Poster Abstract: The Standby Energy in Smart Homes: Problems, Progress, & Potential

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ABSTRACT

The Internet of Things (IoT) has dramatically expanded the capabilities of everyday devices. These smart devices bring improved convenience, better energy management, and over-the-Internet control, but are also unfortunately reversing an important trend: they are contributing to an increase in phantom standby energy consumption. While many miscellaneous loads have seen steady standby power improvements over time, adding persistent connectivity and advanced features to otherwise simple devices is causing some loads to get worse. This paper provides an analysis of this growing problem, and identifies four primary issues that contribute to the standby energy problem based on a study of commercially available smart devices. Further, it presents a prototype to demonstrate how smart device-specific approaches can help.

KEYWORDS

Standby Power Reduction, Internet of Things, Smart Homes.

1 PROBLEM STATEMENT

This shift in IoT technology add radios and intelligence to everyday things has poses a pressing challenge for the community to not undo prior efforts in standby energy reductions in buildings. To show the challenges in standby power, we provide an analysis of commercial IoT devices, explain the difference from traditional non-smart devices, and identify four primary emerging challenges.

1.1 The Standby Power Gap

We analyzed two aspects of this problem:

1.1.1 Standby Power Adds Up. Smart lighting is a popular IoT device with many products. we compare the standby energy used by Philips Hue (off mode) to leaving existing lighting types on, using the fact that average households have 67 light bulbs [2], as shown in Figure 1. A smart home with all smart bulbs consumes the same energy per day as leaving three 60 W equivalent LED bulbs on continuously. This indicates that using smart devices does can result in more energy consumption compared to legacy devices.

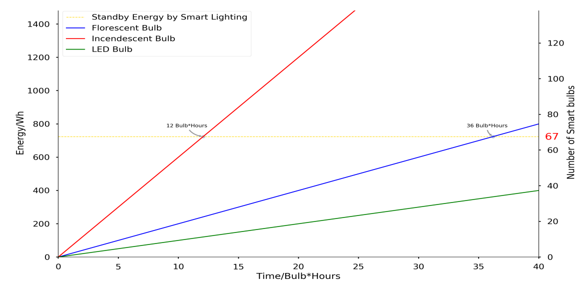

Figure 1: Standby energy of smart lighting (off mode) compared with waste energy of leaving common lighting on. Daily standby energy in average households is equal to leaving incandescent, florescent or LED bulbs on for 12, 36 or 72 hours, respectively.

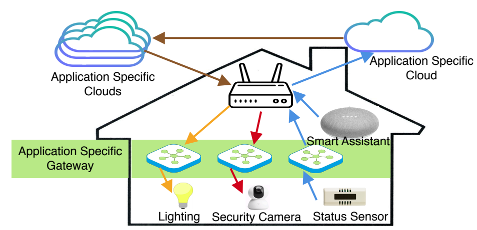

Figure 2: The gateway problem for smart devices. Difference in vendor silos and application layer made it impossible for new devices to join existing networks.

1.1.2 Commercial Devices Lag Best Practices. The broader research community has made significant progress on creating very low power wireless IoT devices. However, current products on the market are not exploiting the results from cutting-edge research. We study the standby power of several common smart home devices, results show that replacing all the components with best off-the-shelf items can save the standby power on an average by 30%, with items from cutting-edge research, an average of 60% can be reached. This is indicating that current commercial devices are not leveraging the best available technology.

1.2 Gateway Redundancy

Many IoT devices require a gateway to bridge the low-power radios used by wireless nodes to existing networks. Both wall-powered and battery-powered devices use gateways, new devices from different manufacturers often can't join the home network through existing gateways even when using the same radio, due to vendor silos and application layer differences, as shown in Figure 2. If vendored silos remain the norm, energy waste due to redundant gateways will continue to grow as users adopt more smart home systems.

