Mobile Agents for Supporting Ubiquity in Telecommunication Services

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Abstract

Telecommunications have had a strong impact on the society in the last decades. Nowadays, this role is ever increasing and pushing the technological and economic evolution of our society. The evolution of telecommunications creates new services that exploit the convergence between data communication, computation and entertainment. In this context, we are interested in service portability and adaptability as a result of personal mobility – a concept known as VHE (Virtual Home Environment).

In the specification and development of this new generation of services, which incorporate VHE in some extent, object orientation, component reuse, open distributed systems, and service architectures are words of order. Among these specifications we can emphasize TINA (Telecommunication Information Network Architecture). Moreover, architectures based on mobile and intelligent agents may open new, efficient, and flexible ways to distribute control and management for this new generation of telecommunication systems.

In this article, we propose a service architecture that preserves the positive aspects of TINA and relies on *de facto* open standards (e.g., the Internet) and mobile agents for supporting service and personal mobility. In order to evaluate the proposed architecture with respect to personal and service mobility, a prototype of a multimedia service was implemented.

Keywords: Telecommunication Services, Service Ubiquity, Personal Mobility, Mobile Agents, TINA Architecture, CORBA.

1 Introduction

Recently, many changes are being experienced in the telecommunication industry. These changes include the communication and computer integration, the ubiquity of the Internet, the intensive use of mobile computation, and the increasing of network bandwidth thanks to a massive deployment of optical fiber. As a result, effective multimedia services are ready to be deployed. These changes point to a future where citizens will be connected to a global telecommunication infrastructure wherever they are located. Moreover, small devices will be part of this digital communication infrastructure [1].

Considering this scenario, the future of the telecommunication market converges to a competitive and global environment in which the telecom operators must differ from each other. This differentiation will be relied more and more on the offering of novel services than on the offering of connections through their transport network [2]. Facing this context, the Telecommunications Information Networking Architecture Consortium (TINA-C) [3] was established by the major telecommunication operators, equipment vendors, and research centers. TINA aims to define a common software architecture for information and multimedia telecommunication services. The TINA Architecture is based on concepts of reuse of software components, distributed transparency, and open patterns of utilization. At the same time, the convergence of computing and telecommunication is creating a synergy that is fueling the Internet growth. Furthermore, the systems involving interactivity and multimedia communication are becoming more and more popular, making the Internet a real multi-service network.

This work describes a computing environment that allows the access to a certain set of services from different devices and locations. The environment takes into account the ability of each device in dealing with the transit information (e.g., video, audio, mail and fax). As such, users will be provided with the access of services adapted to their needs and access devices.

This article is organized as follows: section 2 characterizes the main points related to terminal, personal, and service mobility. Section 3 describes the support for personal and service mobility using mobile agents. Section 4 presents a implementation of the proposed environment as well as the results obtained. Finally, section 5 presents the conclusions of this work.

2 Terminal, Personal, and Service Mobility

Nowadays, wireless communication is a segment with the highest growth in the telecommunication industry. The demand for service based on voice and data spanned through the limits of the wireless technology to an even bigger market of ubiquitous services. The next generation of wireless systems, combining the functionality of the wireless and wired networks will support multimedia-oriented services independent of user location and access terminal. At this point, the management of mobility becomes a major issue. In order to achieve wireless global communication, it will be necessary the development of architectures that guarantee terminal and personal mobility plus services able to adapt to different terminals and networks.

Terminal mobility allows the terminal to change its location while preserving the connection to the network. The identification of a terminal is made through the assignment of a global number to it. Of course, different networks such as mobile telephone networks and wireless LANs provide different approaches to deal with terminal mobility. As a rule, terminal mobility is supported by the physical and data link layers.

Personal mobility allows users to access their services no matter the terminal or access point. This concept is also known as global roaming, being extensible to other networks such as Internet and public switched telephone networks (PSTN). Today, users are identified by their terminals. In a near future, a universal personal telecommunication number will be assigned to each user. This number permits to identify an user no matter what terminal is being employed to access the network.

Finally, service mobility supplies users outside their home network with contracted services, guarding the limits imposed by the infrastructure of the foreign network. In this context, VHE (Virtual Home Environment [4]) is defined as a concept for service mobility and adaptation across the network and terminal limits. This concept supplies UMTS (Universal Mobile Telecommunications System) users with the same personal service set independently of their location and access terminal.

3 Mobile Agents in Mobility Support

Based on the verified deficiency in the implementations of the TINA Architecture [5], this paper presents an approach based on mobile agents for supporting personal and service mobility in telecommunication services. TINA supposes that the access terminals have computational capacity enough to house complex software constructions (e.g., Java objects). Obviously, this is a severe deficiency when considering portable devices. An alternative is to have a service provider involving not only with the connectivity aspects of the service, but also with the supplying of resources not present in the access terminals. However, given the variety of services, supporting infrastructure, and terminals, supplying this deficiency may be cumbersome.

