TeleCARE: Collaborative virtual elderly support communities

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Abstract. The growing percentage of 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 specialized care services are built.

1 Introduction

One of the key challenges faced by modern societies derives from the fact that with increasing speed our average population is getting older [11]. During the last three decades, the number of people aged 60 years or more has risen by about 50% in Europe. By 2020, it is estimated that for every person below the age of retirement, there will be 4 elderly people requiring support and care from their community. The impact on costs to the community will become considerably high. To deal with this challenge, new ways of providing elderly assistance and care, namely resorting to technological support, must be found.

New technological infrastructures, although not the solution for all problems, can be part of a new concept of integrated care system. An integrated elderly care system consists of a number of organizations such as care centers / day centers, health care institutions, social security institutions involving the cooperation of a number of human actors e.g. social care assistants, health care professionals, elderly people, and their relatives. When based on computer networks and adequate supporting tools, the collaboration among the care institutions may evolve towards operating as a long-term virtual organization and the various involved actors become part of a virtual community (VC).

In recent years various research projects have been engaged in developing technological solutions to increase the care services and reduce their costs. For

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instance, various initiatives have established “social alarm” systems [13], namely in the case of 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 center when there is an emergency situation. More recent works are focused on mobile social alarm systems and online monitoring systems based on a diversity of sensors and other devices. Other projects are focused on the development of smart home appliances or specialized user interfaces [7, 8]. Advances in computer networks and ubiquitous computing suggest the opportunity for more advanced care approaches including comprehensive status monitoring, other forms of assistance such as agenda reminders, but also the creation of the opportunity for the elderly becoming involved in the community, and thus reducing their feeling of loneliness.

In order to let elderly stay at home, and keep, to certain extent, their typical life style, new support services are necessary to address, among others, the following problems:

- **Loneliness** is one of the most serious problems affecting the elderly population. Development of applications to enrich the elderly’s social life and avoid problems of loneliness is of great importance. Fieldwork data [10] show that today the elderly hardly participate in activities relating with others, and 16% of them express dissatisfaction with their social lives. 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 the family** members caring for an elderly person 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.
- Widening the **interconnection to also include entities dedicated to providing different services for the elderly**, such as the residential centers, social centers, and social services, will bring potential benefits to the elderly. These interconnection systems, based on using new technologies, would reduce the loneliness problems of the elderly, would avoid the need for care workers to travel each time a person who needs some sorts of assistance or a company, and would permit continuous contact with the elderly person without the need for being physically present.

A crucial issue when developing a system to provide care and assistance, whilst preserving the elderly person’s independence, is the **privacy** assurance, and special care must be invested in mechanisms that will protect the elderly person’s privacy.

In this context, the IST TeleCARE project [3, 4, 5] aimed at the design and development of a configurable framework focused on virtual communities for elderly support. The proposed solution has to be seen as complementary to other initiatives for the integration of elderly in the society and reduction of their isolation. With different organizations developing different products and services, in a variety of different areas, there is a need for a common platform into which all these developments may be plugged so that interoperability is possible. The TeleCARE project proposes such a common and extendable platform as a common infrastructure.

2 TeleCARE platform

The TeleCARE approach for aiming at a technological infrastructure to enhance the collaborative virtual elderly support communities resorts at the base to the Internet and mobile-agent technologies (Fig. 1). Internet, although appealing as a base infrastructure, itself raises some difficulties, such as:

- i) In application domains such as elderly care, high levels of heterogeneity are expected in the sensorial and equipment richness of the remote places (homes), which demands appropriate solutions to guarantee the necessary levels of flexibility and scalability;
- ii) The Internet is characterized by long and variable time-delays and, very often, suffers from low levels of availability, raising new challenges in what concerns the reliability of the implemented system and its dependence on the characteristics of the network;
- iii) The emergence of mobile and ubiquitous computing raises the importance of wireless connections where the actual connection to the network has to be reduced to short periods;
- iv) The execution environments, involving legacy components, are potentially unstructured and uncertain, which 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 addresses the above issues [6]:

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

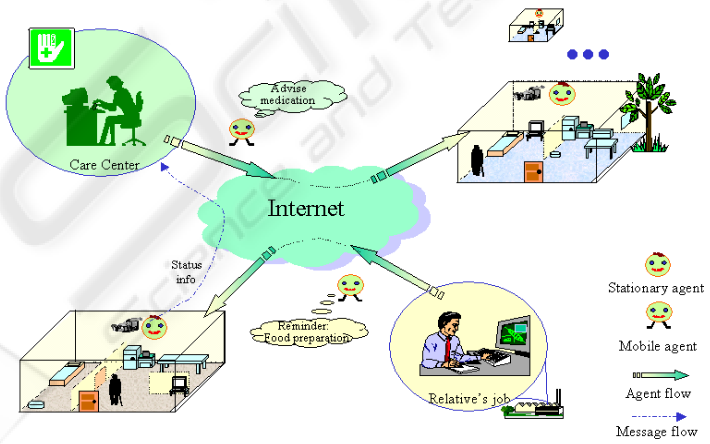

Fig. 1 – The TeleCARE approach

Fig. 2 shows a block diagram of the TeleCARE infrastructure to support collaboration in the elderly care virtual organization [2, 5]. The *Basic Platform* is intended to be installed at each node of the TeleCARE network. The *Specialized Components* (vertical services) have a distributed implementation over the TeleCARE network. The three-level infrastructure comprises:

• **External Enabler Level**: Supports the communication over the network and interfacing to the external (local) devices. In specific it includes:

a) *Safe communications infrastructure*, that 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 Internet, may be supported and hidden by this layer.

b) *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. UPnP [12] is one of the approaches adopted to interface devices.

