A Fast Stand-by Mode Transition Scheme Using TV Power-off Signal for Set Top Box Power Saving

Ikram Syed, Daesik Shin, Hoon Kim

Department of Electronics Engineering, University of Incheon, Incheon, Korea
engr.ikramsyed@gmail.com; hoon@incheon.ac.kr

Abstract: This paper proposes an efficient set-top box (STB) power-saving scheme using TV power-off signal. Unlike a conventional mode transition scheme requires user input monitoring for stand-by mode transition, the proposed power-saving scheme transits to stand-by mode immediately when the STB detects TV power-off signal. The fast mode transition to stand-by mode saves the power consuming remarkably. Simulation results show that the power consumption is reduced with increase in TV power-on/off event rate which is modeled as Poisson process. The proposed scheme saves the power up to 19% compared to the conventional scheme.
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1. Introduction

Recently, set-top box (STB) market has rapidly grown, due to world-wide spread of digital broadcasting [1]. Functionalities, meanwhile, have been added for improved services such as High Definition Television (HDTV), Video On Demand (VOD), Voice over IP (VoIP) or internet access [2]-[3]. This growth trend of market and addition of STB functionality promotes the need of technologies for STB power-saving [4], being colligated with reinforced regulation on STB energy consumption.

Research has been carried out to develop and design energy efficient STB. [5] presents the design of green internet protocol television (IPTV) STB composed of system-on-chip (SoC) supporting low-power mode, hardware system for controlling power of each block and power management middleware. A detail description of STB structure and operations to enable the low-power mode such as stand-by mode of STB is presented in [6]. In [7]-[10], a practical stand-by mode transition scheme named as auto power down (APD) has been proposed for stand-by mode operation. APD transits to stand-by mode for no viewer input to STB remote control over certain duration. APD is effective against the power consumption in that it automatically transits to stand-by mode, but there is always the transition delay of monitoring duration while STB consumes on-mode power.

In this paper, a stand-by mode transition scheme is proposed that performs faster mode transition than APD in the event of user input for TV power-off. When STB receives the user input signal of TV power-off, STB immediately switches into stand-by mode, which enables faster mode transition than APD. The performance evaluation of power consumption is made with the assumption that the events of TV power-on/off are modeled as Poisson processes. The performance evaluation result shows that the proposed scheme achieves improvement in power-saving. This paper is organized as follows. Section II presents a system model and section III introduces the proposed power-saving scheme. Section IV presents the performance evaluation results, and the conclusion is presented in section V.

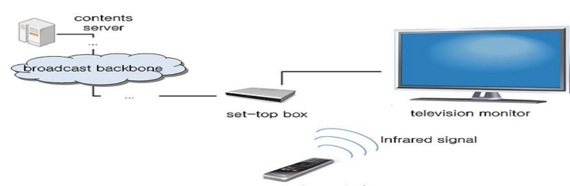

Figure 1. Broadcasting system and set-top-box (STB)

2. System Model

This work considers a digital broadcasting system which consists of STB, TV, and Infrared (IR) remote control as shown in Figure 1. STB receives IR signal from the remote control and a broadcasting signal from the broadcast system. IR signals, such as TV channel selection and volume control, consist of Lead Code (LC), Custom Code (CC) and Data Code (DC) [11]. LC denotes IR signal preamble, CC is target device information, and DC represents control information. This work assumes that IR signals for STB and TV share the same frequency band, while the target device is identified by customer code (CC) [12]-[13]. The broadcast system signal is composed of audio/video (A/V) signal and supplementary information such as Electronic Program Guide (EPG). STB operates in two modes, namely on-mode and stand-by mode. In on-mode, STB receives all signals from a remote controller and broadcasting system. On-mode operations include conversion and transmission of A/V signal of a TV channel selected by the viewer. In stand-by mode, STB receives only supplementary information from a broadcasting system. Table I lists several functions of each mode.

TABLE I. STB FUNCTIONS IN ON-MODE AND IN STAND-BY MODE

Mode	Functions of STB
On	Receive the IR signal Receive encoded/compressed the broadcasting signal Update a firmware and EPG Perform decompression and decode the broadcasting signals Convert digital signals into standard AV content Provide viewer with AV content
Stand-by	Receive the IR signal Receive encoded/compressed broadcasting signal Update a firmware and EPG Perform decompression and decode the broadcasting signals Convert digital signals into standard AV contents

3. POWER-SAVING SCHEME

It is known that on-mode operation consumes more power for executing more functions. It is reported that the power consumption of on-mode is about 9W/h more than stand-by mode [8]. To reduce power consumption, it is desirable to change the operating mode to stand-by immediately if the viewer stops watching TV. The mode transition can be enabled by viewer input of STB power off/on remote controller, but STB power off is a viewer behavior dependent event, which cannot be expected to happen immediately or consistently. An alternative method of mode transition is automatic mode transition that automatically transits the mode to stand-by.

3.1. Auto Power Down

When STB is operating in on-mode and if a user does not give any input in the user command monitoring time (Tth), the STB will recognize that the user is not watching TV.