Mobile agent technology is maturing and, in the authors' viewpoint, will play a key role in mobile telecommunication systems. In fact, this paper refines the TINA architecture by incorporating mobile agents and WWW technologies to it. The refinements let subscribers to move to a domain where they do not have contracted services and, even this way, have their home services adapted to the new domain. The positive aspects of TINA are preserved, manly its Service Architecture, Distributed Processing Environment (DPE), and the concept of reference points.

Figure 1 depicts the main components for service provisioning considering the support of personal and service mobility through heterogeneous networks. These components are: retailers, home and foreign networks, users, and devices (or terminals). The terminal mobility support, as discussed before, is assured by the lower layers of the network. As such, the proposed service architecture for service mobility does not address this issue. The architecture introduces a reference point between retailers, or RP-Retl. This reference point has two main differences compared with the TINA Retailer Reference Point (Ret): **a.** it is much simpler in terms of number of operations it supports; and **b.** it preserves the retailer's legacy systems of subscription, access and service (allowing non-TINA retailers to preserve their service infrastructures).

In this proposal, a retailer can perform the role of home retailer or foreign retailer. Home retailer is a retailer where the user had contracted services, so the user has a profile and a contact stating the user rights and preferences at this retailer. In the foreign retailer, the user doesn't have a contract of service use, but can use the retailer as an initial contact point for services.

A user can have contracts with more than one retailer. As such, the user has a profile in each of these retailers. In the foreign domain, the foreign retailer is an initial contact point for an user through his name@domain. To validate this name@domain in the federation, it must be authenticated by the home retailer. Services of a contracted domain could be offered in a new domain, considering the new infrastructure (e.g., hardware and software

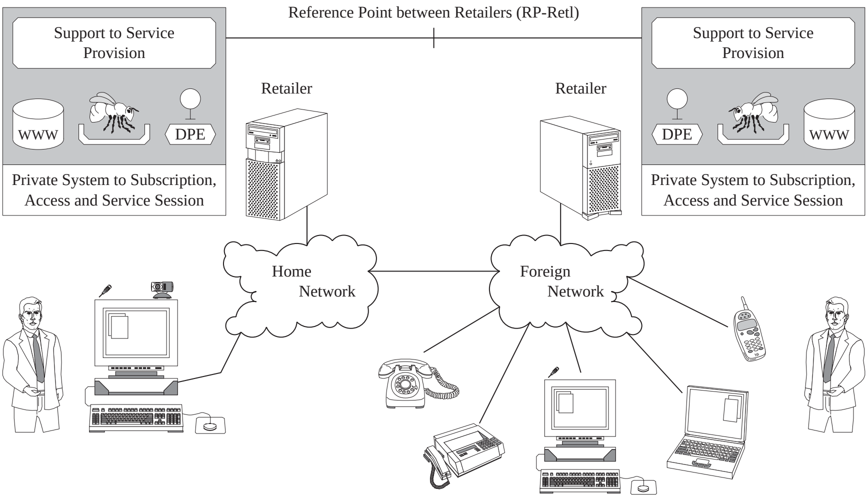

Fig. 1: A model for supporting personal and service mobility.

resources in both retailer and terminal). In this case, besides being in conformance with the reference point between retailers, the retailers also negotiate the accounting aspects of the service offered through the federation.

This paper describes the design and implementation of a "TINA-like" service architecture with mobility support. This architecture allows multiparty services (e.g., videoconference) to work across different network and terminals. User and service mobility are provided by this service architecture by exploring the following aspects: **a.** a federation of retailers operating different networks; and **b.** support for personal mobility; and **c.** support for service mobility and adaptation. Mobility and adaptation are provided by two mobile agents: user agent and service agent.

The RP-Retl reference point defines a set of interactions between two federated retailers. The interactions are conducted by five components as pictured in Fig. 2. These components, three fixed and two mobile (implemented as mobile agents) expose standardized interfaces specified in CORBA IDL (Interface Definition Language). As such, RP-Retl is defined only by the IDL interfaces, leaving the object implementation as a retailer's internal decision. CORBA [6] was chosen due to its maturity and ability to interwork with many information technologies (mainly databases). In the sequence it is presented a general description of the components of the reference point between retailers (RP-Retl) and the interactions with the retailer's internal subscription, access and service components.

