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Development of Context-Aware Power Management Scheme Using Beacons

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Abstract

In this paper, we propose a context-aware power management (CPM) scheme using beacons to reduce the power consumption of personal computers (PCs). In the proposed CPM scheme, the PC, smartphone, control server, and Internet of Things (IoT) device are necessary. PC users first log in the control server using their smartphones and select PCs to turn on. Then, the selected PCs automatically go into three different modes, i.e., sleep, shutdown, and standby power off modes, in order when the PC users leave the PCs without turning off them. Further, we develop a testbed with the proposed CPM scheme using the Arduino with Bluetooth low energy (BLE) and relay modules. Finally, it is shown that the proposed CPM scheme outperforms the conventional scheme in terms of the power consumption.

Keywords: Power Management, Context-Aware, Beacon, Arduino, Standby Power, Bluetooth.

1. Introduction

Recently, in many different research areas, power saving is one of the hottest issues since the amount of CO_2 increases rapidly and thus the world is getting hotter, i.e., global warming[1]. In order to reduce global warming, new electronics are required to have a function that decreases standby power of those because it wastes a significant amount of power[2]. Further, the Internet of Things (IoT) is receiving a great deal of attention from both academia and industry that are working on technologies to develop intelligent devices[3]. In [3], authors introduce technologies for intelligent environments to provide the convenient life for people. That is, a lot of IoT devices at home are connected to each other and they always check the location of users. For instance, after people use a program with a personal computer (PC) in the living room, they move to the study room and continuously use the same program with another PC without turning on and logging in the PC. For this, the IoT devices need to exchange the beacon with the smartphone of the PC users.

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Therefore, in a couple of power saving schemes, authors proposed intelligent power control algorithms with the IoT technology[4,5]. In [4], authors introduce a power management system using the Arduino and beacons. Users control the power of electronic devices with their smartphone. That is, they turn on and off the IoT switch that is connected to the electronic devices. However, the power management system is not automatically operated. Thus, users have to control the IoT devices by themselves. In [5], authors introduce a power management system (PMS) supporting automatic detection and cutoff of standby power. They developed a PMS client, i.e., multiple-tap, with the IoT and then the users control the PMS client to cut the standby power using their smartphones. However, for this, users need to check the power consumption of devices through the control server and it is inconvenient. Therefore, a new power management scheme is necessary to automatically control the power and standby power of electronics, i.e., intelligent power management scheme based on the location of the users.

In this paper, we propose a context-aware power management (CPM) scheme using beacons to reduce the power consumption of PCs. In the proposed CPM scheme, the PC, smartphone, control server, and IoT device are necessary. PC users first log in the control server using their smartphones and select PCs to turn on. Then, the selected PCs automatically go into three different modes, i.e., sleep, shutdown, and standby power off modes, in order when the PC users leave the PCs without turning off them. Further, we develop a testbed with the proposed CPM scheme using the Arduino with Bluetooth low energy (BLE) and relay modules. Finally, it is shown that the proposed CPM scheme outperforms the conventional scheme in terms of the power consumption.

The rest of this paper is organized as follows. Section 2 introduces the related work while Section 3 proposes the CPM scheme. Then, Section 4 shows the testbed and evaluates the system performance compared to the conventional scheme while Section 5 finally concludes this paper with future research direction.

2. Related Research

2.1. Internet of Things

Internet of Things (IoT) is a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects through wireless and wired connections. Further, each thing/object has a unique address to interact and cooperate with each other to create new applications/services and reach common goals. The goal of the IoT is to enable things to be connected anytime, anyplace, with anything and anyone by ideally using any path/network and any service[6,7].

2.2. Arduino with BLE Beacon and Relay Modules

Arduino is an open source computer hardware and software company, project, and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. The Arduino project started in 2003 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats, and motion detectors[8].

