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Energy Saving Method in Wireless Communication System

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Abstract: Energy-saving Method (ESM) plays an important role in Long Term Evolution (LTE) system for reducing operator's Operational Expenditure (OPEX) and protecting environment. However, traditional energy-saving methods have many limits and may damage user experience. In this article, two specific ESM algorithms are proposed, eNodeB-based Energy Saving Method (NESM) and Carrier-based Energy Saving Method (CESM). The former one is an inter-base-station ESM, suitable for the earlier stage of the network deployment. The later one is an intra-base-station ESM, suitable for the later stage of the network deployment. Simulation results illustrate that the proposed methods can greatly reduce the energy consumed in LTE system without damaging the user experience. NESM could save 20% of the energy consumed in LTE system while CESM could save 23%. Moreover, based on different situations, the two algorithms can also work together to obtain better energy saving performance.

Key words: Dynamic load balance, energy saving, intelligent carrier shut off, eNodeB-based energy saving method, carrier-based energy saving method

INTRODUCTION

With the development of economy and society, human consumed more and more energy which caused the global warming. As it is known to all, global warming has many potential impacts on environment, such as sea level rising, changes in agricultural structure, etc. For the goal of sustainable development, the whole world is working together to find ways to reduce carbon emissions and build a low-carbon society.

In 2009, the global CO_2 emission of information industry was more than 0.75 billion tons. A country's information industry consumed more than 200 million degrees electricity and produced 17 million tons of CO_2 which equivalents to 6.76 million tons of coal. The number of global phone users is expected to reach 5 billion, so Long Term Evolution (LTE) system's deployment and operation will consume more energy which makes energy saving even more important. Besides protecting the environment, energy saving could also reduce operator's OPEX (Operational Expenditure), so finding an effective energy saving method is essential. Though researchers are trying to minimize energy consumption, they still need to guarantee the quality of service perceived for users (Lu *et al*., 2011).

There are some researches about energy saving methods before 2009, but these methods have many limits and would damage the user experience to some extent. So, far the energy saving of communication system is mainly on policy. But the real energy saving technology is still under study and no specific research result is presented. Now there are three main energy saving research directions:

- Optimize the number of the eNodeBs. Deploy the fewest eNodeBs in communication system while guarantee the quality of service, the capacity of network and the network coverage (Ismail and Zhuang, 2011)
- Improve the energy utilization of eNodeBs and reduce the energy consumed by eNodeBs, but the impact on the network should be accepted by operators (Chang *et al*., 2013)
- Find new reusable energy and use clean and low-carbon-consumed fuel, such as solar energy and wind energy (Peng and Wang, 2008)

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This research is mainly about the second research idea and proposed two innovative energy saving methods, NESM (eNodeB-based Energy Saving Method) and CESM (Carrier-based Energy Saving Method).

ENERGY SAVING METHODOLOGY

In order to provide service for all users at any time, the network is designed to meet the highest traffic load. Fig. 1 shows the change of daily traffic load, it can be seen that peak time lasts no longer than 6 hours during a day, so there is no need to maintain the full set of Network Elements (NEs) capabilities (Boyapati *et al*., 2012). Researchers are trying to find an adaptive energy saving method which is determined by system load and traffic properties. The proposal (3GPP, 2010) gives an idea of turn on/off eNodeBs or carrier frequencies according to the dynamic changing traffic load in the network, so the unnecessary energy consuming during non-peak times can be avoided. But no statistical data has been given for when to turn on/off eNodeB and how to implement this method still need to be resolved.

Based on the above analysis, two specific algorithms are proposed to reduce LTE system's energy consuming. The two algorithms are suitable for different scenes. And their network models are similar to each other. The only difference is on their eNodeB's coverage areas. According to study (Kunze *et al*., 2010), starting point is a network with a hexagonal layout of 48 sectors sites. The network model is illustrated in Fig. 1. Besides the (complete) 48×3 layout, a model of k*3 network layouts is considered, with k∈{12, 24, 26} where a specific subset of the original set of sites is switched off. In evaluations, the down tilt that is optimized for the full (48-site) configuration is also maintained in the "reduced" configurations; hence, no tilt adjustments are applied (Kin *et al*., 2009).

