DoNet

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Abstract. With the giant steps in technology and the massive strides in hardware, software and communication it is not in the very distant future that complete households will be entirely networked as a de facto standard. In this work we examine current research trends and illustrate our work in the area of domotics where personalization, semantics and agent technology come together. We look at the different aspects of identification, interconnectivity, virtual representation, user interfaces and context, and develop a home system oriented ontology in OWL. This ontology provides the ability to describe events, states, information, agents, items, locations, operational ECA rules, user preferences and their relations. We also propose an agent based framework and abstraction and reasoning mechanisms to permit modular and rapid development of home control and automation components. A web based interface provides suggestions, information and ontology access, while a puzzle based graphical user interface, provides simplified rule construction capabilities. The ever changing nature of the home, places the user in a position where he needs to be involved and become, through DoNet, a part of an ongoing home system optimization process.

1 Introduction

Every human being naturally thrives to improve his/her home such as to make it a better place. The home is analysed as an intersection of sociology and technology. The networked home is subdivided as two human networks, the internal household network and the external human network [2]. It is also perceived as a living space involving a social space, a physical space and a technological space. Age and location are indicated as being a determining factor for acceptance and use of different and new technologies. It is also clear that the current direction points towards progressive adoption of specific technologies rather than mass adoption. Domotics is the application software and hardware in housing applied to the areas of safety and security (ex. Alarms, surveillance etc.), comfort and self-care (ex. Light control, ventilation control, heating control, organisational aids etc.), communication (ex. Telephone systems, videophone, distant working and education etc), property control and management [4, 8, 9]. It is frequently used in relation with 'home automation', the automation of a number of manual functions which are usually performed during daily tasks at home. Its objective is to improve and enhance an individual's lifestyle through the use of a number of devices and a number of services, turning one's dwelling into an 'active participant' of one's life. A smart space is defined as an environment where a set of elements capable to sense, think, act, communicate and interact with people exist in a way which is robust, self managing and scaleable [7]. For smart spaces to be used effectively there must be handling techniques for a multitude of interacting systems and spaces themselves [1]. They must also be able to support different interfaces and be user context-aware. The mass deployment of pervasive devices within the home, our working and leisure environments will effect the perception we have on our surroundings and will have greater social, economic and political implications.

Our work originated from our commitment and interest in Personalized Information Systems being investigated and researched within the Semantic Web environment through the European Network of Excellence called REWERSE [10]. Our objective consists in the development of an effective representation and architecture focusing mainly on the elements of configurability and personalization of a domotic environment able to handle the progressive adoption of technologies within the home. In this paper we present our work and demonstrate the prototype system we developed and deployed. The rest of the paper is organized as follows. In the next section we will introduce the ontology that will be necessary to define a home system that essentially is human readable as well as computer readable. Section 3 will go through the entire DoNet framework which we propose in our work presented in this paper. The rules and reasoning involved within this network is highlighted in Section 4, while we present our conclusions in the last section.

2 Home System Ontology

To define a home system a human readable and also computable language is essential. The DoNet ontology makes use of SOUPA and SOUPA extensions [6] together with time-entry (sub-ontology of OWL-Time) and OWL-S. Its purpose is to enable multiple representations for things within the home system. The DoNet ontology provides means to describe Services, Function and their relation with ServiceManager entities. States and different type of representations for objects and locations can also be easily specified. A building, a room, an area within a room, areas in between rooms, corridors are all represented as DoNet SpatialThings. It is assumed that anything which has spatial properties can possibly hold a function and/or state, wherever it is located. Items and locations are also defined as state and function holders.

The DoNet Ontology specifies Event-Condition-Action rules, influenced by the work done by Alferes, J.J. and W. May [3]. An ECA Rule has three types of triggers:

- Event Trigger – The Event Trigger is defined as subclass of DoNet InstantEvent.
- Lack of Event Trigger – The Lack of Event describes the lack of event for a specific period of time
- Time Based Trigger – A time based trigger is a subclass of SOUPA time ontology Instant

These together with composite and language independent conditions provide a variety of rule definition options. There are also a number of other important direct and indirect relationships between general DoNet entities.

