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무선망에서 기지국의 전력소모에 대한 운영 방안

박상준[*]

A operation scheme to the power consumption of base station in wireless networks

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요 약

무선 네트워크의 계층적 구성은 다양한 네트워크 환경을 지원하기 위해 제공된다. 기지국에서는 두 가지 시스템 상태가 기본적으로 고려될 수 있으며, 이에 대해 액티브와 슬립 모드 사이에서 상태 전이가 발생할 수 있다. 그러므로 에너지 사용을 줄이기 위하여 저전력의 시스템 운영 관리가 기지국 시스템에 고려되어야 한다. 따라서 본 논문에서는 시스템 관리를 다루기 위해 Discontinuous Reception (DRX) 분석 모델을 고려한다. DRX 모델을 통하여 기지국 시스템의 운영에 대한 분석 방안을 제시하며 에너지 소비를 위한 저전력 강도를 살펴본다. 또한 시스템 상태에서 기지국의 저전력 소모에 대한 성능을 분석하기 위해 무선 자원 요구와 서비스 호 도착의 운영이 고려되며, 이를 위하여 유한 마르코프 시스템 모델을 사용하였다.

ABSTRACT

The configuration of hierarchical wireless networks is provided to support diverse network environments. In the base station, two system state can be basically considered for the operation management so that the state transition may be occurred between active and sleep modes. Hence, to reduce energy consumption the system operation management of the low power should be considered to the base station system. In this paper we consider the analytical model of Discontinuous Reception (DRX) to investigate the system management. We provide the analysis scheme of base station system by the DRX model, and the low power factor would be investigated for the energy consumption. We also use the finite-state Markov system model that in a system state period the wireless resource request and the operation of service call arrival interval is considered to numerically analyze the performance of energy saving operations of base station.

키워드 : 무선 네트워크, DRX, 저전력 기지국, 에너지 절약

Keywords : Wireless networks, DRX, low-powered base station, energy saving

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Ⅰ. 서 론

In recent, there has been explosive growth in cellular networks to the user mobility and network service availability [1]-[5]. The wireless networks show the cooperative communication mechanism for the heterogeneous mobile network environments. We can see that the multimedia network service market is being increased tremendously. The heterogeneous cellular networks should provide such diverse network services. In heterogeneous cellular networks, the configuration to the several network types such like macro- and micro-, pico- and femtocell can be shown to deploy the overlaid network operations. The base station in a wireless cell has usually consumed most network power to manage the network operations. Hence, the energy saving should be considered to reduce the power leakage in the system operation. In [5], the power optimization mechanisms were introduced for the energy saving.

In the base station, the system modes are scheduled to implement the power management. We investigate an analytical model for studying the base station behavior to non-deterministic time period of the system mode. Firstly, let us consider a Markov model which is used to analyze the call process for the power saving operations. Also, to derive the featured system states of base station we once consider two basic operation modes (active and sleep modes) [5][6] that affect its energy consumption for the network service. The system mode can be transitioned to another mode by specific condition parameter that the channel request density is a factor to lead the state movement. We also introduce a time period as called the duration window that it is flowed in the system state period. As an example, the sleep duration windows will be assigned in the sleep mode period after the system state is changed from the active mode. If the resource occupation in a sleep duration window increases so that the channel request density is over a settled call occupation threshold, the system state returns into the active mode. After returning to the active mode, the base station immediately provides the available resources for arrived calls. To investigate the performance of energy consumption, we derive a new power saving factor that it was originally introduced in [5][6]. In the estimation of the power saving factor, two types of static and flexible duration windows are respectively taken to present the influence about the power consumption of base station [5][7]-[10]. Also, we analytically find out the relation between the duration window size and the power saving factor. In addition, we describe the conduct of cooperative base stations by the service request after a base station enters into the sleep mode.

The remainder of this paper is configured as follows. In Section 2, we provide a illustration of proposed scheme with the analytical model and the analysis results are showed in Section 3. In Section 4, we conclude this paper.

