A Distributed Energy Saving Mechanism in Wireless Access Network

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***Abstract*—In this paper we come up with a division method of station operating period, and describe a distributed energy saving mechanism based on X2AP which stepwise turns off stations. We also propose a method to evaluate energy efficiency. To verify our proposed mechanism, we used data collected from practical network of four regions in simulation. The result shows that our mechanism can achieve better energy-saving gains than most energy-saving mechanisms with one-time execution. As far as SINR and RSRP is concerned, our mechanism also performed better than multi-stage contrast mechanism.**

***Index Terms*—wireless access network; energy saving mechanism; energy consumption model;**

I. Introduction

Since number of BS sites is quite huge, the method of decreasing BS number is proved to be more effective. With the decrease of serving stations, coverage gap might emerge and cause outage issues, and appropriate energy saving mechanism is quite needed.

[1] proposed a multi-stage ES mechanism. Some of the BS in one grid are closed after users under these BS handoff to other BS in the same grid during traffic decreasing period.

Our roadmap for the rest of the paper is as follows. Section II describes the proposed distributed energy saving mechanism. Section III describes the BS consumption model and evaluation method. Section IV evaluates energy saving efficiency and performance of our mechanism as well as contrast mechanisms. Section V concludes this paper and discusses our future work.

II. General automatic ES mechanism

Some BS are turned off during low traffic time, they are called Switching-off Stations (**SS**). Some BS enlarge coverage to cover the gaps brought by SS, they are called Compensation Stations (**CS**). Usually an SS is compensated by two or more CS, these CS composes a Compensation Combination (**CC**) of this SS. The remaining BS are called Normal Stations (**NS**).

A. division of ES period

Consider a region $\mathcal{L} \subset \mathbb{R}^2$ that is served by a wireless communication system with a set of BS B. Suppose an ES period is denoted as T. Let $x \in \mathcal{L}$ be the possible location of user equipment (UE) and $t \in T$ be a certain time point. Assume that service requests follow an inhomogeneous Poisson point process with arrival rate $\lambda(x;t)$ and average service time that are independently distributed with mean $1/\mu(x;t)$ at location $x \in \mathcal{L}$ at time point $t \in T$. Thus traffic load density is defined by $\rho(x;t) = \lambda(x;t)/\mu(x;t)$. The variation of $\rho(x^*;t)$ for a certain $x^* \in \mathcal{L}$ is illustrated in Fig. 1. We train four time points t_α, t_β, t_γ, t_θ according to traffic trend.

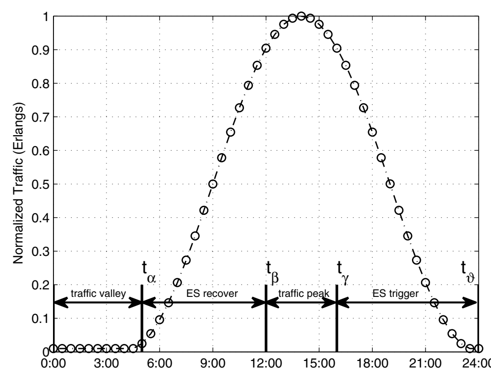


Fig. 1: Normalized traffic for example

(1) For $t \in [t_\delta, t_\alpha]$, average traffic load $\bar{\rho}(t) < \psi_l$, where ψ_l is lower threshold. Such time interval is called **traffic valley phase**.

(2) For $t \in [t_\beta, t_\gamma]$, $\bar{\rho}(t) > \psi_u$, where ψ_u is the upper threshold. Such time interval is called **traffic peak phase**.

(3) For $t \in [t_\gamma, t_\delta]$, $\psi_l < \bar{\rho}(t) < \psi_u$ and $d\bar{\rho}(t)/dt < 0$, such time interval is **ES trigger phase**.

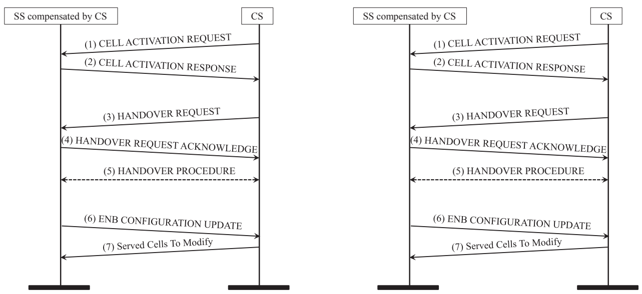
(4) The lase phase is called **ES recover phase** where for $t \in [t_\alpha, t_\beta]$, $\psi_l < \bar{\rho}(t) < \psi_u$ and $d\bar{\rho}(t)/dt < 0$.

B. The ES trigger algorithm and ES recover algorithm

Here we introduce a distributed algorithm to choose BS to switch off. A successful communication process between SS and one BS of its CC is illustrated in Fig. 2(a).

In case one SS candidate has more than one CC, we propose a CC selection method to choose the most appropriate CC for the SS candidate. The procedure of this method is demonstrated in Fig. 3.