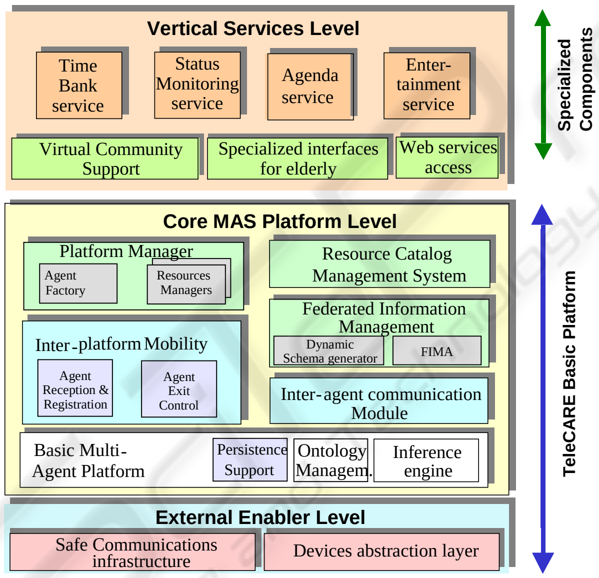

Fig. 2 - The TeleCARE platform architecture

• **Core Multi-Agent System (MAS) Platform Level**: It 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 catalog 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* – Extension to the MAS platform, providing some basic recovery mechanisms in case one node goes down.
e) *Inter-platform mobility* – Extension to the basic MAS platform to support generalized mobility of agents, including security mechanisms. This module includes the *Agent Reception & Registration* component (for incoming mobile agents) and the *Agent Exit Control* component (for outgoing mobile agents).
f) *Inter-agent communication* – Extension to the basic MAS platform to support communication between / coordination of agents independently of their current location, via FIPA ACL messages.
g) *Platform manager* – To specify and configure the operating conditions of the platform in each site, recover from errors, monitor operation status, etc. It includes:
   - *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* – To support the necessary management of information while preserving the 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* – providing the possibility to retrieve information from a number of TeleCARE nodes.
   - *Federated access control* – querying and providing access to the stored information.
   - *Automatic ontology-based schema generation* – generating database schemas from the ontology definitions provided by TeleCARE software developers.
i) *Resource catalog 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 specialized services:

a) Base horizontal services – A set of specialized base services that provide specific functionality for the other (vertical) services, including the following:
   - ❑ *Specialized interfaces for elderly* – In the case of home sites, specialized interfaces are required for elderly that are not familiar with the use of computers. The ultimate goal is therefore to make the usage of the system pleasant and easy, and thus to make 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 to have access to the TeleCARE network from their working places.

b) Vertical Services – A set of specialized 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 an 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 bi-lateral interactions and some semi-automatic supervision functionalities, but also the collection of additional information when help is needed or requested. The tranquility and assistance given 24 hours a day increase in a significant manner the elderly’s quality of life and relative’s 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 well being. 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 center.
- *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 elderly feel and provide light entertaining applications to improve their sense of well being, contributing to the maintenance of a social life and also an active aging. As a first demonstration a combination of games, music and education programs are offered.

3 TeleCARE platform implementation

A TeleCARE prototype platform is developed in Java that integrates and resorts to various open source or freeware supporting technologies, e.g. AGLETS mobile agents platform [1], Protégé ontology manager, SAP DB management system, and CASTOR.

Fig. 3 – TeleCARE interface for the care center

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

- *Inclusion of agents' persistence support*. Persistency is a mechanism that allows storing 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 to 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 localization*. 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) as well. 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 Organization 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, and
  - *TLUD* – The *TeleCARE User Data* that contains human readable identification of the user who created the agent;

  Please note that the native AGLETS *AgletID*, which is a string of 16 hexadecimal characters, is not a user-friendly identifier. Furthermore, it might change if a clone replaces the original agent as a result of the persistency support mechanisms.

TLAID is, therefore, a high-level user-friendly identifier. If only part of *TLAID* information is given, the result of the method `tcGetAgentTAL` can be a set of agents. This happens when a *TLAID* object is used to get the *TAL* or passport of an agent. In many cases the result of the query is a set of agents.
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 in 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 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 mobile agents, when an agent arrives at one node, or remote (inter-node) agent communication, it is important to know who the agent is / who it represents. For this purpose, the concept of *passport* is introduced and associated to each agent (Fig. 4). It is the official "travel document" recognized 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).

