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A solution for heterogeneous domotic systems integration

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Abstract
The Information and Communication technologies spread across our life to make easier our everyday tasks and to increase the quality of our existence in every domain, realizing the Pervasive Computing vision. As in other domains, also in home environments many appliances are rapidly becoming computationally enabled, equipped with different communications protocols, and therefore connected to home networks. Domotic systems, variously called "smart homes", "smart environment systems", "intelligent buildings", or "intelligent homes", can now be proposed and would go far towards simplifying the interaction between the people and their domestic environment. A great number of benefits would stem from the implementation of such systems: greater safety, autonomy and self-esteem for disabled and elderly people, energy saving, and consequently better comfort.
The problem of modern domotic systems arise often from the communication incompatibility among products of different manufacturers. The lack of a unique acknowledged standard hinders domotic diffusion. In "Domotics Lab" of Italian National Research Council was designed a general tool aimed to obtain interoperability, able to communicate with all different domotic systems and devices using different protocols.

Keywords: Building automation, Domotics, Home automation, Interoperability, Open standards

INTRODUCTION

Current concept of domotics is based on devices and applications integration obtained with Ambient Intelligence, communication, home networks, etc. Many companies are now producing domotic systems aiming to realize intelligent home environments, automating some particular sequences of tasks and integrating the home with the outside world, especially with the Internet.
However, home appliances and devices belonging to different systems today are completely isolated from each other, creating the main obstacle to the domotic market growth. Without an universal standard also the cost of he software and of the devices can't decrease as they must be differentiated for different protocols and middlewares. For example, there are middleware such as UPnP [11], Jini [12], and HAVi [13] for connecting audio and video devices while protocols such as Konnex [14], LonWorks[5], or X10 [6] are suitable for appliances for security and home automation. Those middlewares are incompatible each other but, as each one is optimized for a set of requirements, and often we need to have the advantage of more the one of those middleware.

This presentation describes a service-oriented solution framework designed for home environments. A pragmatic approach is developed to help integrate conventional home automation systems following the service oriented computing paradigm. We believe it is improbable that there will be a single dominant middleware for the home computing that would be right for different appliances. A number of middlewares [4] [8] [9] [10] [3] have recently emerged and it is common knowledge that they haven't a sufficient degree of interoperability. Because of this, the authors show how the approach based on XML, Web Services, and Internet protocols, provide a uniform and novel architecture to cope with the architecture complexity in a open standard way. Furthermore a converging layer is conceived to incorporate a high level abstraction by an XML-based home automation language.

The state of art

Many new technologies for communication (Zigbee, IrDA, Bluetooth, Wi_FI, etc.) are now available and the industry use them in many popular applications such as mobile telephone, GPS navigators. The wide involvement of significant

user groups and associations, industrial partners, universities and research institutes, will have the demonstration functions that can support a wider use.
Besides the standardisation effort put in the sector, a lack of standardisation is still affecting the market, particularly in the field of intelligent user interface with a clearly defined architecture able to manage data, as a basis for all particular home interfaces []. This has led some producers to try to reduce costs basing their interfaces on computer solutions, and others to follow more advanced and more expensive proprietary development. Touch-screen and voice modules tend to become standard interface media, but with very different software-hardware requirements and based on different dialogue interaction techniques. Other I/O elements are only considered for very specific users applications, without attempting their possible connection to a standard interface base, identifying benefits in using some of them for all users.

Home automation

As for home automation, compared to a varied landscape architecture and protocols interoperable promulgated by various industry associations (Havi, HPA, Jini, OSGi), some years have begun to establish open standards (eg Konnex and UPnP). They have a good level of maturity, but the truth is that there is a significant lack of interoperability between systems: this condition will favor innovative solutions for seamless integration.
In such technologies the technical device descriptions are published so any company can decide to develop compliant devices. In general these systems are proposed by associations or consortia of large companies (sometimes corporations) who, using their skills, create real references market. The advantages of these systems are reliability, scalability and the possibility of choice between multiple devices manufacturers belonging the particular standard.
Another classification criterion concerning their architecture (ie the way in which they are connected and controlled the devices) and the location of "decision-making capacity" of the system. It can be identified three types of architectures:

