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TeleCARE: Collaborative Virtual Elderly Care Support Communities

*Luis Camarinha-Matos, Hamideh Afsarmanesh**

New University of Lisbon/Uninova, Quinta da Torre, Portugal and * University of Amsterdam, Kruislaan, The Netherlands.

ABSTRACT

The growth in the elderly population imposes an urgent need to develop new approaches to care provision. Integration of a number of technologies such as multi-agent systems, federated information management, safe communications, hypermedia interfaces, rich sensorial environments and increased intelligence in home appliances represents an important enabling factor for the design and development of virtual elderly support community environments. In this paper, a platform based on mobile agents combined with federated information management mechanisms is introduced as a flexible infrastructure on top of which specialised care services are built.

INTRODUCTION

One of the key challenges facing modern societies is the increasing speed at which the population is aging[1]. In Europe, for example, during the last three decades the number of people aged 60 years or more has risen by about 50%. This inevitably places a considerable strain on resources and finances. To deal with this challenge, new ways of providing elderly assistance and care must be found, including the creation of a new technological infrastructure.

Although a new technological infrastructure will not be the solution to all problems, it will play a fundamental role in the creation of a new concept of an integrated elderly care system. This system will consist of a number of organisations such as care centres, day centres, healthcare institutions and social security institutions acting in cooperation with relevant personnel, e.g. healthcare professionals, social care assistants, elderly people and their relatives. When based on computer networks and adequate supporting tools, collaboration among care institutions may evolve towards operating as a long-term virtual

Correspondence and reprint requests: Professor Luis M. Camarinha-Matos, New University of Lisbon/Uninova, Quinta da Torre, 2829-516 Monte Caparica, Portugal. E-mail: cam@uninova.pt.

organisation and the various involved humans will become part of a virtual community (VC).

The potential for technological solutions to increase care services and reduce costs has been demonstrated by various research projects. One example is 'social alarm' systems[2], developed for people living in remote and hard-to-access areas. Such systems comprise a portable alarm trigger and an alarm telephone that dials a social alarm control centre in the event of an emergency. More recent work has focused on mobile social alarm systems and online monitoring systems based on electronic sensors and other devices. To enhance applicability and ease of use, recent projects have focused on the development of smart home appliances and specialised user interfaces[3,4]. Advances in computer networks and ubiquitous computing offer not only the opportunity for more advanced care approaches including comprehensive status monitoring and other forms of assistance such as agenda reminders, but also the creation of the opportunity for the elderly to become involved in the community and thus reduce their feelings of loneliness.

To enable elderly people to stay at home and live an independent, active lifestyle, new support services are necessary. These are particularly required to address the following problems:

- **Loneliness.** This is one of the most serious problems affecting the elderly population. The development of applications to enrich an elderly person's social life and to avoid the problem of loneliness is of great importance. Fieldwork data show that today the elderly hardly participate in activities relating with others and 16% of them express dissatisfaction with their social lives[5]. According to family members, 28% of the elderly have little or no contact with other people.
- **Interconnection between the homes of the elderly and the homes or workplaces of family members caring for them**. Such a connection is important to provide access to loved ones. According to a survey carried out with relatives caring for an elderly person, 31% of them stated the need to be in contact with the elderly person (currently done either by phone or personal visits) at times when they are alone[5].
- **Interconnections to entities dedicated to providing different services for the elderly**. Connections to care centres, social centres, and social services, will also bring potential benefits to the elderly. It will reduce their loneliness and make it easier and quicker for them to obtain help and advice. The connection is also likely to benefit healthcare workers. By enabling continuous contact with the elderly person, without the need for being physically present, it is likely to reduce the number of visits they have to make to the elderly.

To achieve these objectives, the TeleCARE project[6–8] has aimed to design and develop a configurable framework focused on virtual communities for elderly support. The proposed solution is seen as complementary to other initiatives for

the integration of the elderly into society and reduction of their isolation. With different organisations developing different products and services in a variety of different areas, it was felt an important consideration was the need for a common platform into which all these developments could be plugged so that interoperability was possible. The TeleCARE project proposes such a common and extendable platform as a common infrastructure.

A crucial issue when developing a system to provide care and assistance to elderly people living independent lives in their own homes is the assurance of privacy. Consequently special care must be devoted to establishing mechanisms that will protect the elderly person's privacy.