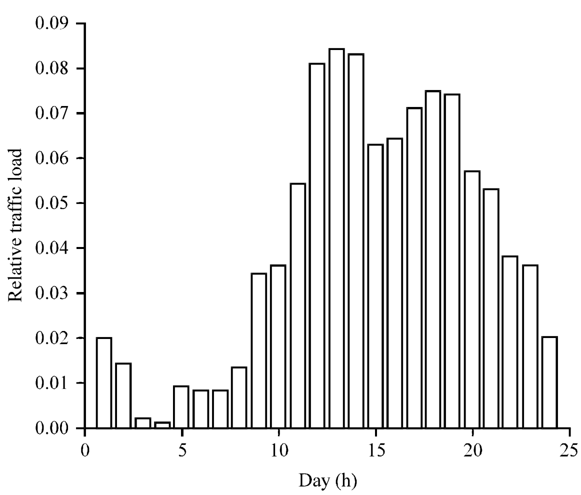

Fig. 1: Daily traffic load variation, each column shows traffic percentage in an hour against total daily traffic

Each sector supports a maximum of 5 MHz carriers (totally 20 Hz). As shown in Fig. 2, in the considered evaluations, the uniformly set number i of active carriers at a set is 1, 2, 3 or 4 in (a), (b), (c) and (d), respectively (3GPP, 2010).

NESM is an inter- base-station energy saving method which is suitable for the earlier stage of the network deployment. In the earlier stage of network deployment, there is no overlap between two adjacent eNodeBs. If one eNodeB is powered off, it will produce irreparable network blind spot. So it could only shut down some carriers of the eNodeB (Wu *et al*., 2010).

CESM is an intra-base-station energy saving method which is suitable for the later stage of the network deployment. During the later stage of the network, the communication system is highly mature and overlapping area between two adjacent eNodeBs is unavoidable (Madfors *et al*., 1997). In this case, power off one eNodeB or more is permissible, because its neighbor eNodeBs could make up for the gap.

When designing an energy saving method, there are two principles must be followed. One principle is the eNodeBs' traffic load shouldn't exceed its capacity so does to a carrier (Hu *et al*., 2010). The other principle is that measures must be taken to avoid eNodeBs or carriers entering or quitting energy saving mode frequently when the traffic load fluctuates around a value.

The reason for the first principle is obvious, when the traffic load exceeds an eNodeB's (or a carrier's) capacity, some users couldn't be served (Torrea-Duran *et al*., 2010). It is unacceptable for the network operator. And when eNodeBs or carriers enter/quit energy saving mode frequently, it will make users hand off between eNodeBs or carriers (Kim and Mohanty, 2010). This case will cause bad user experience.

Carrier-based energy saving method: According the above analysis, an eNodeB in the earlier stage of network deployment couldn't be shut down, the way to achieve energy saving is shutting down some carriers of an eNodeB (Boyapati *et al*., 2010). In order to meet the two principles proposed in Section 2, β is set as the enter-CESM threshold and β is set as the quit-CESM threshold for carrier.

The energy saving progress is shown in Fig. 3, in which T denotes the current traffic load of an eNodeB and N is the number of active carriers:

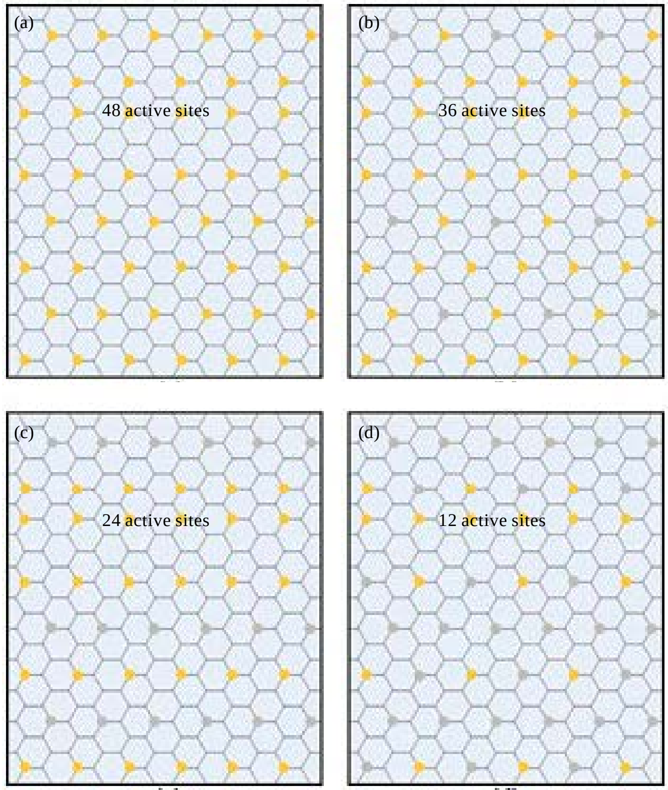

Fig. 2(a-d): Network layout in ESM (a) Network layout when all eNodeBs are turned on, (b) Network layout when 75% of the eNodeBs are turned on, (c) Network layout when 25% of the eNodeBs are turned on and (d) Network layout when 25% of the eNodeBs are turned on; Yellow Point means stands for eNodeBs in activate mode, grey point stands for eNodeBs in dormancy mode, ESM: Energy-saving method

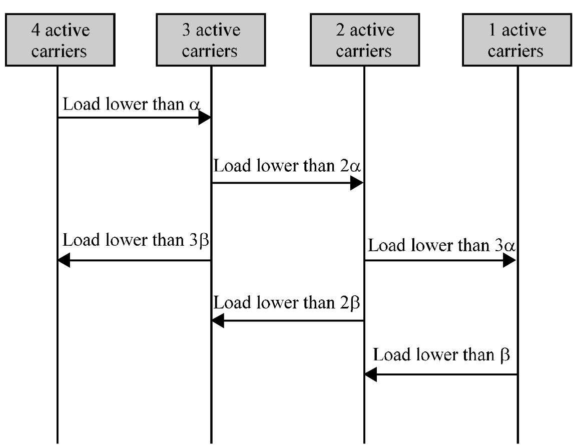

Fig. 3: Carrier based ESM progress: The No. of active carriers is changed according to the current load of network, in this way, to keep the high efficiency of a network and save energy. ESM: Energy saving method

- When $T<3\alpha$, N = 4, eNodeB will find the carrier which has the least traffic load then transfer the traffic load to the other three carriers. The traffic load will be shared on average by the three carriers. Then the least-loaded carrier is shut down
- When $T<2\alpha$, N = 3, eNodeB will find the carrier which has the least traffic load and transfer the traffic load to the other two carriers. The traffic load will be shared on average by the two carriers. Then the least-loaded carrier is shut down
- When $T<\alpha$, N = 2, N will continue to be decreased, eNodeB transfer one carrier's traffic load to other carrier. Then the empty carrier is shut down
- When $T<\alpha$, N = 1, eNodeB will power on one carrier. Then distribute the traffic load to the 2 carriers on average
- When $T<2\beta$, N = 2, eNodeB will power on one carrier. Then distribute the traffic load to the 3 carriers on average

- When T<3β, N = 3, eNodeB will power on all carriers. Then distribute the traffic load to the 4 carriers on average

eNodeB-based energy saving method: According to section 2, during the later period of the network deployment, there would be many hot point regions. In these areas, shutting down some eNodeBs is permitted, for their neighbor eNodeBs could make up for the gap (Han *et al*., 2009). And the two principles in section II need to be followed. Familiar with CESM, there are also two thresholds for NESM, enter-NESM threshold β and quit-NESM threshold β.

Different from CESM, the traffic load used to determine whether to enter energy saving mode is not an eNodeB's traffic but a set of several eNodeB's totally traffic load. Here a set of eNodeBs are used as a research model, whose locations are adjacent. There are three states of eNodeBs in energy progress: Energy-saving mode, energy-saving compensate mode and normal mode. Energy-saving mode means an eNodeB shutdown itself. "Shutdown" here doesn't mean totally power off, it more likes a sleeping mode. Energy-saving compensate means an eNodeB makes up for the gap emerged in energy saving progress.