- centralized architecture
- distributed architecture
- mixed architecture

Centralized architecture consist on only one unit of decision (typically a controller) which may be split into several smart units, can have different hierarchical levels and sometimes can be physically distributed with a master/slave configuration. Distributed devices can be equipped with its own capacity for self-diagnosis but they aren't capable to make decisions, delegating this function to the controller.
In this type of architecture the weakness of the system is the central unit that in case of failure, could make the whole system unusable.
However, within distributed architecture all devices are intelligent and are able to perform a variety of functions in complete independence. Each component is firstly configured with a unique address (to be identified in the network) and then programmed to execute commands and perform specific functions. In this type of architecture, devices talk to each other through a messaging standard that can create links (associations) between logical components without limits.
The advantages of this architecture are the great flexibility, the reliability (if a device is broken it will lose its functions but the rest of the system continues to work) and the performance. The disadvantage are higher costs and greater programming complexity.
In the mixed architecture there is a main building wiring like the distributed architecture that it is connected through a number of units located in the building.
There are also systems that use existing electrical systems to communicate with each other (powerline) and there are more popular other systems that use radio wireless technology.
Finally, the integration of new generation of sensors and actuators with modern domotic technologies allow to simplify the electrical plants adding important potentialities.
The home automation technology in fact allows with simple devices the following advantages:

- Comfort (Wellness)
- Security, intended as "safety" or as "security"
- Increased independence (for elderly and disabled people)
- Energy saving
- Entertainment
- Remote Control
- Access to external services

These services are based on hardware and software infrastructures commonly called domotic systems, such as X10, Konnex, LonWorks, UPnP, HAVi, Jini, etc.; each one of them supports the main available communication standards (Ethernet,

FireWire, Bluetooth, ZigBee, IrDA, proprietary buses, etc.).
These systems are often promoted by private companies, either single or consortiated and, therefore, distributed as proprietary and closed technologies.
Currently, too many domotic systems are crowding the market, and they are rarely interoperable: these facts represent the main obstacle to a solid market growth. Consumers should be given the possibility to choose their devices accordingly to typical criteria (such as cost, performance, trend, confidence, etc…) without having to worry about compatibility issues with their already installed home systems.
Today, common market logic is to tie the consumer forcing him to purchase only devices that are conforming to a single system in order to keep a suitable level of interoperability.

DOMONET

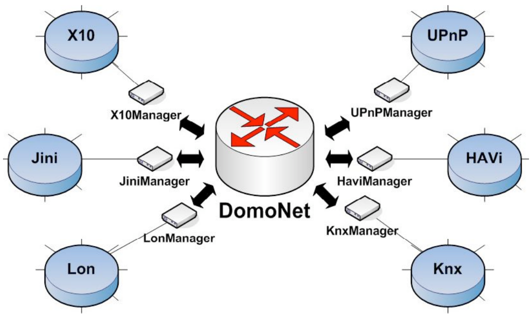

Figure 1; Domonet structure

In order to solve the interoperability problem the

Domotics Lab of Italian National research council has produced DomoNet: home network and protocols for automation and domotics currently provide a dispersive range of closed systems, which are rarely interoperable with each other.
This new infrastructure, called Domotics Network (DomoNet), is based on a Service Oriented Architecture (SOA) model, in which the services coincide with the functionalities offered by devices. DomoNet uses Web Services technology, a standard communication paradigm in distributed SOA contexts. Moreover, Domonet defines, through the use of XML and XML-Schemas, a possible standard language to describe datatypes, messages, devices and their services. This language, called DomoML, is used in every communication inside DomoNet.
The prototype developed at ISTI - CNR (Italian National Research Council) Domotics Laboratory in Pisa is an open source software released under GPL licence. It was written using Java language and open source libraries and tools.
The DomoNet consists of a network connecting application gateways called TechManagers, TMs, (one for each middleware we want to interconnect) and Web Services, each one handling a different device typology. In Figure 1 we show an example of a home network connecting six domotic subnets (each subnet represents a particular domotic technology, such as UPnP, Jini, Konnex and X10) to some Web services (handling lighting devices, clocks and alarms) through the use of four TMs. This modular structure is there to ensure that a progressive development may be undergone to include more protocols in the future, inside the interoperability framework. As figure 1 depicts, domoNet can be seen as a central network infrastructure and each domotic system represents a sub-network connected through a proper gateway techManager.
It should be noted that these technology choices are enabling factors for remote control, along with interoperability. The web service at the core of our infrastructure, called domoNetWS, is, in fact, a real Internet node designed to share environments and services in a distributed fashion with any other domoNetWS regardless of its location.
Our objectives were:

- to create a modular engine capable of managing entire domotic systems without introducing specific drivers for specific device typologies,
- to automate the configuration process by providing an environment to refine it and set the behaviours of devices in the home environment;
- to make the system scalable both by introducing different techManagers for each technology, and by allowing the distribution to remote locations of several domoNetWSs on the Internet.

At the core of the framework there is domoNetWS, a WebServices-based engine whose task is to create a real cooperation between nodes. It constructs a unique view of the system including all the devices belonging to all the different technologies available throughout the system.