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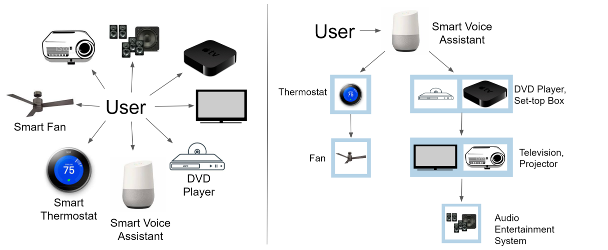

Figure 3: The network of smart devices under different users. Logically grouping smart devices is a major challenge, as different users have different usage patterns.

Project	User Presence	Usage Prediction	Control Energy	Smart Devices
BuildSys'18 [6]	✓		✓	
IEEE SMC'13 [7]	✓	✓		
Energy Build'13 [4]		✓		
IEEE PerCom'16 [8]	✓	✓		
UCAmI'14 [10]		✓		✓

Table 1: Existing home energy management systems focus on different aspects, with very few targeting on smart devices. More advanced management systems considering all aspects are required to optimize power savings.

1.3 Network of Devices

Prior work has shown that it is beneficial to look at appliances from a network perspective [5], where devices frequently used together are controlled as a group. Commercial products like Currant [3] are still providing energy saving on a per device level, due to the lack of ability to group devices. Research community has presented a more advanced method to group devices by tasks [8], however, this system lacks the feasibility to work on different devices and different rules. Logically grouping smart devices is a major challenge, as different users have different patterns to use these devices, an shown in Figure 3. New frameworks in IoT like IFTTT [1] allow users to customize relationships between devices. However, it still require manual grouping of devices, provide a new direction in future work.

1.4 Control Systems Issue

Smart devices have different operational patterns from legacy devices, as they have non-human-present updates and a continuous power draw when turned to idle/off. Several control systems to better manage the use and standby energy of loads have been presented in the last decade, and a few are shown in Table 1. Although many approaches have focused on device usage prediction, most focused on traditional non-smart devices, which lacks the evidence to show promising results in smart devices. A more advanced framework considering the new characteristics of smart devices is required to help reduce the total household standby power in smart homes.

2 PRELIMINARY IMPROVEMENTS

We design a control prototype leveraging the idea of IoT, to show that promising results can be achieved in standby power reduction. We choose a sophisticated device (Sony PlayStation 4) with multiple power modes, and where fully disconnecting it from power (as with

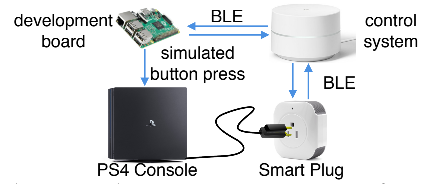

Figure 4: The control system prototype, interfaces with both device and smart plug to optimize standby energy savings.

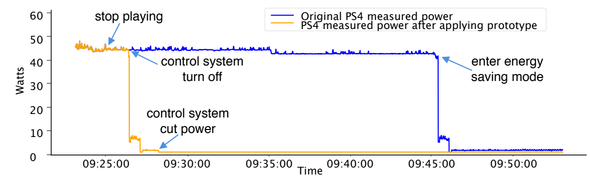

Figure 5: Comparison of energy consumption of PlayStation 4 with and without external control. The energy consumed after a user finished playing is reduced by 14 Wh.

a smart plug) can result in significant disruption for users as well as reliability issues for the device itself. A smart plug attached to the PS4 measures its power draw and control the power of the device, a development board is attached to PS4 to simulate external button presses, as shown in Figure 4. The control system aims to eliminate the high-power state before turning off the device, and is deployed on a gateway using a unified resource description architecture [9].

2.1 Results and Discussion

Figure 5 demonstrates the power draw of two comparison experiments where same user finished playing PS4 and leave it in home screen. In our prototype, standby energy is reduced by 14 Wh in turning off period, which equals to the energy draw of leaving PS4 in its lowest power saving mode for 24 hours, indicating huge potential in standby energy reduction by leveraging IoT technologies.

Future research directions includes designing a more advanced system using customized low-power smart plug with logic grouping and device pattern prediction to optimize standby energy savings in smart homes.

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