Bluetooth beacons are hardware transmitters - a class of BLE devices that broadcast their identifier to nearby portable electronic devices. The technology enables smartphones, tablets and other devices to perform actions when in close proximity to a beacon[9]. Bluetooth beacons differs from some other location-based technologies as the broadcasting device (beacon) is only a 1-way transmitter to the receiving smartphone or receiving device, and necessitates a specific app installed on the device to interact with the beacons. This ensures that only the installed app (not the Bluetooth beacon transmitter) can track users, potentially against their will, as they passively walk around the transmitters.

The relay module controls the standby power of high-voltage electrical devices (maximum 250 V). It can be used in interactive projects and can also be used to control the lighting, electrical and other equipments. It can be controlled directly by a wide range of microcontrollers and can be controlled through the digital input/output (IO) port, such as solenoid valves, lamps, motors and other high current or high voltage devices[10].

3. Proposed CPM Scheme Using Beacons

3.1. Architecture of the Proposed CPM Scheme

Fig. 1 shows the architecture of the proposed CPM scheme that consists of the PC, smartphone, control server, and IoT device. The PC and smartphone are normal and thus we use them every day. The control server has a couple of databases (DBs), e.g., user DB, PC DB, and so on. The user DB has user identification (ID), password, login information, PC number that the user currently uses. The PC DB has the three modes of PCs, i.e., sleep, shutdown, and standby power off modes. Lastly, the IoT device is developed using the Arduino with BLE beacon and relay modules and it is connected to the PC with batteries. The IoT device periodically

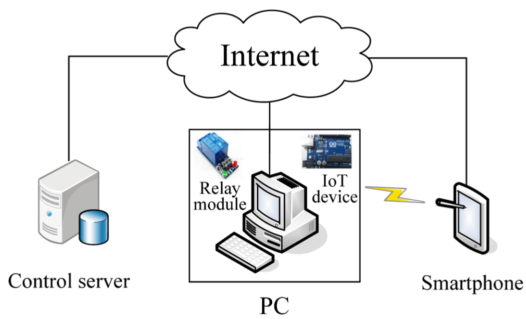


Fig. 1. Architecture of the proposed CPM scheme.

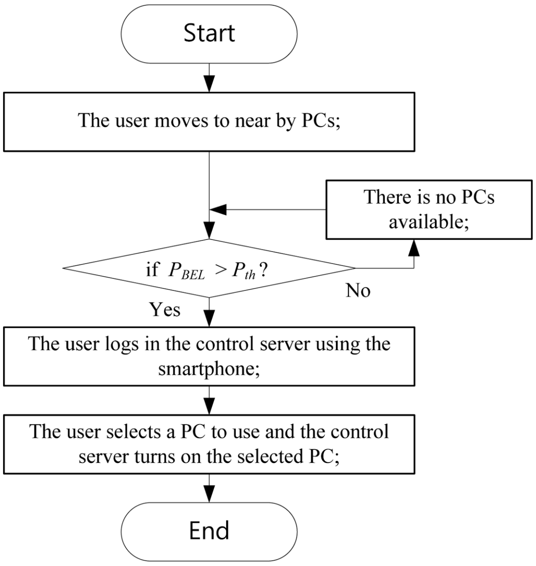
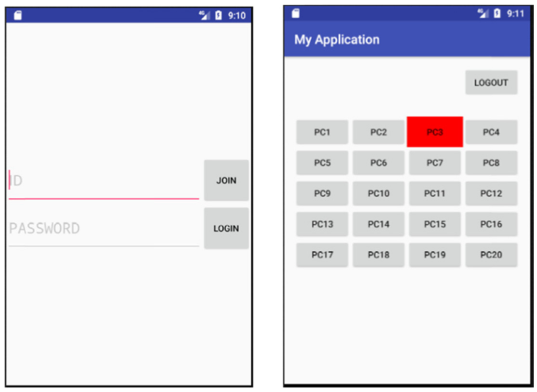


Fig. 2. Procedure of user authentication and PC selection.



