BET Estimation Accuracy on Intermittent Disabling Network Device for Saving Smartphones Power Consumption

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I. INTRODUCTION

Large power consumption is an important issue for smartphones [1][2]. Applications in a smartphone are invoked and perform communications with its network device even in the screen-off state. Naturally, these behaviors consume its battery. Repeating to disable and enable the network device, we call it *intermittent disabling network device* [3], is one of the most effective methods for decreasing power consumption.

However, a transition of network device state consumes power and disabling a device in too short a time increases power consumption. Thus, estimation of BET (Break-even time), with which the increased and decreased power consumptions are the same, is essential for utilizing the method. In our work of [3], we proposed a method for estimating BET and evaluated the method in a simple benchmark condition. In this paper, we evaluate the proposed method with another device and an application set based on a practical application usage model [4].

II. POWER SAVING BY INTERMITTENT DISABLING NETWORK DEVICE

In this section, we explain the method for decreasing power consumption by intermittent disabling the network device and its BET [3].

Fig. 1 illustrates the model of transition of the power consumption including enabling and disabling the network device. The areas of A_0 and A_1 are the power consumption increased by disabling and enabling, respectively. The area of B is the power consumption decreased by disabling the device. The length of b is the difference of the power consumptions with the device enabled and disabled. The following inequality must be satisfied in order to decrease the power consumption.

$$A_0 + A_1 < B \qquad (1)$$

In addition, we define BET as the length of disabled time with which the following equation is satisfied.

$$A_0 + A_1 = B \qquad (2)$$

We have to make the device disabled longer than BET in order to reduce power consumption. However, BET is not provided usually. Therefore, estimation of BET is essential.

III. ESTIMATION OF BET

In this section, we introduce an existing method for estimating BET based on the average electric current [3].Fig. 2

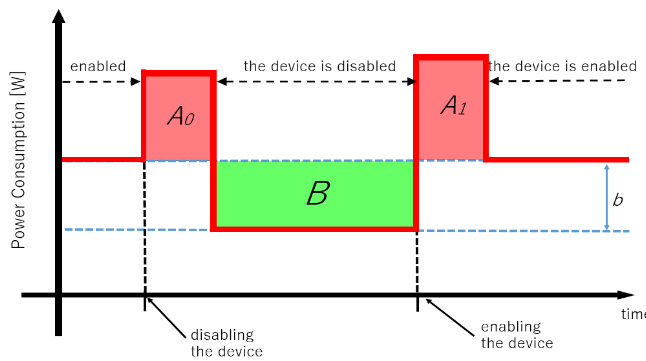

Fig. 1.Intermitten disabling network device

illustrates the model of the power consumption in one cycle of the loop of repeating to disable and enable the network device. This method assumes that the voltage is constant and the power consumption is proportional to the electric current. Thus, this method measures the electric current, which is available in smartphones, for discussing power consumption. i_{on} and i_{off} are the electric currents with the network device always enabled and disabled, respectively. t_{com} is the amount of time required to enable and disable the device. t_{on} and t_{off} are the times in which the device is enabled and disabled, respectively. A is the total power consumption increased by enabling and disabling. i_{loop} is the average electric current when the network device is repeatedly enabled and disabled. The figure presents the following equation.

$$i_{loop} = \frac{\mathrm{A} + i_{on}(t_{com} + t_{on}) + i_{off} \cdot t_{off}}{t_{com} + t_{on} + t_{off}} \qquad (3)$$

That is,

$$A = (t_{com} + t_{on})(i_{loop} - i_{on}) + t_{off}\,(i_{loop} - i_{off}) \qquad (4)$$

All the values in (4) except for A can be obtained by measurement. Therefore, A can be obtained by the equation (4). BET is t_{off} such that

$$i_{loop} = i_{on} \qquad (5)$$

That is,

$$BET = \frac{\mathrm{A}}{i_{on} - i_{off}} \qquad (6)$$

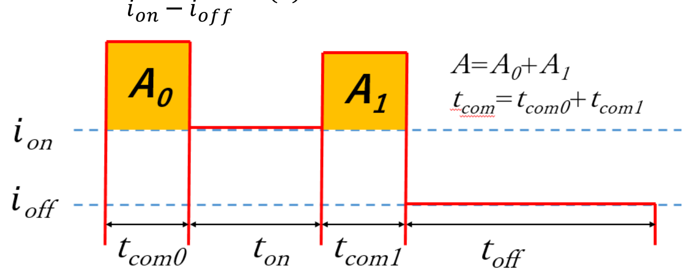

Fig. 2.Model of power consumption of one cycle of loop of enabling and disabling the network device

IV. EVALUATION

A. Device dependency

In the previous work [3], we evaluated the proposed method only with Nexus 7 (2013). In this subsection, we evaluate the method with Nexus 5X in order to investigate its device dependency. We installed a set of applications into Nexus 5X and estimated its BET. The application set was composed of the top 20 applications ranked in the Google Play Store on Dec. 6, 2016. These are same as those of the previous work [3].