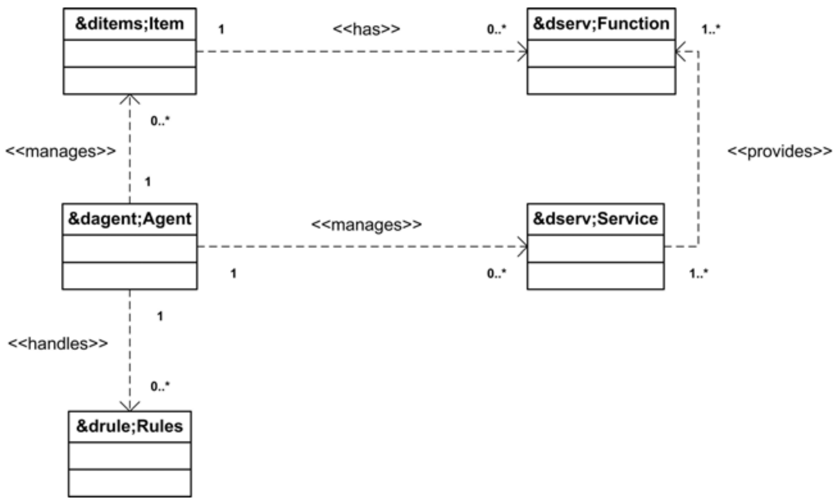

Figure 1 – Relationships between main entities

The diagram clearly shows how agents are capable of managing items and services and handling rules. Items hold functions while services provide them indirectly. The ontology also provides means to define users and their preferences in relation to functions.

3 DoNet Framework

A proper hardware infrastructure is an essential element for a more effective implementation of any home system. In DoNet this consisted in star network distribution CAT5E and coaxial cabling, together with standard protected power lines. The DoNet agent based software architecture is biased towards loosely coupled distributed context paradigm similar to Peer to Peer applications. Whilst still withholding to the concept of a context server described by Chen, H. [5] we extend it by enabling the non-brokering context aware agents themselves to have context interpretation and reasoning capabilities. Each agent has its own context information and can request or update common context when it considers it necessary. The advantages of this approach are that the functionality and context interpretation of the system is distributed across multiple agents which may reside on different devices with different resource capabilities. This makes it easier to have different, infrequently connected agents working autonomously in different locations ex. at the office, summer residence etc. Agents are thus capable of selectively deciding which context is private and which context is to be shared, for security purposes. Thus the context management agent need not be accessible for the system to function correctly.

There are 4 types of predefined agents in DoNet

- Central Event/Context management agent – This context management agent is an extended type of broker agent. It records and analyses events, context changes and also distributes shared context on request.
- Physical Function Agent – This type of agent handles a number of items/devices and is responsible to interact with them. It is responsible to implement the relative services which give access to these items/device functionality and representation.
- Virtual Function Agent – It provides a software realised function for the user and home system.
- A Web Application Agent – The Web Application Agent handles web interaction and is the gateway to the context for the main user interface.

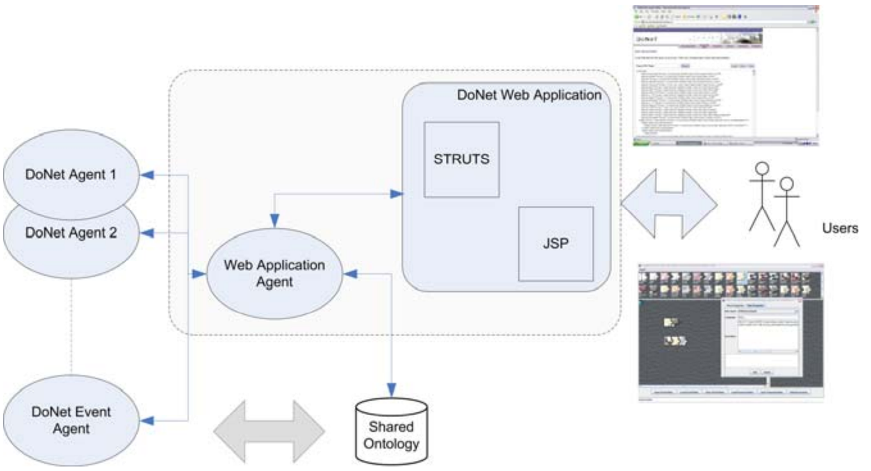

Figure 2 – General Software Overview

Making the user interface accessible from any web accessible location is of obvious advantage for a home system since one can remotely oversee and control his system. Once the user has logged in he/she has access to a number of pages including a raw ontology editor, entity pages, a suggestion page and information page.