When the state of a generic device xDevice (where x represents a generic technology) is modified, an event is generated, and then subsequently captured, through a techMessage, by the xManager. The xManager translates the techMessage into a domoMessage, converting all possible data into the intermediate format supported by domoML. The xManager is now able to route all the information related to this event to the domoNetWS through the searchExecLinkedSer method. By analyzing the xDevice description, domoNetWS can identify the service associated with the captured event, and all the information required in order to create the related domoMessage and route it to the right techManager. Its execution is then requested, and data is converted from the intermediate domoNet format into the target one, belonging to the underlying subnetwork. The yManager then interacts with yDevice with the final techMessage.

DOMOML

Through the use of XML and XML-Schemas we defined a possible standard to describe datatypes, messages, devices and their services. We use this language, called DomoML, in the communications between TMs and DeviceWS.
DomoML defines the specifications for future standardization processes regarding domotic devices, their communication models and their functionalities. Through domoML, data type models are also standardized, providing a suitable intermediate representation, from and to which to convert outbound and inbound values, in order to enable data marshalling among heterogeneous technologies. DomoML is also aimed at formalizing abstract communication messages expected within domoNet and between domoNet abstract devices.

Prototype validation

The prototype has been tested and is currently under further development at Domotics Lab and it's currently mature enough to correctly import every available devices like interrupts, televisions, washing machines and light bulbs and interact with them regardless of the specific domotic system they belong to.
To test the software's functionalities we have chosen three very different domotic systems with different functionalities and surely not interoperable between one another: Konnex, UPnP and MyHome (BTicino). They have two fundamental differences:

- the ability to configure their devices (in the first one this must be done by specialized persons, systems and software, and the second one has an automatic plug and play auto-configuration system)
    - the functions of their devices (Konnex and MyHome are more oriented to lighting, energy saving, safety and comfort, UPnP is more oriented to multimedia applications).

Fig. 2: DomoNet prototype under construction

Many works based on this project were or will be launched. The main current and most important project concerns defining an XML language able to give semantic to domoNet [1] in order to increase the usability of this layer of abstraction. A starting project about this work is the development of an auto-configurable universal remote control with a real user friendly interface capable of being easily interacted by elderly and disabled people.

Figure 3: DomoNet prototype

The next important step is to enhance the system's robustness, in fact the current system has not yet been tested with a large number of devices. A more solid approach regarding information storage (device descriptions, mapping tables, etc.), currently realized by means of simple file dumping, could make use of a relational db.

Another crucial enhancement will involve setting up a really user-friendly interface system, supporting dynamic interface adaptability and reconfiguration. This will be done through the development of a universal remote control, which can also be interacted with by elderly and disabled people. By interacting with domoNet, this remote control, will be able to operate all devices available in the home environment and belonging to any domotic protocol, and will be made so that it will automatically adapt to several different platforms.

This is the right moment to clearly establish the needs for the elderly regarding the management of devices in the home environment and the access to information, pushing the market in the right direction and contributing to create the critical mass across Europe.

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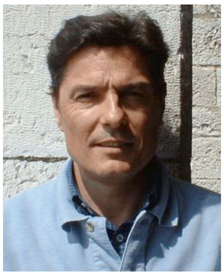
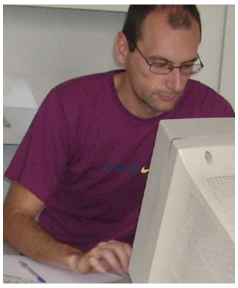


Vittorio Miori is the director of Domotics research Laboratory of the Information Science and Technologies Institute (ISTI) of the Italian National Research Council, since 2008.
His research areas includes pervasive computing, ambient intelligence, e-gov and information systems. He has a degree in Political Science from the University of Florence and a Master Degree in Internet Technologies from the Engineering Department of University of Pisa in Italy. He is the project leader of important national and international research projects and his present interests comprises e-democracy, context-aware middlewares and intelligent agents technologies areas with special attention at elderly and disable people needs.

Rolando Bianchi Bandinelli - received his Laurea Degree in Computer Science from the University of Pisa (Italy). Since 1971 he has been working at Italian National Research Council (CNR in Pisa, currently at ISTI). Since 2002 he is Professor of the "Domotics" course at the University of Pisa. From 2002–Founder, and Head till 2007, of the Domotics Lab at the Institute of Science and Technologies of Information -. Inside the laboratory the research on home automation and interoperability was developed. Several education activities where supported for people interested in domotics and housing. He has leaded many national and international projects and was head of many CNR's divisions such as "The computer capacity management and performance evaluation division", “Statistic Group”, “Gaid Group”, Etc..



Dario Russo joined the Information Science and Technologies Institute (ISTI) of the Italian National Research Council (CNR) in 2006. He has a degree in Computer Science from the University of Pisa. Today he is a member of the ISTI Domotics Lab research staff and he takes part of national and international research projects particularly applied to home-network technologies and e-gov. His current interests include the area of domotics, interoperability, ambient intelligence, ontologies and e-government.