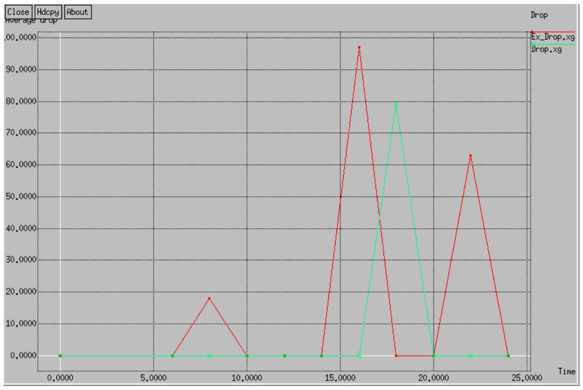

Fig. 3. Comparison graph of average packet drop

Fig. 2, shows the average residual energy comparison of the NRES algorithm and the algorithm in [1]. The x-axis represents the time (in min) and y-axis represent residual energy in KWHr. The red graph corresponds to the algorithm in [1] and green graph corresponds to residual energy by NREBS algorithm. The BS switchings are represented by dots in the graph. The graph indicates that there is a significant amount of energy saving when NREBS is implemented. Fig. 3 shows the comparison graph of average packet drop for NREBS algorithm and algorithm in [1]. The x-axis represents the time (in min) and y-axis represents the drop (in no. of packets). The red graph corresponds to the algorithm in [1] and green graph corresponds to average packet drop by NREBS algorithm. The dots in the graph represent BS on/off switchings. The graph shows that there is a significant reduction in packet drop when NREBS algorithm is implemented.

VI. CONCLUSION

In the last few decades, there has been an explosive growth in energy consumptions and carbon footprint of the mobile communications industry. With increasing awareness of the potential harmful effects to the environment caused by CO2 emissions and the depletion of non-renewable energy sources, it is more critical to develop more energy-efficient systems in all industries, and telecommunication systems is not an exception. In cellular networks, the operators need to deploy their BSs to support the peak time traffic, it is inevitable that the BSs are under-utilized most of other times, especially, at night and on weekends. The switching-on/off based dynamic BS operation allows the system to entirely turn off some under-utilized BSs during low traffic periods and this can account for potential energy saving. In the existing system [1], the BSs are turned off/on depending on the system load of individual BSs. As an enhancement to the existing system the decision metric is taken as the energy consumption in the individual BSs. This is more reliable than the system load method. The simulation can be done in heterogeneous environment. The heterogeneous environment will consist of macro and micro cells. The simulation of the proposed algorithm shows significant energy conservation when compared to the algorithm of existing system.

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