Poster Abstract: Delivering Intelligent Home Energy Management with Autonomous Agents

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***Abstract*—This poster discusses the design and implementation of the decision making/reasoning infrastructure of an intelligent home energy management system that was developed as part of the Autonomic Home Area Network Infrastructure (AUTHENTIC) Project. Specifically, the poster focuses on the Agent Factory Micro Edition (AFME) functionality that enables the Home Area Network (HAN) to be managed for two home energy management scenarios representative of this space. The energy management system was tested and deployed in both laboratory and real home settings.**

I. Intelligent Home Energy Management

In this poster, the decision making infrastructure of an intelligent home energy management system that was developed using Agent Factory Micro Edition (AFME) [2] is discussed. To drive the development of the home energy management system, two use cases were considered and tested in rooms within the Tyndall National Institute, University College Cork and a real home. The rooms were equipped with temperature, light, contact, and PIR sensors along with pressure mats, which were placed on seats.

In the first use case, when the occupant enters the room, their presence is detected and light levels are adjusted to their preferred settings. If the temperature is below a point specified by the occupant, the air heater is switched on. If the temperature is too high, a message is displayed on the occupant's tablet device to indicate that the room is being cooled. When the occupant sits down in front of the TV, chair occupancy is detected by a pressure mat. The light level is then adjusted and the TV is switched on through the use of a smart plug. When the occupant leaves the chair, light levels are switched back and a warning message is displayed on the TV for a manual switch off. When the occupant leaves the room, both the air heater and light are switched off. At any stage, if the window is opened, it is detected by a contact sensor and a message is displayed on the occupant's tablet.

In the second use case, a weather event is simulated through the use of a Waspmote that can detect water. When the event is detected, a message is displayed on the occupant's tablet and the water heater is turned on, which is simulated by turning the kettle on through, again the use of a smart plug. The idea is that the system should adapt to occupant behaviour – heating water for a shower when the occupant is on their way home from work and it is raining for instance. When the water reaches the occupant's preferred temperature, availability is shown to the occupant on the tablet. If the water is not used within a certain time period, an alert message is displayed. If water is repeatedly wasted, the occupant is asked to change their heating schedule. Subsequently, an energy and cost report is displayed on the occupant's tablet.

The reasoning/decision making module to realise the use cases has been implemented with AFME. AFME is a minimized footprint intelligent agent platform for the rapid development of Multi-Agent Systems. It is based on the Agent Factory development framework [1], but designed for use with the Java Micro Edition (JME) Constrained Limited Device Configuration (CLDC). Although primarily intended for highly constrained devices, applications developed for JME CLDC can also be used on desktop and server machines.

AFME is concerned with the development of computationally reflective agents. Computational reflection is a technique that enables a system to maintain meta-information about itself (an agent's belief set) and to use this information to determine its behaviour. The behaviour of agents in AFME is represented using declarative antecedent-consequence rules, referred to as commitment rules, that determine the conditions under which commitments are adopted and actions are performed. To facilitate this, the conditions are matched against the agents' belief sets at periodic intervals using resolution-based reasoning. Resolution-based reasoning is the goal-based querying mechanism that is employed within Prolog interpreters. The reasoning process results in either failure or in a set of bindings being identified that cause commitment rules to be evaluated as true, leading to a number of commitments being adopted and actions being performed.

The AUTHENTIC Reasoning Module comprises a set of agents, a set of software actuators, a set of perceptors, and the AUTHENTIC Service. The AUTHENTIC Service is a class that enables agents to interact with SIXTH, which is a Java-based middleware for the Sensor Web [3] that allows sensor-driven applications to be abstracted from the sensors they depend on. It provides a unified interface that enables a variety of sensor types to be integrated along with a standardised way for interacting with them. SIXTH allows the behaviour of sensors and physical actuators to be altered through the use of a re-tasking service. It is a modular framework and facilitates component updates in a distributed manner and without the need for a restart. For example, if the agent code were updated by the developer and the HAN was in operation in a number