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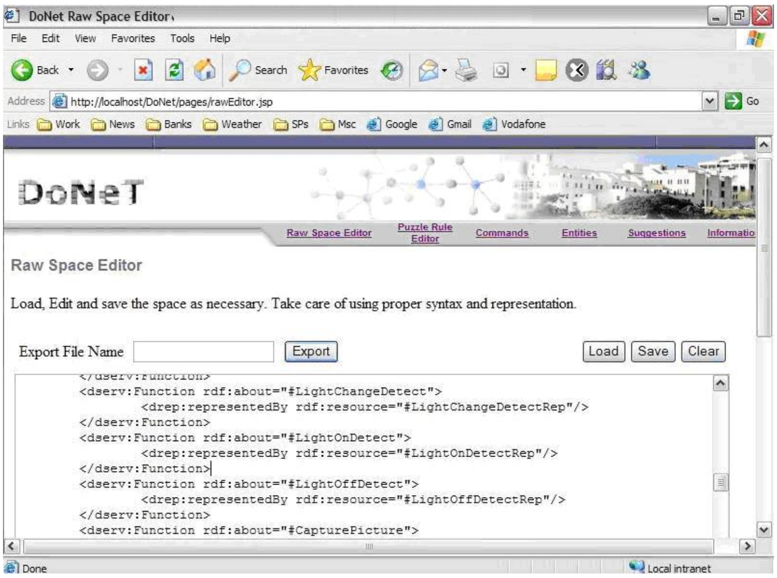

Figure 3 – The DoNet Portal

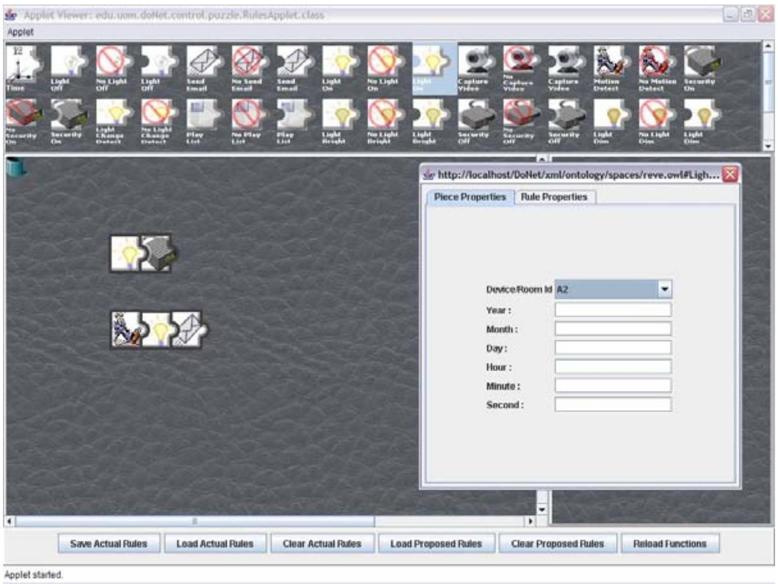

Figure 4 – Puzzle Based Rule Definitions

DoNet also provides a puzzle editor, which is a user application based on Accord's puzzle editor interface [11]. The Java Swing based interface was enhanced following the Model-View-Controller model. While a user is building the puzzle he is building intermediate rule representations, which are then persisted appropriately on command as OWL representations. Each puzzle piece has a set of properties, editable through a properties panel and frequently containing function invocation parameters. Rules can be defined both at the item level or an abstracted location level. This editor interface is sub-divided into three main areas consisting of puzzle piece choice panel, the proposed rules panel and the actual rules panel, to provide a drag and drop rule building environment.

4 Rules and Reasoning

An important and basic functionality of all DoNet agents is their ability to interpret DoNet Event Condition Action Rules (ECA rules). These rules define the reactive behaviour of the agent and each agent is responsible only for a subset of rules within the whole context. The agent preloads the rules at start up and stores them within a set of memory based data structures, to enable the immediate processing of rules when needed. When an event occurs and is detected by the agent, it searches the related triggers and performs the necessary operations and pre-defined actions.