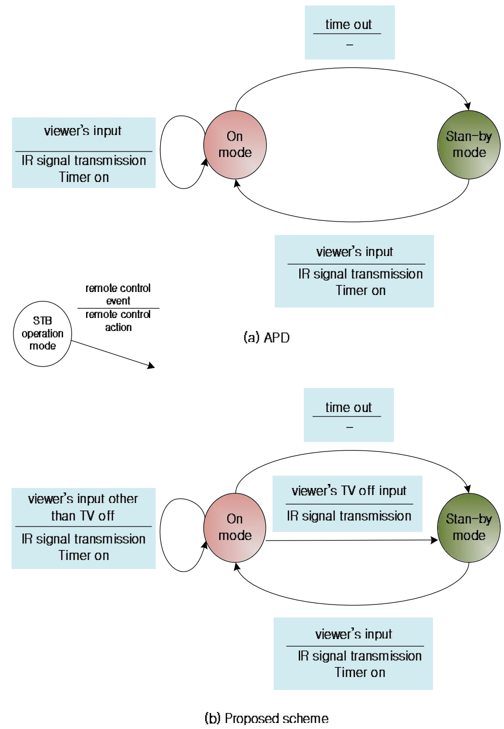

Figure 2 State diagrams of STB operation based on viewer's remote control input event for APD and for the proposed scheme

APD will check the user's last input time, and if Tth has elapsed then the STB will switch to stand-by mode for power-saving. We can improve the power-saving of STB without waiting for Tth by switching into stand-by mode immediately, if STB receives TV power-off signals by IR remote control. Figure 2(a) shows the state diagram representing APD operation, where events of time out for viewer's activity transit STB mode from on-mode to stand-by mode.

3.2. Proposed scheme

An efficient STB power-saving scheme is proposed, which switches the STB immediately to stand-by mode when TV power-off signal is recognized. Figure 2(b) shows the state diagram representing the proposed fast mode transition, where not only the events of time out for viewer's activity but also the events of TV power-off transit STB mode from on-mode to stand-by mode. Figure 3 shows more details of mode- change procedures, where STB recognizes transmissions of TV power-off signal from user side by detecting the code information encoded to IR signals. STB firstly checks if there is any IR signal transmission from remote control by LC code correlation. Then STB sequentially detects CC and DC signals to get target device information and button information, respectively. If STB recognizes that the device type is TV and the user input is TV power-off from the CC and DC detection, STB immediately switches to stand-by mode regardless of timer value. Figure 4 illustrates an operation example to introduce the power consumption of APD and the proposed scheme. Let τk denote the time duration between the time points of k-th TV power off event and the following (k-th) TV power-on event, and also let Tk's denote the time duration of additional power saving at kth TV power-off of the proposed scheme compared to APD. As shown in Figure 4, Tk's may increase as τk grows but limited by T_{th}, which is represented by

$$T_k' = \min(\tau_k, T_{th}) \qquad k = 1,2,3,\ldots K. \qquad (1)$$

Accordingly, the energy reduction for k_{th} TV power-off can be calculated by $T_k'(P_{ON} - P_{SB})$, which corresponds to the area of part in deviant crease lines in Figure 4.

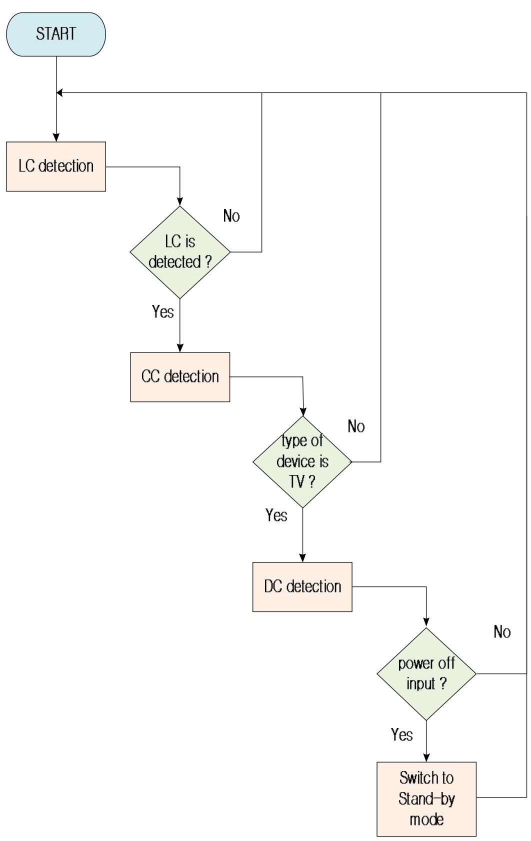

Figure 3 Flowchart of proposed power-saving scheme in STB.