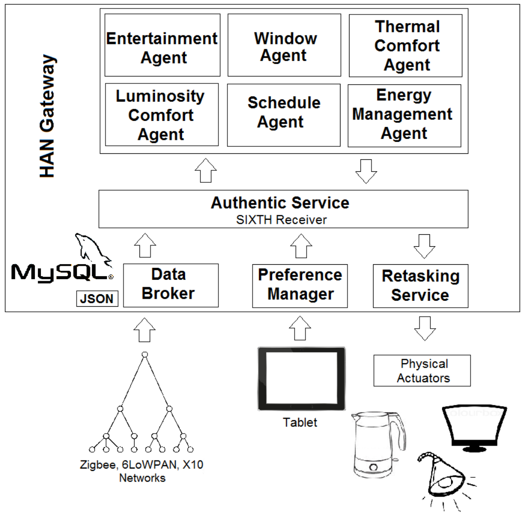

Fig. 1. Data flow within the HAN

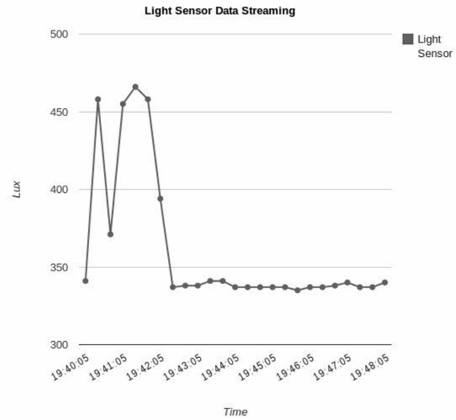

Fig. 2. Graph of streaming data from light sensor

of homes, the updated code could be deployed without having to perform on-site installations or restarts.

At present, within the AUTHENTIC Reasoning Module, there are 6 agents (see Figure 1). The Thermal Comfort Agent ensures that temperature levels in the room match the user preferences. If the temperature in the room is at a lower level than the occupant has specified, it sends a command to the HAN to turn the air heater on. Conversely, if the temperature is too high, a command is sent to cool the room. At present, this results in a cooling message being displayed to the occupant. The Luminosity Comfort Agent acts in a similar manner to the Thermal Comfort Agent, but with regard to light – changing the lighting to the appropriate levels using a lamp and a smart plug. The Window Agent informs the occupant when a window is opened by displaying a message on the tablet and the Entertainment Agent controls the application behaviour when the occupant is sitting down and watching television. This results in the light dimming in cases where the light level is high. The Energy Management Agent proactively heats water in anticipation of occupant behaviour. In cases whereby the water has been wasted, the Schedule Agent informs the occupant with an alert message. Subsequently, it requests that heating preferences be changed.

As can be seen from Figure 1, the agent-based reasoning and decision making is performed on the HAN Gateway (base station), which is an Intel Mini ATX. There are two reasons for this: (1) the HAN makes use of a pre-existing communications middleware that has been designed for sensing without regard to device actuation and (2) the types of sensors used are not Java-based and, thus, cannot host AFME agents. The communications middleware delivers messages to SIXTH in the form of JSON messages, which are converted to a standard SIXTH format and delivered to the database along with the AUTHENTIC Service, which also receives information from the Preference Manager. In relation to information coming the Data Broker, AUTHENTIC provides Google Analytics graphing functionality (see Figure 2). Perceptors, which are Java classes, are used to enable agents to obtain various type of information received by the AUTHENTIC Service. Agents make decisions with regard to this information and trigger software actuators that cause commands to be sent to physical actuators via the AUTHENTIC and re-tasking services. At present, the user must explicitly specify their preferences in terms of their desired lighting levels, heating levels, etc. Future work will investigate the use of (1) Machine Learning algorithms to enable the system to learn user preferences and needs over time in an autonomous manner and (2) in-network decision making to control devices within the HAN.

II. Conclusion

This poster presented the decision making/reasoning functionality of the AUTHENIC home energy management system. The functionality was delivered through the implementation of a group of AFME agents. The system was tested using two home energy management use cases and deployed both within laboratory and home settings. Future work will investigate the use of Machine Learning algorithms to enable the system to autonomously learn user preferences along with in-network device actuation.

Acknowledgments

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