(a) Login **(b) Select PCs**

Fig. 3. An example of authentication and PC selection using smartphones in the proposed CPM scheme.

transmits beacons and thus users know which PCs are nearby them. Further, the IoT device controls the relay module to cut the standby power of electronic devices. From subsection 3.2 to 3.4, we explain the authentication and three different modes in the proposed CPM scheme.

3.2. User Authentication and PC Selection

Fig. 2 shows the procedure of user authentication and PC selection. In order to use PCs, the user first needs to log in the control server using the smartphone. Fig. 3 shows an example of authentication and PC selection using smartphones. In Fig. 3(a), the user logs in the control server using the ID and password and the control server authenticates the user based on the ID DB. Then, in Fig. 3(b), the user selects a PC to use in the PC list of the computer room. For instance, the user selected PC 3 (red square) to use. The control server turns on the selected PC by sending a message through the Internet and a LAN card of the PC (LAN card has a remote control function to turn on PCs) after the user selects a PC.

3.2. Scenario 1: Sleep Modes

Fig. 4 shows the procedure of Scenario 1. Let P_{BLE} and P_{th} denote the received signal strength (RSS) of the BLE beacon and a given RSS threshold to shut down

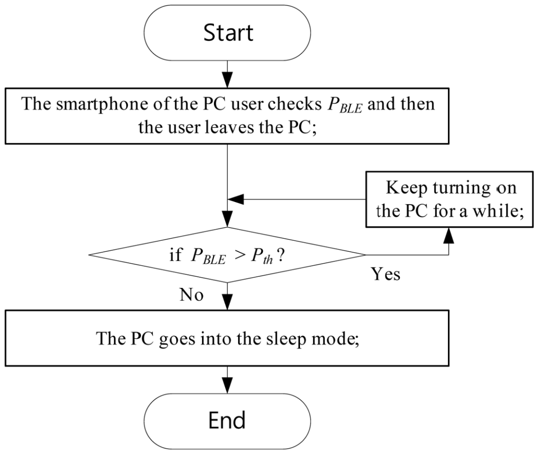


Fig. 4. Procedure of Scenario 1 (sleep mode).

the PC. In Scenario 1, the smartphone of the PC user checks P_{BLE} and then the user leaves the PC without turning off the PC. Then, the smartphone transmits a logout message to the control server to change the mode of the selected PC to the sleep mode if $P_{BLE} < P_{th}$ but the PC keeps turning on if $P_{BLE} > P_{th}$. Fig. 5 shows an example of changing from the operating mode to the sleep mode, i.e., log off the selected PC.

3.3. Scenario 2: Shutdown Modes

Fig. 6 shows the procedure of Scenario 2. After Scenario 1, the PC is currently in the sleep mode. In Scenario 2, there are two ways: one way is that the PC goes into the shutdown mode and another way is that the PC

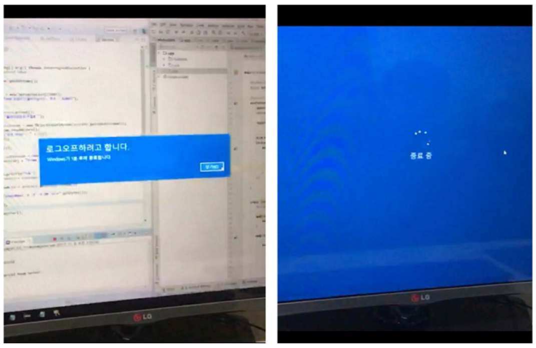


Fig. 5. An example of changing from the operating mode to the sleep mode.