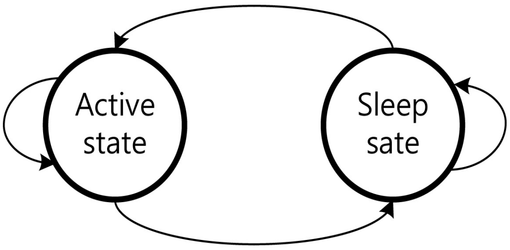


Fig. 1 Base station system state

Ⅱ. 기지국 DRX 방식

The system mode of base station can be shown in Fig. 1. Its state basically consists of two states: active state and sleep sate. The base station system monitors the channel resource using rate to the total system capacity. The resource occupation threshold is considered to manage the state transition extent. If the resource consumption is below its occupation threshold, the system state can be changed into the sleep state for the energy saving of the base station. The period diagram to the system modes is considered from the Discontinuous Reception (DRX) operation for the mobile service in wireless environments. Hence, for the system states two period types is taken to investigate system operations:

active period and sleep period. If the resource request is higher than the resource occupation threshold in the sleep date, the system state changes form the sleep mode to the active mode. Also, the system state transition can be occurred to change into the sleep mode because of the low resource request. We use the duration time to mean a certain time to the system state of base station. Let us assume the active period and the sleep period as A and S, respectively.

We assume that the random variables $D_A$and D_S mean the spent times of the active state and the sleep state. Let us assume that $E[D_A]$ and $E[D_S]$ as the expectation of random variables so that energy saving factor of system period f_E can be shown by

$$f_E = \frac{E[D_S]}{E[D_S]+E[D_A]} \tag{1}$$

We assume that the period size values T_A and T_S can be considered as the active time and the sleep time durations. Let P_{AC} and P_{SC} be the continuation probabilities of the active and the sleep periods, respectively. Hence, the expectation $E[D_A]$ of overall active time can be driven as follows

$$\begin{aligned} E[D_A] &= \sum_{i=1}^{m} iP_{AC}T_A \\ &= \sum_{i=1}^{m} i\left(1-e^{-\lambda_T T_A}\right)^{i-1} e^{-\lambda_T T_A} T_A \\ &= \frac{\left[1-\left(1-e^{-\lambda_T T_A}\right)^m\right]T_A}{e^{-T_\lambda D_A}} \end{aligned} \tag{2}$$

where i the number of the active period and the call arrival interval is exponentially distributed with the mean $1/\lambda_T(= 1/\lambda_{f_E})$.

$$\begin{aligned} E[D_S] &= \sum_{j=1}^{n} jP_{SC}T_S \\ &= \sum_{j=1}^{n} j\left(e^{-\lambda_T T_S}\right)^{j-1}\left(1-e^{-\lambda T_S}\right)T_S \\ &= \frac{\left[1-\left(e^{-\lambda_T T_S}\right)^n\right]T_S}{1-e^{-T_\lambda D_S}} \end{aligned} \tag{3}$$

where j is the number of the sleep period.

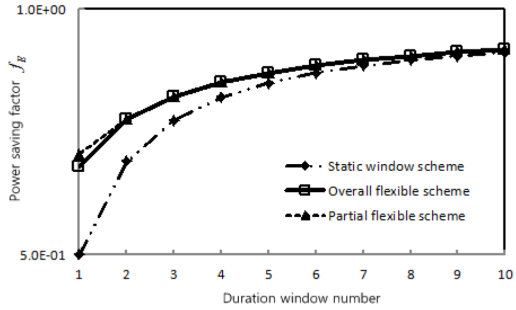
Let us define f_E as the power saving factor. Consequently, by substituting (2) and (3) into (1) we can derive the power saving factor of the system f_E as

$$\begin{aligned} f_E = &\left\{\frac{\left[1-\left(e^{-\lambda_T T_S}\right)^n\right]T_S}{1-e^{-\lambda_T T_S}}\right\} \\ &\times 1 \Big/ \left\{\frac{\left[1-\left(e^{-\lambda_T T_S}\right)^n\right]T_S}{1-e^{-\lambda_T T_S}} + \frac{\left[1-\left(1-e^{-\lambda_T T_A}\right)^m\right]T_A}{e^{-\lambda_T T_A}}\right\} \end{aligned} \tag{4}$$