THE TELECARE PLATFORM

The TeleCARE approach for providing a technological infrastructure to enhance collaborative virtual elderly support communities is based on using the Internet and mobile agent technologies (Figure 1). The Internet, although appealing as a base infrastructure, raises some difficulties. These include:

- In application domains such as elderly care, high levels of heterogeneity are expected in the sensorial and equipment richness of the remote places (homes). This demands appropriate solutions to guarantee the necessary levels of flexibility and scalability.
- The Internet is characterised by long and variable time-delays and very often suffers from low levels of availability. This raises new challenges in

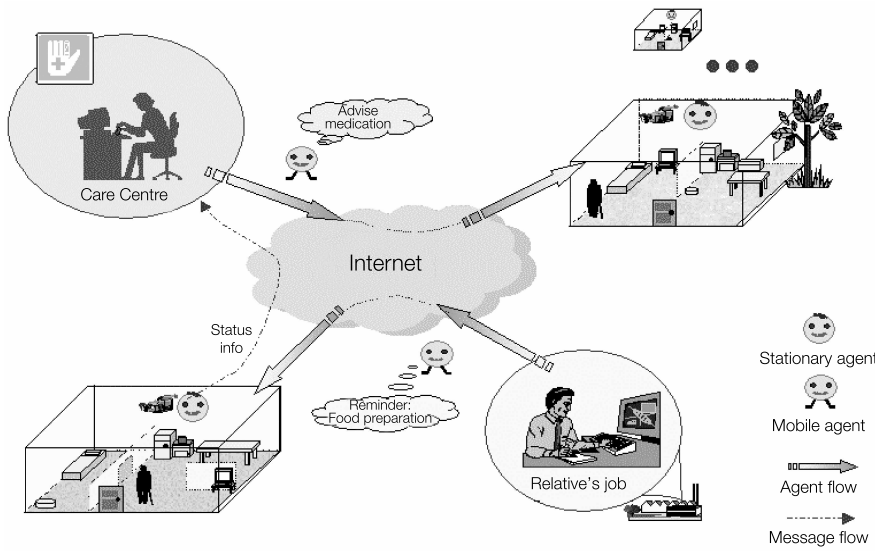

Figure 1. *The TeleCARE approach*

assuring the reliability of the implemented system and its dependence on the characteristics of the network.

- The emergence of mobile and ubiquitous computing raises the importance of wireless connections where the actual connection to the network may have to be reduced to short periods.
- The execution environments, involving legacy components, are potentially unstructured and uncertain. This means that it is difficult to cope with these environments by resorting to deterministically programmed systems.

The mobile agents paradigm offers interesting characteristics that in fact directly address several of the above issues[9]:

- Moving the code to the place where actions are required enables real-time response, autonomy and continuity of service provision with reduced dependency on network availability and delays.