The energy saving method of NESM is relatively simple. When the traffic load of the set is high (exceed β), all eNodeBs are turned on and work together to serve users (Han *et al*., 2009). But when traffic load is lower than the threshold β, some eNodeBs could be turned off, their neighbor eNodeBs could replace them to guarantee users would not be affected, but the launching power of energy-saving-compensate eNodeBs need to be increased.

Divide the set of eNodeBs into two classes: energy-saving eNodeBs and non-energy-saving eNodeBs. The two classes have no differences in hardware but in function. Energy-saving eNodeBs could enter energy-saving mode when traffic load is low, while non-energy-saving eNodeBs are always in working condition and need to make up for the blank space caused by energy-saving eNodeB. Here the geographic position of eNodeBs is used as dividing basis. Because whether energy-saving eNodeBs can make up the blind spot while causing minimum interference to other eNodeBs is determined by geographic position.

According to Fig. 2, 48-cell network model is used, when turning off 12 eNodeBs or 24 eNodeBs, the network distribution is asymmetric. As it's known to all, the theoretical coverage of a eNodeB is circular. Although, some technologies could be used to resolve the interactions caused by geographical distribution, people still hope to minimize the impact. So turning 36 eNodeBs is the best energy saving network model. In this situation, 3 quarters of eNodeBs are turned off in the network, and the traffic load is carried by another one quarter Energy-saving compensated eNodeBs. The numbers of Energy-saving compensated eNodeBs and Energy-saving eNodeBs determine the value of α and β.

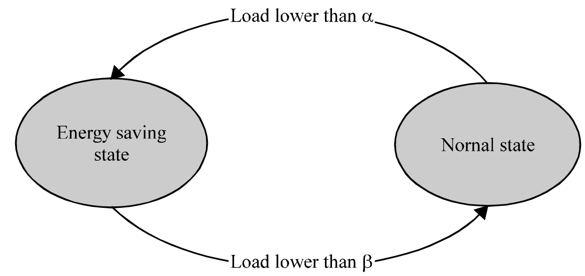

Fig. 4: eNodeB Based ESM progress: The eNodeB working state changes according to the current load of a network, in this way, to keep the network efficient and save energy. ESM: Energy saving method

The energy-saving progress is showed in Fig. 4. The figure only shows the energy saving eNodeBs' actions. The non-energy-saving eNodeBs are not showed, for there is no change in non-energy-saving eNodeBs.

When the non-energy-saving eNodeBs' traffic load is no more than α of its capacity, it will ask its neighbor eNodeBs for traffic load report. If the overall traffic load of N neighbor eNodeBs is less than N*α*C (C is the capacity of an eNodeB, N is the number of an energy saving eNodeB set), the network enter energy-saving mode. That is, the energy-saving eNodeBs transfer their load to the neighbor eNodeBs. The non-energy-saving eNodeBs increase their launching power in order to guarantee the network has no blank space.

When the non-energy-saving eNodeB's traffic load is more than N*β*C of its capacity, the network will quit energy-saving mode. Non-energy-saving eNodeBs will transfer their traffic load to their neighbor eNodeBs on average.

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RESULTS AND DISCUSSION

In the simulation of this study, the number of users was not considered, but the total traffic load in the communication system was considered instead. For the downlink data take up most of the traffic load, the simulation doesn't consider the uplink data. Table 1 shows some important parameters. The inter-site distance is chosen so that UL/DL coverage requirements are met even for the case of 12 active sites (3GPP, 2010).

Simulation is done when the number of sites is 12 (24, 36 or 48). The number of active carrier varies from 1 to 4 and each carrier bandwidth is 5 MHz. Other parameters are settled as needed.

Parameters N_{on} and N_{off} are used to denote the number of active eNodeBs and the number of inactive eNodeBs, respectively. C_{on} and C_{off} stand for the number of active carriers and inactive carriers respectively. The activity factor is denoted by α which is the fraction of Pcarrier (Pbase): The minimum energy consumption of a carrier/base.

