Energy Saving System for Set-top Boxes with Passive Standby Mode

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Abstract— **Set-top boxes are widely deployed because of digital broadcasting, channel availability, high quality video, and other functionalities. Many set-top boxes do not have energy-efficient standby mode. To reduce standby power of set-top boxes, set-top boxes with energy-efficient passive standby mode have been developed. However, previously proposed methods of utilizing passive standby mode have energy efficiency and user inconvenience problems. In this paper, an energy saving system for set-top boxes with passive standby mode is proposed to fully utilize passive standby mode. The history of TV/STB power-on/off events is analysed to predict usage pattern. The system switches a set-top box to passive standby mode or active standby mode based on the prediction.**

Keywords— **Electricity consumption, set-top box, power management, standby power reduction, intelligent energy saving system.**

I. INTRODUCTION

Set-top boxes are widely deployed because of digital broadcasting, channel availability, high quality video, and other functionalities [1]. Recent set-top boxes consumes more electricity due to their multifunctional, high performance chips. Reducing electricity consumption of set-top boxes is an important aspect of household energy management.

When a user switches off an electrical appliance, the appliance transits to standby mode. Many electrical appliances have energy-efficient standby mode in which appliances consume small amount of power [2]. However, many set-top boxes do not have energy-efficient standby mode. Even when a set-top box is in standby mode, it consumes 80~90% of active power mode. Standby modes of set-top boxes are not energy-efficient because many set-top boxes only turns off video/audio out when they are in standby mode [3].

To reduce standby power of set-top boxes, set-top boxes with energy-efficient passive standby mode have been developed [3]. Previous works have proposed Auto Power Down (APD) scheme to utilize passive standby mode [4] [5]. A set-top box switches to passive standby mode when there is no user input for predefined duration in the Auto Power Down scheme. In another power saving scheme [6], a set-top box switches to passive standby mode when the infrared signal for TV power-off is intercepted.

However, the Auto Power Down scheme and the infrared signal intercepting scheme have disadvantages. In APD scheme, unnecessary electricity is wasted for predefined APD duration if a user does not watch TV during that duration. In the infrared signal intercepting scheme, a user may frequently experience long wake-up time if transition from passive standby mode to On mode takes considerable time. It is difficult to apply the infrared signal intercepting scheme when the infrared signal for TV power-off is the same as the infrared signal for TV power-on.

An energy saving system for set-top boxes with passive standby mode is proposed to solve aforementioned problems in this paper. In the system, TV/STB(set-top box) power-on/off events are recognized by intercepting infrared signals and receiving HDMI-CEC (High Definition Multimedia Interface-Consumer Electronics Control) signals. The history of TV/STB power-on/off events is logged and analysed to predict usage pattern. The system switches a set-top box to passive standby mode or active standby mode based on the prediction.

II. ENERGY SAVING SYSTEM FOR SET-TOP BOXES

A. System Architecture

Figure 1 shows the architecture of the energy saving system for set-top boxes. The 'Power On/Off Event Logger' module logs power on/off events of a TV and a set-top box. The predictor module predicts usage pattern based on the power on/off event log. When TV or STB is in power-off status and it is predicted to be powered on after considerable duration, the predictor module configures the timer module to transit the set-top box to active standby mode before predicted power-on time and switches the set-top box to passive standby mode.

B. Recognition of TV/STB Power Off

It is desirable for users to turn off set-top boxes when set-top boxes are not used. In that case, the logging of set-top box on/off events is sufficient for prediction of viewer patterns. However, many viewers keep set-top boxes turned on even when they do not use set-top boxes. Thus, recognizing power

on/off status of TV is necessary to tell whether a set-top box is used or not.

One way of inferring TV power on/off status is intercepting infrared signals [6]. The infrared signal intercepting method works only if the infrared signal for TV power-off is different from the infrared signal for TV power-on. If the infrared signal for TV power-off is same as the power-on signal, it is hard to infer TV power on/off status. TVs from some major manufacturers use single infrared signal for TV power on and off.

Another way of recognizing TV power on/off status is receiving HDMI-CEC signals. Consumer Electronics Control (CEC) is an HDMI feature that allows to send control signals over HDMI connection. A set-top box can recognize TV power on/off status by receiving HDMI-CEC signals from TV.