During ES recover phase, traffic load of each CS may reach maximum traffic load limitation, and outage occurs on arrival of new users. Hereby we propose another distributed algorithm



(a) trigger phase　　(b) recover phase

Fig. 2: Interaction in different phases

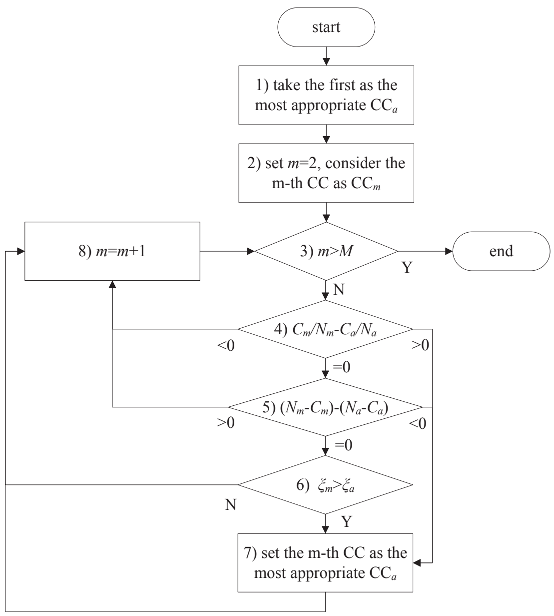


Fig. 3: Procedure for selection of the most appropriate CC

to stepwise switch on SS in this phase. Communication process between CS and SS is illustrated in Fig. 2(a).

Since the ES trigger algorithm and ES recover algorithm are both distributed, the complexity is related to number of neighborhood BS rather than to number of BS in the whole region, which is less controllable. Thus our algorithm is of high efficiency.

III. Modeling BS energy consumption

For purpose of evaluating ES efficiency, we summarized existing BS energy consumption models, and added dynamic traffic load effects on energy consumption. We also proposed an evaluation method which could be used to evaluate ES efficiency of proposed ES mechanism.

Total energy consumption of one BS is denoted as follows:

$$P_{BS} = P_{Tx}/\eta + P_{static} \tag{1}$$

where η is used to denote the efficiency of power amplifier. P_{static} denotes the static energy consumption part.[1] indicates that the antenna input power P_{Tx} can be measured by linear models with reasonable approximation. We suppose that control cost is represented as CL, Maximum user number as U, traffic channel power of BS b_i denoted as P_i. $P^i_{Tx}(t)$ is calculated as follows:

$$P^i_{Tx}(t) = \frac{\kappa \cdot U \cdot f_i(t) \cdot P_i}{(1 - CL)} \tag{2}$$

introducing the power-adjustment parameter κ, which is proportional to variation of BS coverage radius. Let W_{nor} be the energy consume before implementing ES mechanism, and W_{sav} be after implementing ES. Energy-saving efficiency is calculated as:

$$SE = \frac{W_{nor} - W_{sav}}{W_{nor}} \times 100\% \tag{3}$$

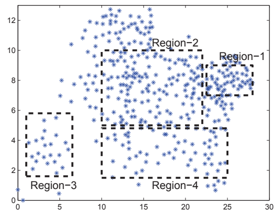


Fig. 4: BS deployment

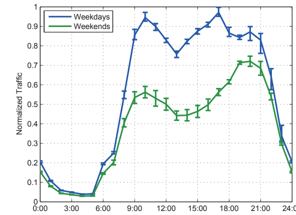


Fig. 5: Arrival rate (normal)

TABLE I: BS operating parameters for different regions.

	Reg-1	Reg-2	Reg-3	Reg-4	Unit
BS deployment density	4.36	2.25	0.95	1.15	KM^{-2}
coverage (normal)	0.45	0.6	0.65	0.65	KM
coverage (maximum)	1.0	1.3	1.4	1.5	KM
traffic channel power	24.7	24.7	24.7	24.7	dBm
receiver sensitivity	-112	-112	-112	-112	dBm
parameter κ	1∼3	1∼3	1∼3	1∼3	-
max user number$U$	65	65	65	65	-
control loadCL	0.15	0.15	0.15	0.15	-
amplifier efficiencyη	0.3	0.3	0.3	0.3	-

IV. Evaluation and analysis

We used some realistic data collected from some district in Beijing by operators for simulation. The BS deployment location is illustrated in Fig. 4. For simplicity, we picked 4 subregions from the whole region. Reg-1 and Reg-2 are considered as urban district while Reg-3 and Reg-4 are considered as suburban district. Fig. 5 shows normalized service arrival rate of two different situations, weekdays and weekends. Energy consumption associated parameters are depicted in Table **??**, Table I lists all related BS operating parameters. Suppose P_{static} is 305W for each region.

A. *energy efficiency*

Fig. 6 shows the efficiency result of our ES and other contrast ES. Note that mechanisms in [2] and [3] are originally not multi-stage mechanisms, but we apply these mechanisms as stepwise turning off/on BS. We can see that ES efficiency during weekends are much higher than that of weekdays, and our ES mechanism performed better than [2] and [3] in all regions, and more effective than [1] in Reg-3 and Reg-4, but less effective in Reg-1 and Reg-2.