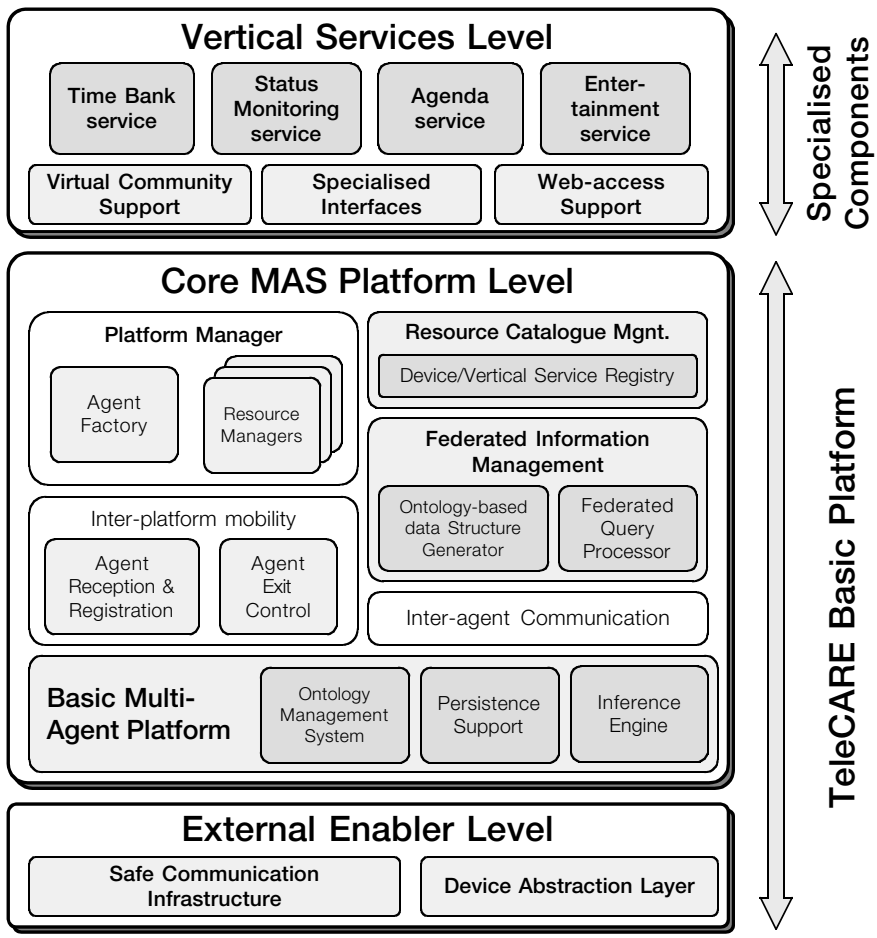

Figure 2. *The TeleCARE platform architecture*

- Since new mobile agents can be built and sent for remote execution whenever needed, higher levels of flexibility and scalability are achieved.

Figure 2 shows a block diagram of the TeleCARE infrastructure to support collaboration in the elderly care virtual organisation[8,10]. The *Basic Platform* is intended to be installed at each node of the TeleCARE network. The *Specialised Components* (vertical services) have a distributed implementation over the TeleCARE network. The three-level infrastructure comprises:

- **External Enabler Level**: This supports the communication over the network and interfacing to the external (local) devices. Specifically it includes:
  a) *A safe communications infrastructure* provides safe communications, supporting both agent mobility and inter-agent message passing. A virtual private network (VPN) approach is adopted. In critical cases where communications reliability is mandatory, redundant channels, in addition to the Internet, may be supported and hidden by this layer.
  b) *A device abstraction layer* interfaces to the sensors and monitoring devices and other hardware (home appliances, environment controllers, etc.). These interfaces represent the bridge to any 'intelligent home' or 'local domotics network', hiding aspects such as low-level protocols, wire-based or wireless communications, etc. Universal Plug and Play (UPnP) is one of the approaches adopted to interface devices[11].
- **Core Multi-Agent System (MAS) Platform Level**: This is the main component of the basic platform. It supports the creation, launching, reception (authentication and some rights verification) and execution of stationary and mobile agents as well as their interactions. It supports the storage and manipulation of data and information to be handled within TeleCARE. It provides a catalogue of all devices and services supported in TeleCARE. As intelligent agents are envisaged, an inference engine is included. Main modules in this layer are:
  a) *Basic multi-agent system (MAS) platform* (based on Aglets).
  b) *Inference engine* (based on a Prolog interpreter).
  c) *Ontology support* (based on Protégé). A facility is developed providing the basic mechanisms for dynamic schema description by TeleCARE service developers.
  d) *Persistence support* as an extension to the MAS platform to provide some basic recovery mechanisms in case one node goes down.
  e) *Inter-platform mobility* is an extension to the basic MAS platform and supports generalised mobility of agents, including security mechanisms. This module includes the *Agent Reception and Registration* component (for incoming mobile agents) and the *Agent Exit Control* component (for outgoing mobile agents).
  f) *Inter-agent communication* is another extension to the basic MAS platform and supports communication between and coordination of agents

independent of their current location, via FIPA ACL (Foundation for Intelligent Physical Agents – Agent Communication Language) messages.

g) *Platform manager* specifies and configures the operating conditions of the platform in each site. It assists in recovery from errors, monitoring the operation status, etc. It includes:
   – *An agent factory*: a module that supports the creation/specification and launching of new agents.
   – *Resource manager agents*: to provide a common and abstract way of dealing with devices and appliances in TeleCARE.

h) *Federated information management* supports the necessary management of information while preserving information privacy and careful control of access rights to local data for external users. This module, installed in each site, is the local component of the Federated Information Management Architecture (FIMA), which includes:
   – *Federated query processing* which provides the ability to retrieve information from a number of TeleCARE nodes.
   – *Federated access control* to assist with querying and providing access to the stored information.
   – *Automatic ontology-based schema generation* which generates database schemas from the ontology definitions provided by TeleCARE software developers.

i) *Resource catalogue management* to manage the catalogue of resources including support for their specification, discovery and access proxies of all devices and services available at each site.