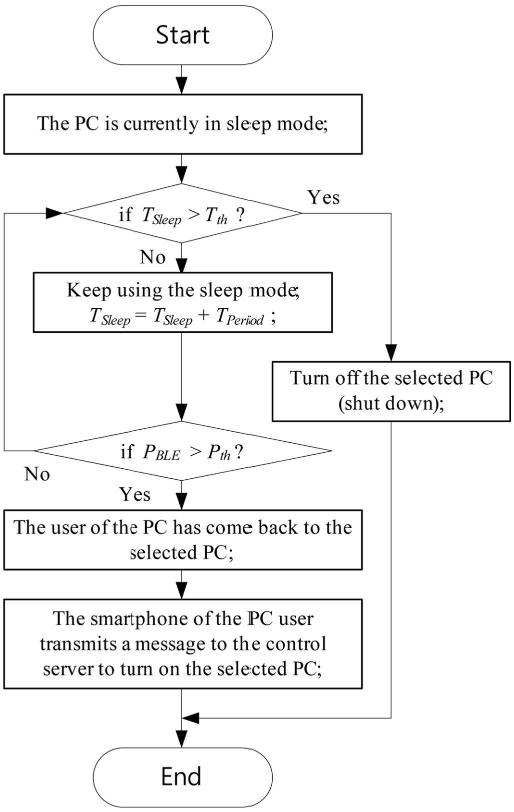


Fig. 6. Procedure of Scenario 2 (shutdown mode).

turns on again. Let T_{Sleep}, T_{th}, and T_{Period} denote a period of time during the sleep mode, a given time threshold to shut down the PC, and a period of time to check the condition again. Then, the control server shuts down the PC if $T_{Sleep} > T_{th}$ but the PC keeps using the sleep mode if $T_{Sleep} < T_{th}$. Further, the smartphone keeps checking

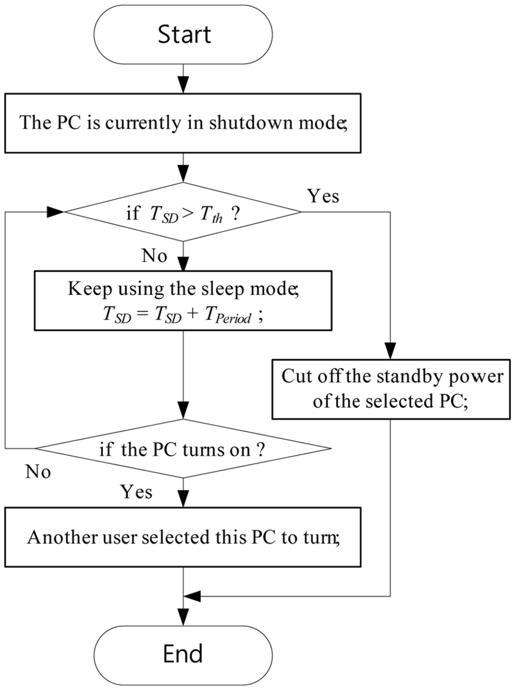


Fig. 7. Procedure of Scenario 3 (standby power off mode).

P_{BLE} if $T_{Sleep} < T_{th}$ and the smartphone transmits a message to the control server to turn on the selected PC again if $P_{BLE} > P_{th}$, i.e., the PC user has come back to the selected PC to use.

3.4. Scenario 3: Standby Power off Modes

Fig. 7 shows the procedure of Scenario 3. In Scenario 3, there are two ways: one way is that the selected PC goes into the standby power off mode and another way is that the PC turns on again. After Scenario 2, the selected PC is currently in the shutdown mode. Let T_{SD} denote a period of time during the shutdown mode. Then, the control server cut the standby power of the selected PC if $T_{SD} > T_{th}$ but the selected PC keeps using the shutdown mode if $T_{SD} < T_{th}$. Then, the control server turns on the selected PC again if another user selects it.