The data labeled *Nexus 5X* in Fig. 3 show the estimated electric current by the proposed method in a situation that the WiFi device is repeatedly enabled and disabled. The electric current with the WiFi device always enabled was 186.0 [mA]. The estimated current equals to that with the WiFi device always enabled at 52.1 s. Thus, the estimated BET is 52.1 s. The results labeled *Nexus 5X* in Fig. 4 depicts the actual battery consuming speed. The speed with the WiFi device always enabled is 7.0 [%/h]. Thus, the actual BET is about 53.9 s, which can be obtained from the measured values of 50 s and 100 s with the linear approximation. These results indicate that the proposed method can estimate BET accurately also with Nexus 5X.

B. Application dependency

In this subsection, we evaluate the proposed method with an application set that is based on a practical smartphone usage model [4]. The application set is composed of famous 11 applications. We installed these applications and estimated BET. The used device is Nexus 7 (2013), which is the same device of [3].

The data labeled *practical application usage model* in Fig. 3 and 4 show the estimated current and actual power consuming speed, respectively. The average current and consuming speed with the device always enabled are 139.0 [mA] and 4.6 [%/h], respectively. Namely, the estimated and actual BETs are 55.9 s and 48.0 s, respectively. These indicate that the proposed method can estimate BET with another application set.

V. RELATED WORK

Nakada et al. proposed a method for computing which aggressively powered off components of computer systems when they needed not to operate [4]. They called it *normally-off computing*. Unlike our work, the work did not provide a method for estimating BET.

VI. CONCLUSION

In this paper, we focus on saving power consumption of smartphones by intermittent disabling its network device and introduced the method for estimating BET. We then evaluated the method with a device and an application set. Our evaluation showed that the method can estimate its BET exactly independent on device and application set.

For future work, we plan to evaluate our method with various network devices such as a cellular network.

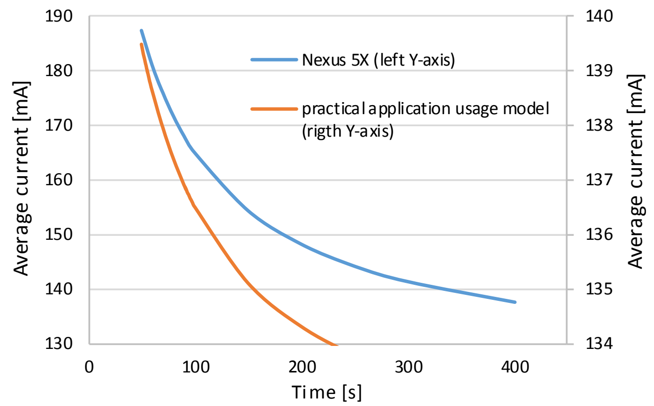

Fig. 3. Relationsip between device disabled time and the average electric current

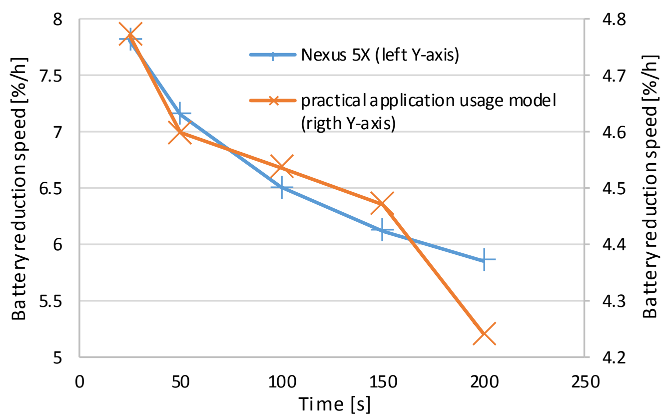

Fig. 4. Relationship between device disabled time and battery consuming speed

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