- **Services Level**: This is the application level and consists of two sets of specialised services:

a) Base horizontal services – This is a set of specialised base services that provide specific functionality for the other (vertical) services, including the following:
   ❑ *Specialised interfaces for elderly* – Specialised interfaces are required to enable elderly people to use the system in their homes as many of them are not skilled in the use of computers. The ultimate goal is to make the usage of the system pleasant and easy, and thus the TeleCARE infrastructure 'invisible' to the elderly.
   ❑ *Virtual Community Support* – To support and facilitate the creation and operation of community-based services designed for the elderly. For this purpose, specific virtual community management functionalities are supported within the service development environment of TeleCARE.
   ❑ *Web service access* – To allow remote access to some services via a web browser. This functionality is particularly useful to allow relatives of

elderly people to have access to the TeleCARE network from their workplaces or their own homes.

b) Vertical Services – A set of specialised vertical services can be implemented on top of the horizontal TeleCARE infrastructure defined in the previous levels to support different interactions with the system. Taking into account the priorities identified through extensive fieldwork, the following initial services have been developed by the TeleCARE consortium:
   - *Living Status Monitoring.* This service represents an advance regarding the more traditional 'social alarm' systems, as it allows not only bilateral interactions and some semi-automatic supervision functionalities, but also the collection of additional information when help is needed or requested. The availability of assistance 24 hours a day significantly increases the elderly's quality of life and relatives' peace of mind.
   - *Agenda Reminder.* The daily activities related to the welfare of the elderly can be easily scheduled in order to improve their quality of life and wellbeing. This service, implemented through a number of agents, is able to remind the elderly of a number of activities, ranging from medication to exercise guidance or appointments made with the care centre.
   - *Time Bank.* This service provides a mechanism for collaborative community building/re-enforcement, i.e. a way for people to come together and help each other. At the same time it represents one of the mechanisms to support the 'active aging' concept.
   - *Entertainment.* The Entertainment Services are designed to ease the sense of isolation the elderly feel and provide light entertainment applications to improve their sense of wellbeing. This also helps to contribute to the maintenance of a social life and active aging. As a first demonstration a combination of games, music and education programmes are offered.

TELECARE PLATFORM IMPLEMENTATION

A TeleCARE prototype platform was developed in Java that integrates and resorts to various open source or freeware supporting technologies, e.g. Aglets mobile agents platform[12], Protégé ontology manager, SAP DB management system, and Castor.

In order to support the requirements of this application domain, a number of innovative technical features and components were developed as the middleware on top of the base development environment. The following is a list of these features and components, with some details about their implemented capabilities:

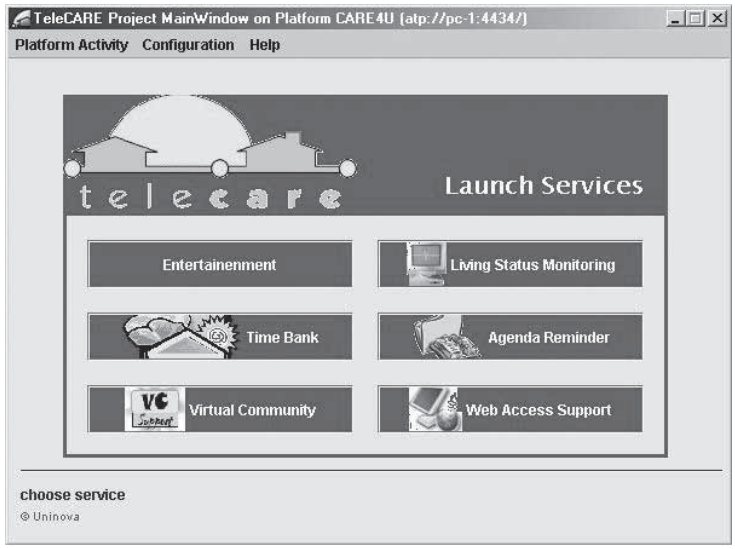

Figure 3. *The TeleCARE interface for the Care Centre*

- *Inclusion of agents' persistence support.* Persistency is a mechanism that allows the storage of information about the running activities of the agents, and whenever a system crashes to allow them to be resumed when the system is restarted. Aglets provides a method called **snapshot**, which saves a snapshot of an agent into a secondary/non-volatile storage. For persistency purposes, every TeleCARE agent can invoke the **tcSave** method, which does a call to *snapshot*, for storing information about its execution status when necessary. If there is a system failure, the last snapshot of the agent is restored and its execution can be resumed with the information stored in that snapshot. In the current version, automatic support for persistency is provided on three events: *(i)* at the creation of the agent, *(ii)* just after the agent arrives at a new location, and *(iii)* when the agent is activated. It is up to the developer to decide where he/she wants to make additional snapshots of his/her agent, calling the tcSave method.
- *High-level agent identification and localisation.* A *TeleCARE Logical Agent Identification (TLAID)* structure was introduced, which is used to validate an agent at any platform and to locate an agent (using human understandable data). With the information provided by the *TLAID*, the developers can identify any TeleCARE agent given its name, type, role or user ID, and/or domain node of the TeleCARE Virtual Organisation that the origin host (or platform) of the agent belongs to. *TLAID* is composed of two substructures:
  - *TLAD* – The *TeleCARE Agent Data* that contains specific human readable identification of the agent.

– *TLUD* – The *TeleCARE User Data* that contains human readable identification of the user who created the agent.

Given the inter-platform mobility and the need to keep track of mobile agents, the following agents are introduced:

- *Agent Registry* – Keeps a record of all agents that are living in the platform. The registration consists of a copy of the passport of each agent.
- *Agent Reception Control* – Responsible for the reception of the incoming mobile agents. Depending on their passports these agents can be accepted or refused. Whether an arriving agent is accepted in the local platform or not, the *Agent Exit Control* of the sender platform is notified.
- *Agent Exit Control* – Controls the outgoing of mobile agents. Every time an agent is due to leave the platform, its passport is first checked to see if the agent has permission to travel, and if the destination of the agent is available and/or is a valid TeleCARE platform.

❑ *New security mechanisms for agents and messages.* Both in case of when a mobile agent arrives at one node or remote (inter-node) agent communication, it is important to know who the agent is and who it represents. For this purpose, the concept of *passport* is introduced and associated to each agent (Figure 4). It is the official 'travel document' recognised by any TeleCARE site of the community. Any mobile agent that intends to migrate to another platform must have a valid passport. The passport includes two fields used for agent identification: TAL and TLAID. *TAL* is the *TeleCARE Agent Locator*, which is a system identifier used to locate an agent. With the information provided by *TAL*, the system can find the proxy of any agent, no matter where it is (for instance, to send it a message).

