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Area of effect and compromising techniques for the detection and resolution of environmental conflicts between services in the Home Network System

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In this research we deal with the problem of service conflicts in the home network system (hereby referred to as HNS). Conflicts arise due to the competition for resources among the services. We propose two methods for the detection of conflicts based on information regarding the "Area of Effect" of those services and the use of compromising techniques for the resolution of a subset of these conflicts know as "environmental conflicts". To demonstrate the above ideas, we created a centralised resource management system, capable of performing conflict detection and resolution in the HNS using the above ideas.

Recently, networking technology is widely being deployed inside houses, allowing devices to communicate and share resources. There has been steady progress in the field of communication protocols and standardization and this has resulted in many protocols and technologies (Bluetooth, UPnP, DLNA, Echonet, others) that allow devices to interoperate.

Having solved the problem of interoperability for devices, the next step is to offer services to the home environment from an external service provider. The home is expected to become a standardized service deployment platform and services running on top of it will be able to harness its resources.

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Such a service platform is described by the Service Intermediary model. The characteristics of the environment (such as temperature, humidity, illumination and sound/noise levels) are also treated as resources.

There are two possible types of service conflicts in the service deployment environment described above:

- device conflicts, where services send conflicting requests towards the same device,
- environmental conflicts, where services operate devices that have conflicting effects on the environment (e.g. operating a heater and an air condition unit at the same time).

The algorithms that have been proposed so far for the conflict resolution involve *suspending at least one of the conflicting services in order to allow the remaining services run successfully.* While this is mostly true for device conflicts, we argue that in the case of environmental conflicts it may be possible to *avoid suspending a conflicting service and still having these services run with relative success.*

To be able to do so, we propose a centralized resource management system for the environmental properties which can be integrated in the deployment platform. This system has complete control over the devices that can affect the environment and it is tasked to fulfil the requests of services regarding the four environmental properties (illumination, temperature, humidity, sound/noise levels), acting as an abstraction layer between the services and the devices. The proposed system provides a service application programming interface (API) so that services can make requests for resources as well as an internal device API to control the devices in the HNS in a unified manner.

The system uses information regarding the "Area of Effect" (AoE)of services and devices as well as compromising techniques to detect and resolve conflicts between services. We defined the AoE of a service (or a device) as the physical space for which the effect of that service (or device) lies between upper and lower intensity bounds that we are interested in. The system uses limited physics simulation to predict the effects and make estimation about AoEs.

Using this information, the system is able to detect conflicts by discovering overlapping AoEs. We take a two step approach: one *per-device* conflict detection step where the conflict is discovered by conflicting settings applied on a device inside the intended AoE and and a second step based on *estimations of overlapping AoEs of devices outside the originally intended scope.*

Regarding conflict resolution, we propose two main categories of compromising algorithms: space-based and intensity-based. Both of these types of algorithms do not require the suspension of any conflicting service.

Space-based compromising algorithms try to limit the AoEs of the conflicting algorithms. These algorithms strive to impose the requested intensity around the *anchor point* of a service. The anchor point is the epicentre of execution of the service and the point which the service is most interested in. These algorithms are effective when there is a large number of conflicting devices and their *locality* is good (i.e. the effects of the service tend to weaken sharply as the distance from the source increases).

Intensity-based compromising algorithms try to choose an *intermediate setting* for devices such that all conflicting services can be satisfied to the maximum possible degree. These algorithms are effective when there is a small number of devices that may also have bad locality.

The above algorithms search the solution space (possible combinations of settings for devices) so that the requests of the services are fulfilled as best as possible. We identified the problem as being an *optimization* problem and proceeded to examine various optimization techniques and their applicability. The implemented algorithms in this prototype system can be said to be variations of local search algorithms combined with evaluation mechanics borrowed heavily from constraint programming.

Two space based algorithms ("greedy" and "forfeit rights") and one intensity based algorithm ("range search") were implemented. Various combinations of conflict detection and conflict resolution techniques were tested in a total of three experiments (scenarios for illumination, temperature and sound/noise levels).

We argue that the use of the prototype system is a significant improvement over the alternatives: suspending a service, or suffering from non-deterministic or erratic behaviour of devices. Finally we believe that the proposed system augments the SI model and there is potential value in a combined system.