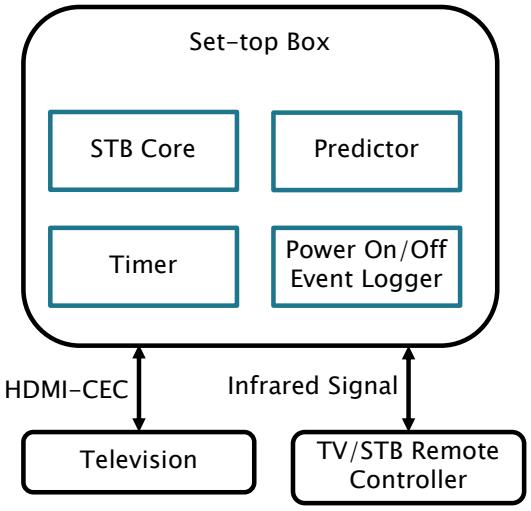

Figure 1. The Architecture of the Energy Saving System for Set-top Boxes

C. Prediction of Usage Pattern

The history of TV/STB power-on/off events is analysed to predict set-top box usage pattern. The power-off periods that are longer than a predefined interval are recognized for each day. Then periods with similar time range are clustered. After the clustering, linear regression is used to predict future power-off periods.

An example of predicting usage pattern is illustrated in Figure 2. The blue dots denote power-off events. The green dots denote power-on events. The red lines are regression lines. The illustrated power-off period usually starts from 9:00 to 18:00.

D. Configuring Wake-up Time

When it is usual TV-off or STB-off period and TV or STB is in power-off status, the predictor module configures the timer module to transit the set-top box to active standby mode before predicted power-on time, then the predictor module switches the set-top box to passive standby mode. This configuring is to minimize user waiting time. Set-top boxes may have long transition time, which ranges from dozens of seconds to a few minutes, to transit from passive standby mode to On mode.

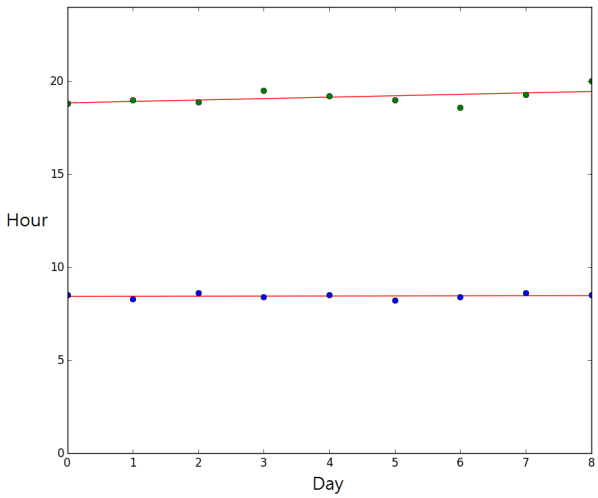

Figure 2. Example of predicting usage pattern

III. CONCLUSIONS

The energy saving system for set-top boxes with passive standby mode is proposed to solve energy efficiency and user inconvenience problems. In the system, TV power-on/off events are recognized by intercepting infrared signals and receiving HDMI-CEC signals. The history of TV/STB power-on/off events is analysed to predict TV/STB usage pattern. The system switches a set-top box to passive standby mode or active standby mode based on the prediction. The system is under development.

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REFERENCES

[1] European Commission DG TREN, “Preparatory studies for eco-design requirements of EuPs (II),” Complex set-top boxes Final Report, Dec. 2008.

[2] Lawrence Berkeley National Laboratory, “Standby power summary table,” http://standby.lbl.gov/, 2012.

[3] S. H. Lee and J. M. Yun, “Design of Energy-efficient Set-top Box,” Consumer Electronics (ISCE), *2011 IEEE 15th International Symposium on Consumer Electronics*, June 2011, pp.75-78.

[4] Energy Star, “Energy Star Program Requirements Product Specification for Set-top Boxes Version 4,” January 2011.

[5] EU-Code of Conduct, “Code of Conduct Energy Efficiency of Digital TV Service Systems Version 8,” July 2009.

[6] I. Syed, D. Shin, and H. Kim, “A Fast Stand-by Mode Transition Scheme Using TV Power-off Signal for Set Top Box Power Saving.” *Life Science Journal* 10.2 (2013).

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