4. Testbed and Performance Evaluation

In this Section, we introduce the testbed with the proposed CPM scheme and describe the performance evaluation in terms of the power consumption. Fig. 8 shows the testbed with the desktop, monitor, IoT device, and smartphone. We evaluate the system performance from

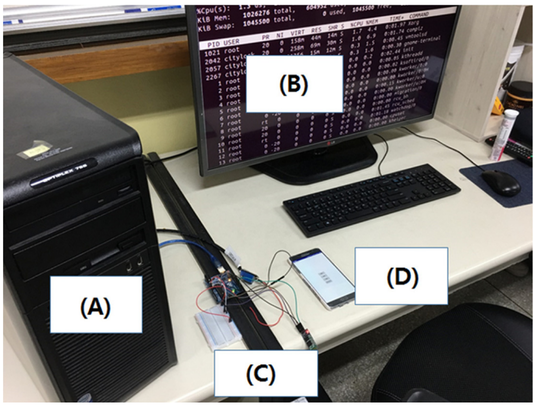


Fig. 8. Testbed: (A) desktop, (B) monitor, (C) an IoT device, (D) smartphone.

Table 1. Power consumption of electronic devices in different modes

Modes	devices	Power Consumption (Watt)
Operating	Monitor	42
	Desktop	45
Sleep mode	Monitor	16.5
	Desktop	1.4
Shutdown mode	Monitor	0.2
	Desktop	0.5
Standby power off mode	Monitor	0
	Desktop	0

Scenario 1 to 3 after a PC user turns on the PC using the smartphone. In order to measure the power consumption of electronic devices, we use a smart plug that provides a real-time monitoring program of power consumption. Table 1 shows the power consumption in Watt for the electronic devices, i.e., monitor and desktop, using the smart plug. The watt (abbreviated W) is the International System of Units (energy per unit time), the equivalent of one joule per second.

Fig. 9 depicts the results of the total power consumption for electronic devices in the operating and sleep modes. The results increase linearly as time goes on. In addition, the results in the operating mode increase rapidly compared to those in the sleep mode. As a result, it is shown that the PC needs to use the sleep mode with intelligence.

Fig. 10 depicts the results of the total power consumption for electronic devices in the shutdown and standby power off modes. The results in the shutdown mode increase linearly as time goes on while those in the standby power off mode are always 0. As a result, it is shown that the PC needs to use the standby power off mode with intelligence.

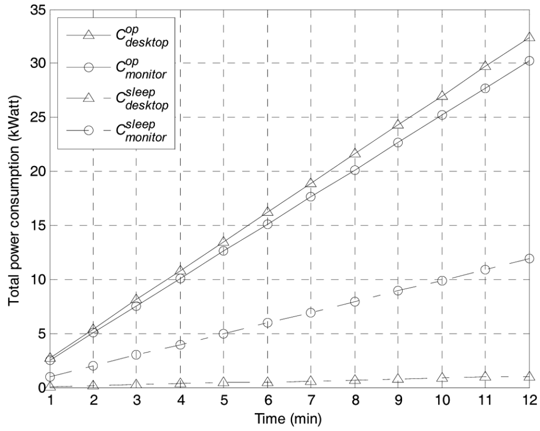


Fig. 9. Total power consumption of electronic devices in the operating and sleep modes.

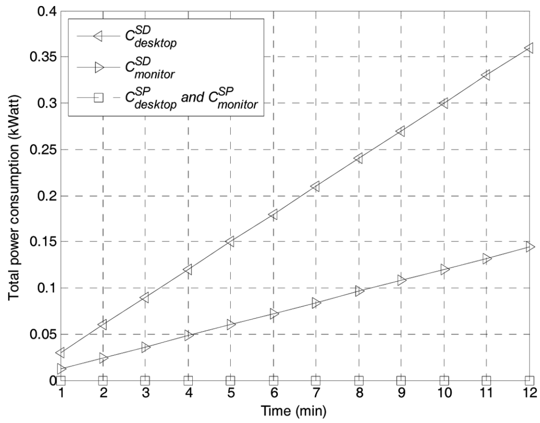


Fig. 10. Total power consumption of electronic devices in the shutdown and standby power off modes.

