Resource Management for Smart Services in the Home

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Abstract

Advances in network technology and consumer electronics have brought the dream of an intelligent home a step closer to reality. Currently, the most common approach to introduce intelligence in a home is by using commercially available home automation systems. However, these automation systems have many disadvantages. A non-exhaustive list of these disadvantages includes the following: home automation systems are platforms that are closed or tightly controlled by a single vendor, have severely limited interoperability and extensibility in terms of supported devices and services, offer limited or no third party services and finally the degree of sophistication of the services that these automation systems bring to the table is relatively low. These disadvantages thus lower the value proposition of home automation.

To address the above limitations of home automation and realize the dream of a truly intelligent home, the idea of middleware platforms, collectively known as “home service platforms”, was pursued by the research community. These middleware platforms address the problems of traditional home automation systems by following a layered design approach. In a home service platform, the intelligent decision making process is decoupled from the actual hardware and devices, and it is delegated to software programs called “smart services”. In turn, these smart services can access any device that is present in the home through a well defined Application Programming Interface (API) that is offered by the home service platform, leading to services of far greater sophistication. This clean separation of devices and application logic with the use of a middleware platform also addresses interoperability issues, and new services may be introduced at will, making such middleware platforms very extensible.

The design of home service platforms enables uninhibited device access to smart services. In contrast to home automation systems that are closed by nature and tightly controlled, this design now raises the possibility for conflicts among services over the use and operation of devices. If such conflicts are not addressed, they will negatively impact the user’s experience, and the illusion of the smart home will dissolve.

The topic of this research is to address conflicts among smart services by introducing resource management as part of the home service platform. Through resource management, the author argues that conflicts among services can be resolved adequately with minimum impact on the user’s overall experience. Other contemporary home service platforms tend to have limited capabilities for addressing conflicts or outright ignore this problem.

In regards to conflicts among services over resources, two types of conflicts have been identified:

• conflicts over devices,
• conflicts over physical properties of space.

The first type of conflict occurs when two or more services try to operate the same device in

contradictory fashion over an overlapping period of time. A typical example would be the operation of an illumination device by two services, with one service trying to turn a light on and the second trying to turn it off; if the middleware platform does not intervene, the outcome of the above operations is time dependent. Furthermore, if device status feedback is available, the above scenario can lead to rapid blinking of the light.

The proposed home service platform addresses conflicts over devices by treating devices as resources, the access to which is managed by the platform itself. The problem of resource management in the home is similar to the resource management in computer operating systems, a source of inspiration for this research. To manage access to devices, the proposed platform introduces four design primitives that are readily usable by smart services:

- device access rights,
- service and user priorities,
- event notification mechanism,
- condition sets.

Using these primitives, the design of resilient services which exhibit well- defined behaviour in case of device conflicts is simplified. Exclusionary access to a device becomes explicit and services have a chance to gracefully recover in cases of conflicts. The effectiveness of these primitives is demonstrated through a set of several scenarios.

The second type of conflict (conflicts over physical properties of space) occurs when two or more smart services operate devices that have conflicting effects on the home environment. For example, the operation of a heater and an air condition unit at the same time is not only self-defeating but also a waste of electric power.

To address conflicts over physical properties, the proposed system man- ages physical properties of space as environmental resources and provides a high-level API to interact with them. Using this powerful API, a smart ser- vice may make requests such as “set the temperature of the room to 25° C” or “set the illumination around the user to 300 lx”, thus further simplifying the development of smart services.

The proposed system is now able to not only detect such conflicts (using the notion of “Area of Effect”) but also attempt conflict resolution, using either a space-based or intensity-based resolution scheme. To find a solution to such conflicts, the platform must decide on a set of device settings that can at least partially fulfill the conflicting environmental requests. As the number of devices and possible device settings increases, the search space becomes increasingly vast and an exhaustive search is prohibitive. The proposed system thus utilizes local and global search algorithms as well as simulation of physical properties in each iteration step to evaluate possible solutions. The effectiveness of this approach is demonstrated over several experiments regarding illumination in which conflicting requests were made. The experiments were performed in a real smart home environment and the difference between estimated and actually measured illumination intensity formed the basis for evaluating these solutions. Furthermore, the system was evaluated in terms of performance. As conclusion, the proposed home service platform is able to produce high quality solutions within a tight execution time frame of 1 second.

The final key piece of information necessary to perform conflict resolution is user location information. Currently, in contrast to outdoor location systems where GPS is the defacto standard, there is no such standard for indoor location. A multitude of indoor location systems exist with different advantages and disadvantages. For the purpose of this research, a user location information

system based on passive infrared sensors and space subdivision was developed. This location system is non-intrusive, relatively low cost and can be replicated with off-the-self parts, while providing location information that is accurate to within 50cm.

Overall, this research led to the development of a home service platform that advances the state of the art of smart homes. The proposed platform offers compelling features and advanced functionality, while at the same time making smart service development simpler and more robust. By addressing conflicts among services adequately, the last technical obstacle towards mass adoption of home service platforms by consumers has been cleared. Any future home service platform that fails to offer functionality that is at least equivalent to that of the proposed platform will face obsolescence.

Keywords. Smart Home, Home Service Platform, Pervasive Computing, Resource Management, Conflict Resolution