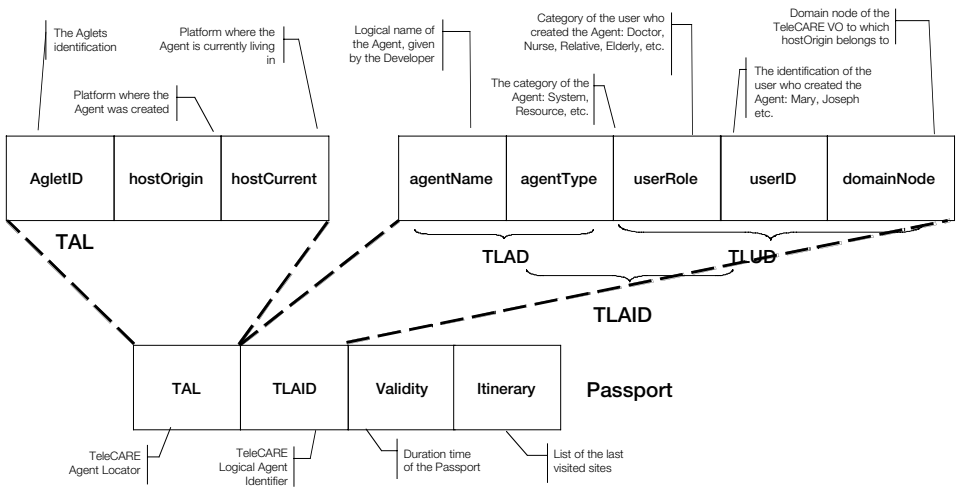

Figure 4. *TeleCARE agent passport*

- *Generalised communication mechanisms.* The Aglets system provides a simple mechanism for inter-agent communication. However, this mechanism is not sufficient for reliable communication for highly mobile agents[13] or when persistence mechanisms based on cloning are implemented, namely due to changes in the *AgletID*. Therefore, the platform implements additional communication services:
  - Extended message exchange mechanisms, which allow reliable inter-agent communication.
  - Handling FIPA ACL messages.
- *Integration and management of resources in TeleCARE.* Two kinds of resources are considered in TeleCARE including the hardware devices and the software services. The Universal Plug and Play (UPnP) specification is an architecture for pervasive peer-to-peer network connectivity of intelligent appliances, wireless devices and personal computers (PCs). Home appliances and sensors are connected to the TeleCARE platform following UPnP. The Web Services Definition Language (WSDL) provides the framework for definition of service specifications and their interfaces. The horizontal and vertical services of TeleCARE are defined and provided through the TeleCARE platform using WSDL.

  The Resource Catalog Management (RCAM) component supports the organisation, storage and access to the UPnP (for devices) and WSDL (for services) definitions of the TeleCARE resources.

  Furthermore, in order to facilitate the access to and invocation of TeleCARE resources an Abstract Resource Manager Agent (ARMA) template is provided. ARMA is instantiated and customised for each resource, becoming its actual Resource Manager. Application services can access a resource's functions through its corresponding Resource Manager that also checks and enforces the access rights of the requesting agents on the requested resource.
- *Integration of Federated Information Management and mobile agents.* Federated Information Management (FIMA) is a key component of the Core Multi-Agent System Platform Level. FIMA enables applications to distribute data transparently across multiple machines within the TeleCARE network. The design of FIMA is based on the federated databases approach, in order to support cooperation and information sharing, while reinforcing the required level of autonomy and heterogeneity among individual data sources (e.g. elderly home, care centre, leisure centre, etc.) within a TeleCARE network. The federated query processing is implemented by MIRA (Mobile Information Retrieval Agent) in such a way that applications can request to execute queries in:
  - **Parallel** mode, e.g. accessing data from several remote sources simultaneously.
  - **Serial** mode, e.g. accessing data from different nodes one after the other.

  - **Sequential** mode, similar to the serial mode but in which the process can be stopped once the client is satisfied with the result, providing a high user interactivity to control the information processing overhead.
- ❑ *Ontology-based database schema generator*. The Dynamic Ontology-based Schema Generation (DOSG) component of the core platform of TeleCARE supports and assists service developers with their direct definition of database schemas for the data that needs to be stored and processed by their code. It can thus eliminate the need for database experts to define and modify these schemas as it provides facilities for dynamic and automatic definition of the database schemas (relational and XML schemas) and the (Java source) code for the structures defined by users, so that they can be automatically stored in a database and processed by application programs. As such, the service developers of TeleCARE, can use the *Protégé* ontology system as the interface for their structure definitions, and do not need to have database expertise to define these database schemas.
- ❑ *Integration of Web services*. In order to provide access to TeleCARE services for relatives having access to the Internet, a mechanism is implemented to provide a bridge between the multi-agent platform and a web browser.
- ❑ *Integration of biometric security*. A fingerprint identification device is integrated with the platform providing a mechanism to implement safer user identification. This is particularly useful in care centres, where different users (e.g. nurses, doctors, care workers) with different information access rights can have access to the system. A taxonomy of users and roles is therefore associated with the biometric-based login process.
- ❑ *Variety of user interfaces*. People using the system will possess a diverse range of computer skills. Consequently access to the TeleCARE platform and services has to be made accessible through a variety of user interfaces. In particular, specialised interfaces have to be provided to make the system easy to use for elderly people with little or no computer skills. For users with good computer skills (e.g. care centre workers or relatives having access through a web browser) the interface can be Windows-based.

TELECARE SERVICES IMPLEMENTATION

In the TeleCARE environment each vertical service can be implemented in different ways as a set of distributed stationary and/or mobile agents. For instance, a monitoring service might involve a stationary agent in the care centre (interacting with the care worker), a number of stationary agents in the elderly home (agents in charge of monitoring local sensors, e.g. temperature sensor, presence sensor), and some mobile agents sent from the care centre to the elderly home (Figures 5 and 6). The mobile agents might carry a mission, for instance MIRAs sent to collect information from different sensors and to report back to the care centre.