Fig. 11 depicts the results of the mean power consumption of the proposed CPM scheme compared to the conventional scheme. In the conventional scheme, the PC continuously operates after the PC user leaves it without turning off and thus the results are always the same as time goes on. On the other hand, in the proposed CPM scheme, the results are reduced after changing the mode. That is, the mean power consumption per

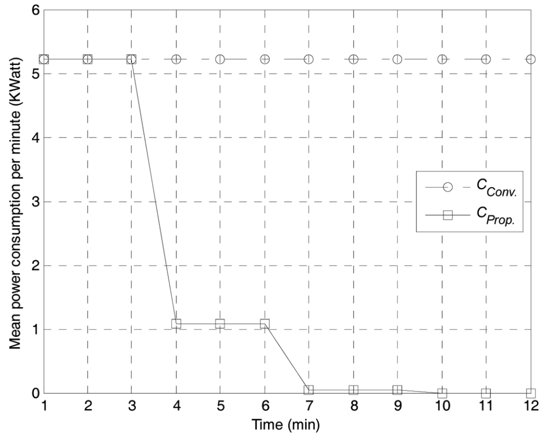


Fig. 11. Mean power consumption of the proposed CPM scheme compared to the conventional scheme.

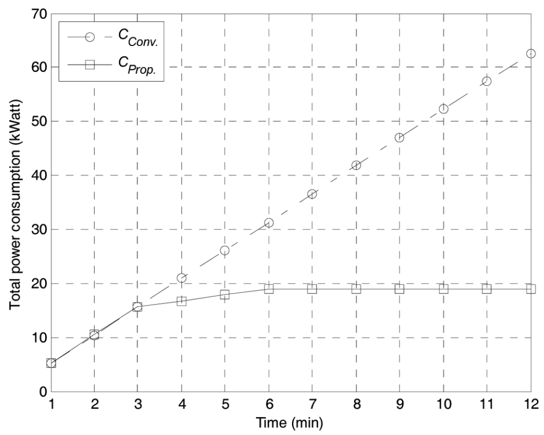


Fig. 12. Total power consumption of the proposed CPM scheme compared to the conventional scheme.

minute decreases from 3 to 4 minute (we use the parameter $T_{th} = 3$) since the PC goes into the sleep mode. Then, it decreases from 6 to 7 minute and from 9 to 10 minute because the PC goes into the shutdown mode and standby power off mode, respectively. As a result, it is shown that the proposed CPM scheme reduces the mean power consumption of the PC while the conventional scheme always uses the same power consumption.

Fig. 12 depicts the results of the total power consumption of the proposed CPM scheme compared to the conventional scheme. In the conventional scheme, the results increase linearly as time goes on since the mean power consumption is always the same as shown in Fig. 11. On the other hand, in the proposed CPM scheme, the results are saturated after the PC goes into the standby power off mode. As a result, it is shown that the proposed CPM scheme reduces the total power consumption of the PC while the conventional scheme wastes the power consumption.

5. Conclusions

In this paper, we proposed an intelligent power management scheme named CPM using beacons to reduce the power consumption of PCs. In the proposed scheme, PC users first log in the control server using their smartphones and select PCs to turn on. Then, the selected PCs automatically go into three different modes, i.e., sleep, shutdown, and standby power off modes, in order when the PC users leave the PCs without turning off them. Further, we designed and developed the testbed with the proposed CPM scheme using the Arduino with BLE and relay modules. From the performance results, it is shown that the proposed CPM scheme outperforms the conventional scheme in terms of the power consumption. For future work, we are planning to study an enhanced CPM scheme that turns on the PC nearby the PC user when the PC user moves. That is, the selected PC is automatically turned off and another PC nearby the user is turned on when the PC user moves from the selected PC to another PC. Therefore, the PC user conveniently uses the PCs without wasting the power consumption.

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