So, the energy consuming can be calculated according to the following equation:

$$E = Non*(Pbase+Con*Pcarrier+\alpha*Coff*Pcarrier)+ Noff*\alpha*(Pbase+4*Pcarrier) \quad (1)$$

The energy saving method proposed in section 3 is simulated and the simulation result is shown in Fig. 5 and 6 which Fig. 5 shows the results of CESM and Fig. 5 shows that of NESM.

According the simulation result, CESM can save 23% of the energy and NESM can save 20% (3GPP, 2010). While (Peng and Wang, 2008) and (Kin *et al*., 2009) can only save 42 and 35% energy. After analyzing the performance of two ESM in different time, it was found that the two energy saving methods perform differently during a day. From 1:00 am to 11:00 am, NESM performance better than CESM, while CESM has a better energy saving result during the rest time. According to the analysis in Section 2, NESM and CESM can be used in the earlier and later stage of network deployment. Which means the two different energy saving methods can be used together to gain a better energy saving result.

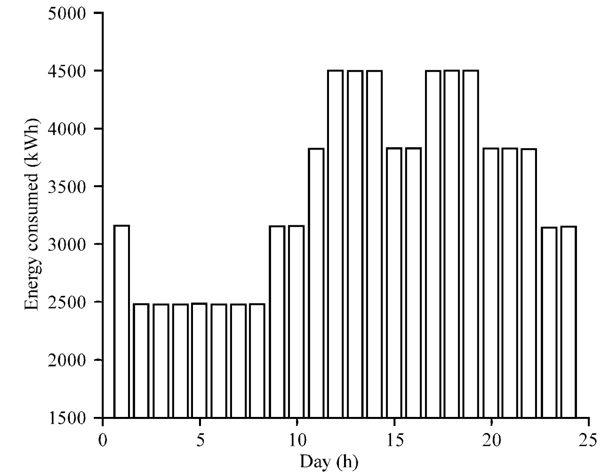

Fig. 5: Energy saving results of CESM: The activate carriers will change with traffic of each eNodeBs. CESM is a sensitive ESM, a little jitter of traffic will lead to a configuration adjustment. CESM: Carrier-based energy saving method

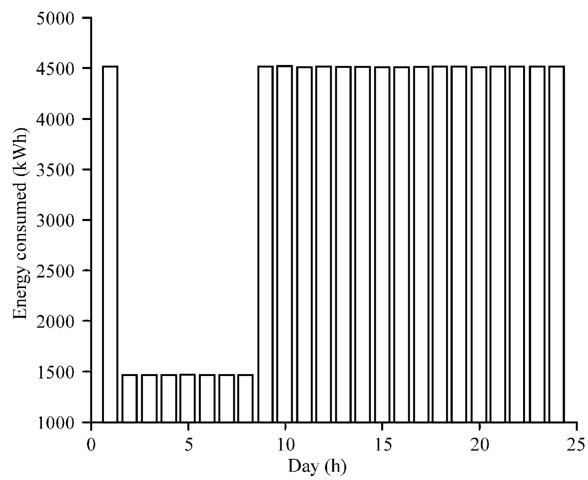

Fig. 6: Energy saving results of NESM: CESM is an insensive ESM, only in particular time of a day there will be implement of ESM. CESM can also gain distinct power saving because eNodeB consumes much more energy than carrier. NESM: eNodeB-based based energy saving method

Table 1: List of the key parameters used in the simulation process

Parameters	Value	Parameters	Value
No. of sites	12/24/36/48	Path loss	123.22+35.22log10 (d_{km})
Inter-site distance	1100 m		
Downtile	4°	Carrier bandwidth	5 MHz
No. of carrier/sector	1/2/3/4	P_{max}	20 W
PCPICH	2 W	Packet scheduling	Round robin
Noise figure	8 dB	Antenna diagram	Kathrein 741989

CONCLUSION

In this study, two energy saving methods are proposed which can greatly reduce the energy consumed in communication system without damaging the user experience. NESM could save 20% of the energy consumed in communication system while CESM could save 23%. Although the two methods are based on different situations, they are combined in the same system to gain a better result.

The following research of this work is mainly on the optimization of the two energy saving methods and evaluate the effect on user experience. The team will continue to optimize the energy saving method and try to use it in practical application.

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