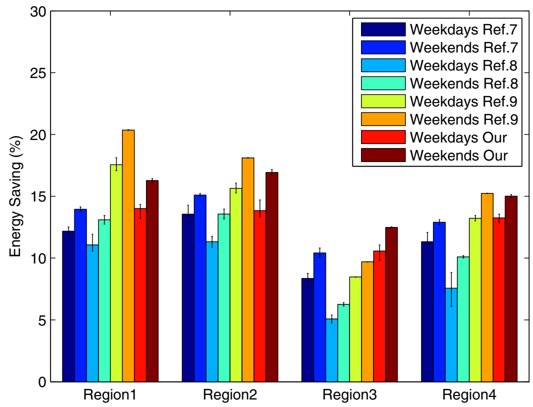


Fig. 6: Energy Consumption

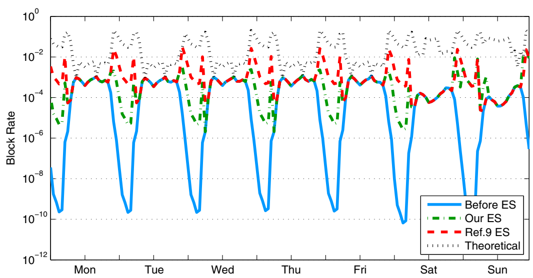


Fig. 7: Block possibility for a week

B. *network performance*

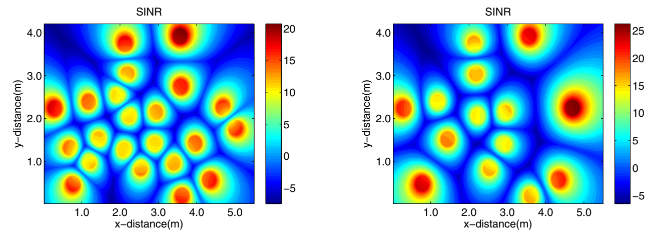
Fig. 7 plots average blocking possibility of each ES mechanism in Reg-2. We can see that our mechanism caused a little rise of blocking possibility during ES hours, but not exceeding the limit 1%, and the contrast mechanism caused much bigger raise in saving hours, which is because more BS were closed in contrast mechanism. We can also see that theoretical energy saving caused high possibility of blocking, thus theoretical energy saving is impractical.

Fig.8 shows comparison between no ES and with ES, where colors indicating the received SINR strength for Reg-3. Part (a) shows received SINR without ES. Part (b) show the received SINR with our proposed ES. It is obvious that SINR decreased in places where BS were closed for ES, but through adjustment of active BS transmit power, SINR in edge area were enhanced.

SINR and RSRP are two important indicators for network performance, and Fig. 9 plots CDF of SINR and RSRP in Reg-3 in traffic valley phase, similar results could be achieved in other regions. In both indicators we got better performance than the contrast mechanism.

V. Conclusiona and Future Work

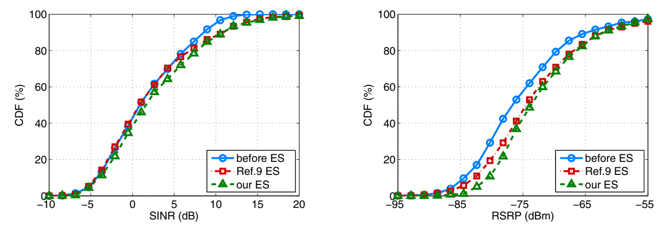
In this paper, we proposed a distributed ES mechanism. The mechanism divides an ES period into 4 phases. During ES trigger phase, parts of BS are stepwise turned off as traffic load goes down, and with only a few working BS, large ES is acquired during traffic valley phase. During ES recover phase, closed BS are stepwise turned on as traffic load increases. ES evaluation method is also proposed to estimate the proposed mechanism, and the result turns out that about 17% and 15% of total energy consumption could be saved for urban and suburban districts respectively. Our future work will focus on implementing more complete models such as involving pilot pollution constrains, and apply our ES mechanism in more complicated heterogeneous scenario.



(a) without ES

(b) with ES

Fig. 8: SINR distribution in Reg-3 during traffic valley phase



(a) SINR

(b) RSRP

Fig. 9: Average SINR and RSRP CDF in traffic valley phase

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References

[1] P. Chunyi, L. Suk-Bok, L. Songwu, L. Haiyun, L. Hewu, *Traffic-driven power saving in operational 3G cellular networks.* Las Vegas:Association for Computing Machinery, 2011, pp.121-132.

[2] Y. Peng, L. Wenjing, and Q. Xuesong, *A regional autonomic energy-saving management mechanism for cellular networks, Journal of Electronics and Information Technology* vol.34, pp. 2707-2714. Nov 2011.

[3] Y. Peng, L. Wenjing, and Q. Xuesong, *A Novel Energy-Saving Management Mechanism in Cellular Networks.* Las Vegas:IEEE Computer Society, 2012, pp. 1-9.