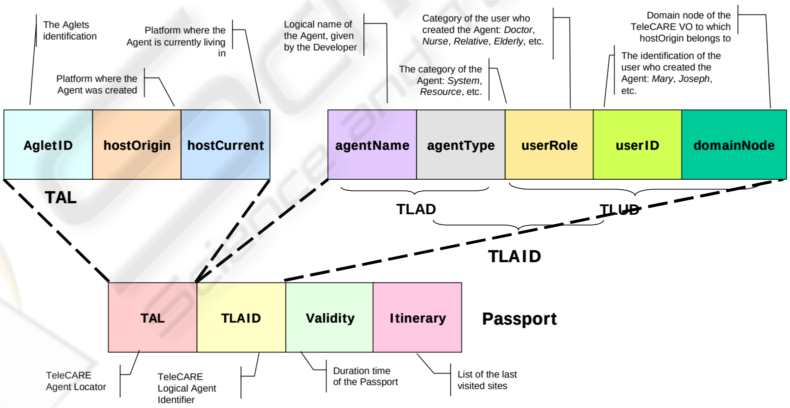

Fig. 4 - TeleCARE agent passport

❑ *Generalized 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 [9] or when persistence mechanisms based on cloning are implemented, namely due to the 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 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 the WSDL.
  The Resource Catalog Management (RCAM) component supports the organization, 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 & invocation of TeleCARE resources an Abstract Resource Manager Agent (ARMA) template is provided. ARMA is instantiated and customized 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*. The 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 center, leisure center, 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, etc.
  - **sequential** mode, e.g. similar to the serial one but in which the process can be stopped once the client is satisfied with the result, providing a high user interactivity to control 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, and thus it can eliminate the need for database experts to define and modify these schemas. Namely, DOSG 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 into database and processed by application programs. As such, the service developers of TeleCARE, can use the ontology system "*Protégé*" as 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 Internet through a web browser, a mechanism is implemented to provide a bridge between the multi-agent platform and a web browser following a philosophy of web services.

- *Integration of biometric security*. A finger print identification device is integrated with the platform providing a mechanism to implement safer user identification. This is particularly useful in the care centers 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 to the biometric-based login process.

- *Variety of user interfaces*. Considering the diversity of computer skills of the various actors in the elderly care virtual community, access to the TeleCARE platform and services needs to be made accessible through a variety of user interfaces, namely for users with computer skills (e.g. care center workers having direct access to the platform, relatives having access through a web browser from their work locations, or elderly without computer skills interacting with the system through a TV set).

4 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 center (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 center to the elderly home (Fig.s 5, 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 center.

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 the extended agent identification (see *passport* section), the receiver of a message can check the identity and rights of the sender, no matter at which location it is running at the moment.

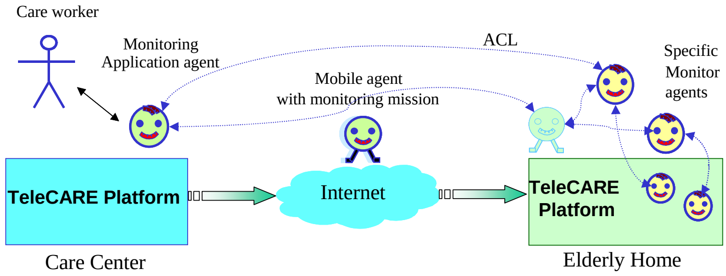

Fig. 5 - Example of service implementation

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

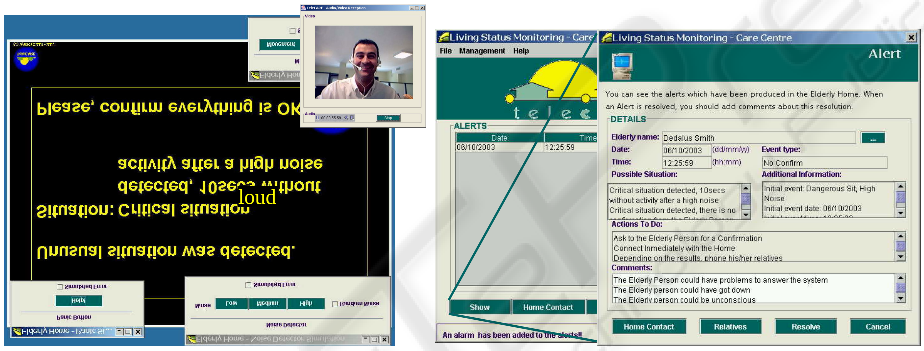

Fig. 6 - Example of monitoring service interfaces at elderly home and care center

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 South of Spain, and involving four classes of potential users: (i) Elderly and relatives, (ii) Care providers / care workers, (iii) Decision makers (on social policies), and (iv) Software developers. The TeleCARE concept and its provided 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.

5 Conclusions

The growing numbers of elderly population impose 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 an important enabling factor 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 provides a flexible infrastructure on top of which specialized care services can be built. Nevertheless, the specific characteristics of the elderly population, not very open to deal with new technologies, require a careful integration of the infrastructure with traditional home appliances and TV sets. Furthermore, the tuning and eventual acceptance of the technology can only be determined when reliable prototypes are tested in field with real users. This field trial constitutes the next phase in the TeleCARE project.

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