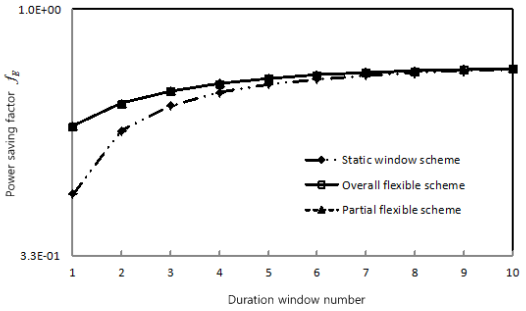
Ⅲ. 성능평가

We show the comparison results to the analytical model that is simulated in C++ environments in this section. It is assumed that the wireless networks have the hierarchical architecture with the UMTS and the LTE cell. The UMTS system supports the cooperative communications with LTE eNodeB for the power saving mode. We assume that cell radius is 400 m for the UMTS NodeB, and 100 m for eNodeB. We show the analysis results of three window period schemes. The channel request arrival is generated in descried assumption of previous section, and all of base stations are connected to electrical grid. Maximum available voice channels of the NodeB and the eNodeB are set to 50 channels, respectively. It is assumed that the average occupied time of a voice channel is one minute, and maximum admission control to the data traffic is 50 users for the NodeB and the eNodeB equally. Here, average traffic rate of each user is 384 kbps for the NodeB, and 1 Mbps for the eNodeB. Also, it is assumed that to the eNodeB the power of 1 W per second is consumed in the active mode, and 20 mW per second in the sleep mode.

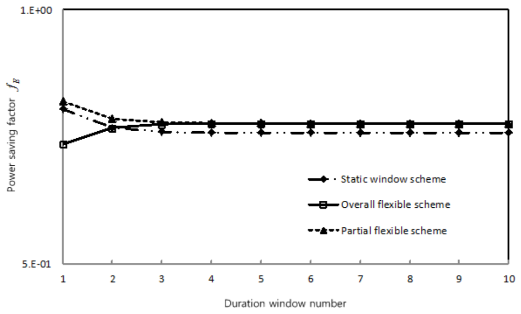
Fig.2 shows the performance results of power saving factor versus the duration window number (n-sleep and m-active duration window numbers). It means the number of consumed window. It shows the comparison to the static and flexible schemes. Fig.2(a) shows the results of power saving factor in the variation of the duration window number n and m. As seen the figure, the values of power saving factor increase as the duration window number increase. The static window scheme shows similar results to the other schemes with high duration window number.



(a) Effect of n and m



(b) Effect of n and $m = 5$



(c) Effect of m and $n = 5$

Fig. 2 Power saving effect of system state.

To identify the different effect of duration window number we have analysis results that the n (or m) is varied when the m (or n) is fixed as shown in Fig. 2(b) and (c), respectively. It can be observed that the n parameter number has more effect to the power saving factor compared to the m parameter. In Fig. 2(b) the power saving factor is more dynamically changed by the n parameter, whereas Fig. 2(c) illustrates that from $m \geq 2$ all of theoretical models show stable performance results. In Fig. 2(c) the overall flexible scheme shows low performance compared to the static window scheme when $m = 1$. However from $m \geq 2$ it shows higher capacity performance than the static window scheme. Also, it is identified that the performance of partial flexible scheme is better than other two schemes. The duration window shows each DRX state size.

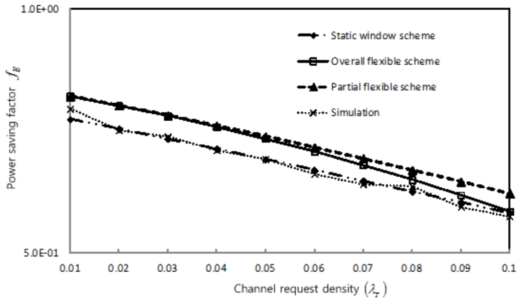


Fig. 3 Channel request versus Power saving factor effect.

Fig. 3 shows the power saving factor versus the channel request density for three proposed theoretical models when window $D_S = D_A = D_{A(I)} = D_{SS} = D_{SA} = 5$ and $D_{LS} = D_{LA} = 10$ seconds (S is the short time period and L is the long time period). The figure approximately shows the power saving factor deceasing as the channel density values. In static window scheme, the window size of each state is allocated as the fixed window value. the duration time of each state is allocated to static window. By the simulation of static window scheme, we compare the simulation results with the results of proposed schemes. Both the results of analysis and simulation of static window scheme show nearly same performance pattern. Numerical results are slightly differ from the simulation results because there are not considered about additional environment parameters in the theoretical model. In numerical results, the partial flexible scheme shows better performances than other two proposed models. If by short interval rate the channel request is higher, it affects the power saving factor to drop the energy saving throughput. The overall flexible scheme shows low achievement to partial flexible scheme as the channel request density is higher.

Ⅳ. 결 론

We study the system state operations of base station for the power saving in this paper. In the evaluating results, we investigate the analysis values of the power saving factor and interrelation between the power saving factor and effect parameters such as the channel request density, state period number and the period size. Also, we can identify that the partial flexible scheme provides more effect for the power saving of base station. The values of the channel request density increases so that the power saving factor shows lower values.

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