Using the class hierarchy and a general OWL Reasoner, the system can reason about a number of relationships between locations and other entities. There are three primary relationships which are used in DoNet to define a domotic space:

- Spatial Subsumption – defined by Region Connection Calculus, permits us to reason about objects location.

- Function Propagation – A bottom up function propagation is achieved by using subsumption through which the system can deduce what functions are provided by a location. The transitive top down control relation (functionOf) indicates what item functions should be triggered when the system refers to a function for a location. Since multiple devices within the same room may provide the same function, it is not always necessary or required that all the functional items be triggered.

- State Propagation – A state is propagated to a location from the items or other locations (hasStateOf) in a similar bottom up approach as in function propagation. This permits the system to deduce room states in relation to specific functions.

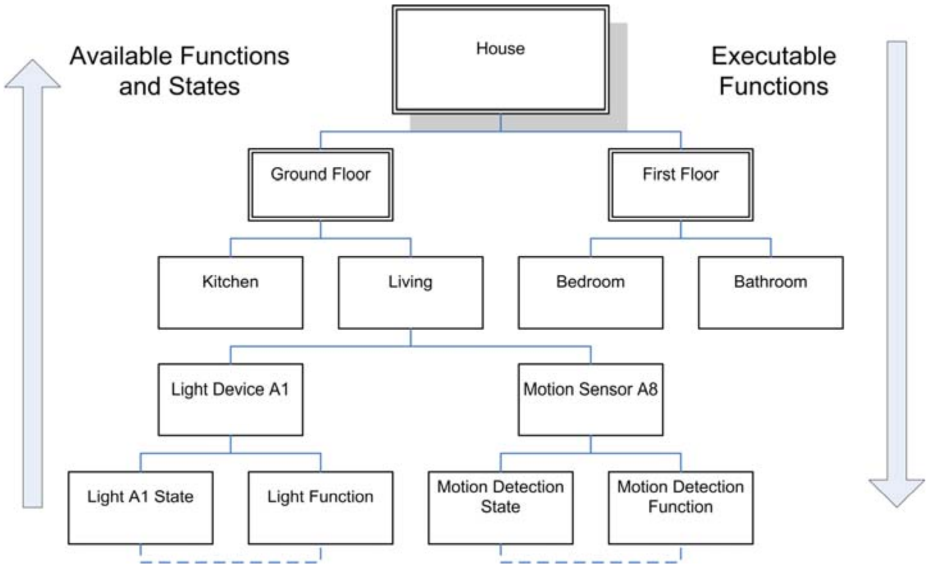

Figure 5 – DoNet location function and state flow

Backward chaining rule based reasoning mechanisms are also used in DoNet. For example energy saving suggestions are based on calculation of power consumption over time and rules to decide which items consume more/less energy than others:

```
(?item1 ditems:consumesLess ?item2) <-
  (?item1 ditems:consumptionDegree ?v),
  (?item2 ditems:consumptionDegree ?w),
  lessThan(?v,?w).

(?item1 ditems:consumesMore ?item2) <-
  (?item1 ditems:consumptionDegree ?v),
  (?item2 ditems:consumptionDegree ?w),
  greaterThan(?v,?w).
```

We also believe that using a combination of rule based and other probabilistic based approaches provide non-trivial performance and functional benefits. Thus the architecture supports the construction of modular DoNet reasoners, which can be re-used in isolation or jointly as needed by other components.

5 Conclusion

This work takes home control systems to a new level, through a loosely coupled distributed architecture with intelligent capabilities. In our opinion DoNet has a great potential in the field of ubiquitous computing at home, whether it is used for the common home user or one with special needs. Developers and users of the system are aided in the different stages of configuration, optimisation and creation of the home automation system. DoNet provides the resident users with important information to help them reduce their energy consumption, secure their space and monitor and control devices as they see fit. It provides developers with means to plug-in modules and to re-use reasoning and communication mechanisms which are not otherwise available. DoNet steps away from the common script based approaches which are found in commercial systems to a well defined semantic core, opening the door to a multitude of extension possibilities and powerful home applications.

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