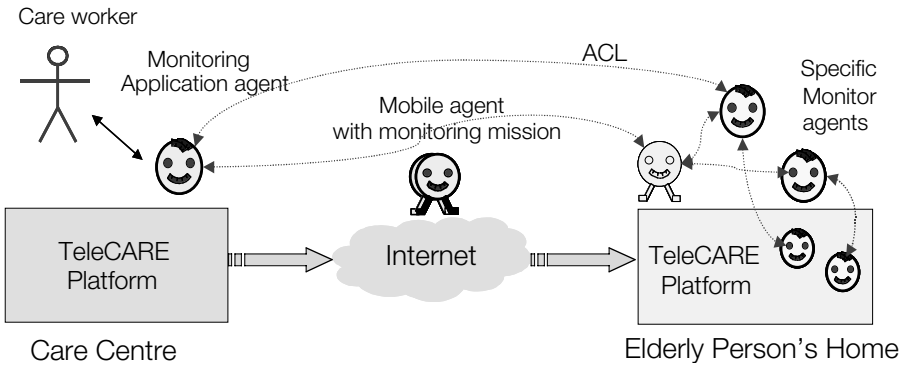

Figure 5. *Example of service implementation*

The stationary agents in one platform can also communicate, via ACL messages, with other mobile or stationary agents residing at another platform. Since a TeleCARE message includes extended agent identification, (as described in the *passport* section above), the receiver of a message can check the identity and rights of the sender, no matter at which location it is running at that moment.

The use of mobile agents facilitates the remote deployment of the service functionalities according to the services required by each elderly person. As different elderly people have different needs, such flexibility is required. With this mechanism it is also easier to install updated versions of services.

An integrated prototype system including the TeleCARE platform and a set of demonstration services was developed, showing the feasibility of the suggested approach. This integrated system was partially validated through a field assessment phase that took place in southern Spain, and involving four classes of potential users: (*i*) the elderly and their relatives; (*ii*) care providers/care workers;

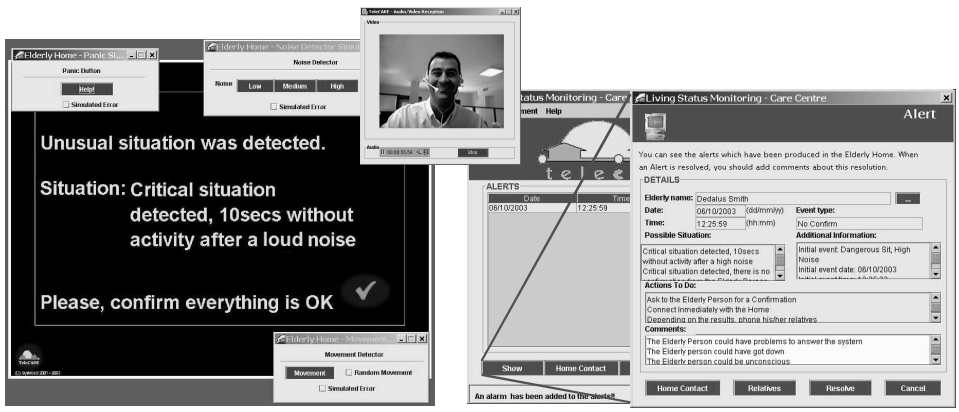

Figure 6. *Example of monitoring service interfaces at an elderly person's home and a care centre*

(*iii*) decision-makers (on social policies); and (*iv*) software developers. The TeleCARE concept and its functionalities were well accepted by these potential users, although it is clear that the system is at a research prototype stage and substantial engineering work is still necessary in order to make it a robust product.

CONCLUSIONS

The growing elderly population imposes an urgent need to develop new approaches to care provision. Recent developments in a number of technologies, such as multi-agent systems, federated information management, safe communications, hypermedia interfaces, rich sensorial environments and increased intelligence of home appliances represent important enabling factors for the design and development of virtual elderly support community environments. In particular, a platform based on mobile agents combined with federated information management mechanisms provide a flexible infrastructure on top of which specialised care services can be built. Nevertheless, the specific characteristics of the elderly population, who are not very open to new technologies, necessitates careful integration of the infrastructure with traditional home appliances including television sets. Furthermore, the fine tuning and eventual acceptance of the technology can only be determined when reliable prototypes are tested in the field with real users. This field trial constitutes the next phase in the TeleCARE project.

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