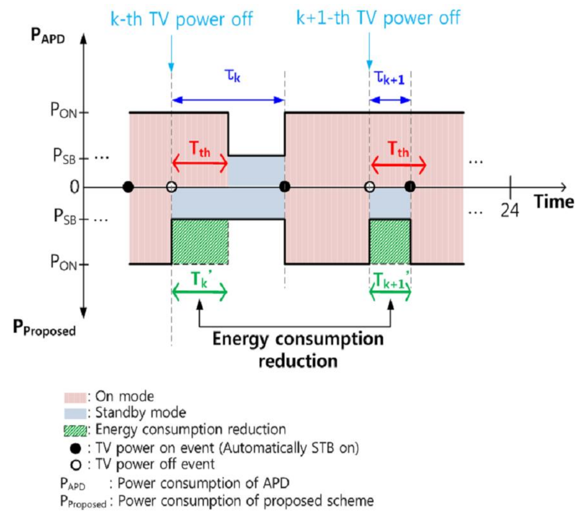

Figure 4. Compare the power consumptions of APD and the proposed scheme.

4. PERFORMANCE ANALYSIS

The performance evaluation of power consumption was made with an assumption that the events of TV power-on/off are modeled as Poisson process. Poisson process has been widely used for modeling random on/off events [14]-[17]. Considering the randomness of viewer's TV power-on/off input in terms of time and rate, the events of TV power-on/off are assumed to be simply modeled as Poisson process. The performance measure is Total Energy Consumption (TEC), defined by average power consumption in a year [7]-[8]. Let $TEC_{(S)}$ denotes TEC in kilowatt hours per year by an arbitrary power-saving scheme *S*. Then $TEC_{(S)}$ is computed as follow.

$$\begin{aligned} TEC_{(S)} &= (T_{ON(S)}P_{ON} + T_{SB(S)}P_{SB}) \times 0.365 \\ &= [(24 - T_{SB(S)})P_{ON} + T_{SB(S)}P_{SB}] \times 0.365 \end{aligned} \qquad (2)$$

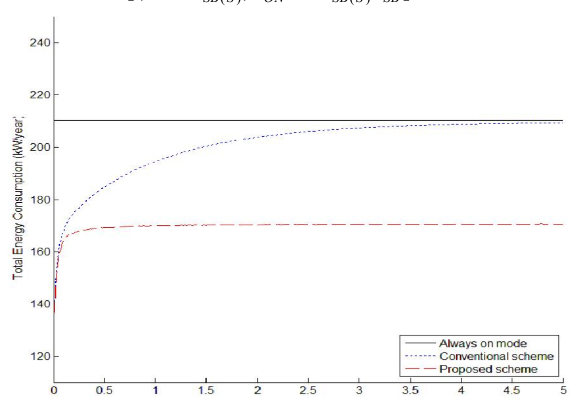

Figure 5. Simulation results of APD and the proposed scheme for variant TV power-on/off rate.

Where P_{ON} and P_{SB} are power consumptions of STB in watt hours for on and stand-by mode respectively.

$T_{ON(S)}$ and $T_{SB(S)}$ are the daily average durations in hours of on-mode and stand-by mode respectively. The sum of $T_{ON(S)}$ and $T_{SB(S)}$ is equal to 24. So the total reduction of energy consumption between APD and the proposed scheme can be obtained as

$$\begin{aligned} TEC_{APD} - TEC_{Pro} &= [(T_{SB(Pro)} - T_{SB(APD)})(P_{ON} - P_{SB})] \times 0.365 \\ &= [T\,'(P_{ON} - P_{SB})] \times 0.365, \end{aligned} \quad (3)$$

where $T_{SB(APD)}$ and $T_{SB(PRO)}$ are daily average durations in hours for stand-by mode by APD and the proposed scheme respectively. The total duration of additional power-saving T' can be obtained by the sum of T_k' s over a day as follows:

$$T\,' = \sum_{k=1}^{K} T_k\,'. \quad (4)$$

Thus the reduction of energy consumption depends on the number of K and duration of T_k' s. Additional assumptions include power consumption of 24W/h for on-mode and 15W/h for stand-by mode [6], and the APD's prior monitoring time of an hour. Figure 5 compares the power consumptions of APD scheme and the proposed scheme with respect to TV power-on/off rate. Time points of TV power-on/off are assumed to be a Poisson process [14]-[15]. The rate parameter of the Poisson process λ corresponds to the rates of TV power-on/off events per hour. Thus, daily average duration of STB mode is computed, and the effect of power-saving is evaluated accordingly. It is shown that the proposed scheme achieved up to 19% improvement in power consumption compared with the conventional APD with variant TV power-on/off incidence. This occurred because the proposed scheme does not require user command monitoring time as APD. As the TV power-on/off rate increases, the APD power consumption increases, because τ_k is not long enough for APD to enable stand-by mode transition for large λ.

5. Conclusions

This paper proposed a fast mode transition scheme for set-top box power-saving scheme based on TV power-off signal detection. By using the proposed power-saving scheme, the monitoring time to check whether the user is watching TV or not, could be reduced. The simulation result revealed that the proposed scheme achieves up to 19% improvement in power saving compared with the conventional APD. Further related research on this topic includes efficient use of signals other than TV power-off to reduce power consumption of STB.

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Corresponding author:
Hoon Kim
Department of Electronics Engineering
University of Incheon
Incheon, Korea
Email: hoon@incheon.ac.kr

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