User Agent Component

The user agent is a service component which represents the user in each retailer he/she established a contract. The user agent is accessible from a network address supplied by

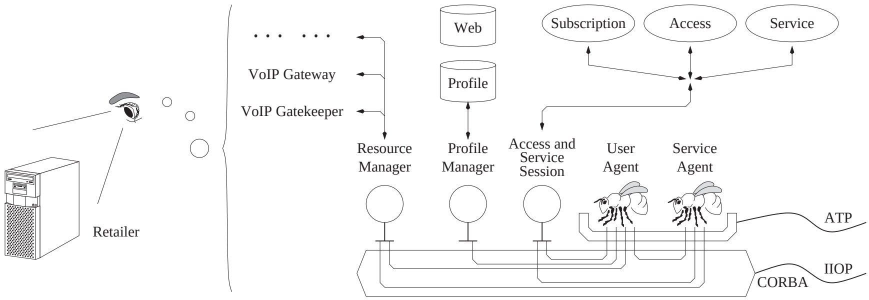

Fig. 2: Retailer's infrastructure for supporting mobility.

a name or directory service. The user agent acts as a single contact point in the service adaptation process taking place at a foreign retailer.

This component manages the user preferences in the access, usage and adaptation of services. It also allows service usage from different terminals including the support for registration and invitations on these terminals.

Service Agent Component

This service component models a variety of applications, in a such way that it can adapt the service to the new domain, considering the user profile and the resources available at this domain. Adaptation is achieved through either personalization or reconfiguration of the existing services.

The service agent provides flexibility, allowing software distribution and/or on demand service provisioning in a configurable manner. Services can be distributed taken into account access networks, terminal characteristics, and user preferences. Considering the appropriate support of hardware and/or software, the service agent can interact with other applications or with the user it is serving.

Profile Manager Component

This service component supplies the user preferences regarding service access and usage. It also states if the adaptation process can make use of some specialized resources (e.g., a VoIP gateway) at the foreign retailer.

Resource Manager Component

This service component supplies information about the hardware/software infrastructure necessary to support service mobility and adaptation. This information includes the conditions found at the foreign retailer, mainly network and terminal capabilities.

This component is also responsible for resource reservation as well as for managing the life-cycle and operation of these resources. The use of the required local resources for supporting service mobility and adaptation depends on the user profile and contracts established between the user's home and foreign retailers.

Access and Service Session Component

This service component allows the exchanging of information between and user and the mobile agents acting in behalf of him/her (the user and service agents).

This component exports an interface that allows the user to receive and generate invitation within a multiparty service. This interface provides invitation management in a standardized way, but the component must translate such invitations to a format compatible to the network (and terminal) the user is connected to.

4 Implementation Issues and Results

As depicted in Fig. 2, all the components of the proposed service architecture belong to the retailer domain. These components coexist with the retailer's legacy systems of subscription, access and service. A prototype of this service architecture was assembled from the TINA service architecture implemented by the authors and described in [5].

The resource management, profile management, and access and service session components are implemented as CORBA objects, exposing their functionalities through interfaces defined in IDL. Added to these components, a WWW server stores HTML pages and Java applets for on-demand service provisioning on terminals that support a Java-enabled Web browser. The user and service components are mobile agents that allow some services be adapted to the new conditions found at the foreign retailer and user terminal.

The interactions taking place at the RP-Retl reference point are transported within two protocols: IIOP (Internet Inter-ORB Protocol) and ATP (Agent Transfer Protocol). IIOP is a native CORBA protocol for transferring requests and replies among client and server objects. ATP is a protocol for transferring agents between agencies (places where agents execute). Both protocols operate over TCP/IP connections.

Java IDL was employed as a CORBA infrastructure. Java IDL is part of the Java 2 developing environment [7] and implements a ORB (Object Request Broker) for the Java programming language. Both Java 2 virtual machine and Java IDL are available on Web browsers such as Netscape 6.

Since two components are mobile agents, a platform that supports mobile code is necessary. *Voyager* [8], a Java-based mobile agent platform, was employed in our prototype due to its stability and ability to interwork with CORBA.

In order to validate the proposed service architecture, the subscription, access, and service were implemented according to the TINA specifications. These components are deployed at the user and retailer domains as shown in Fig. 3. The communication session is based on a OMG standard for control and management of audio and video streams (A/V Streams) [9].

For terminals with reasonably computing power, the user domain houses three TINA components: as-UAP (access session User Application), ss-UAP (service session User Application), and PA (Provider Agent). These components support the subscription and access sessions. The communication session at the user domain are provided by A/V Streams objects [10]. In our prototype, terminals with limited computing power (e.g., cellular phones) are simulated by `vat` [11], an Internet audio-conference application written in C++.

At the retailer's domain, four TINA components were employed: IA (Initial Agent), SUB (Subscription), UA (User Agent), and UAF (UA Factory). These components support the subscription and access sessions. The service session is composed of two TINA components: SF (Service Factory) and SSM (Service Session Manager). The communication session relies on one component of the A/V Streams specification, the stream controller (`StreamCtrl`) [10].

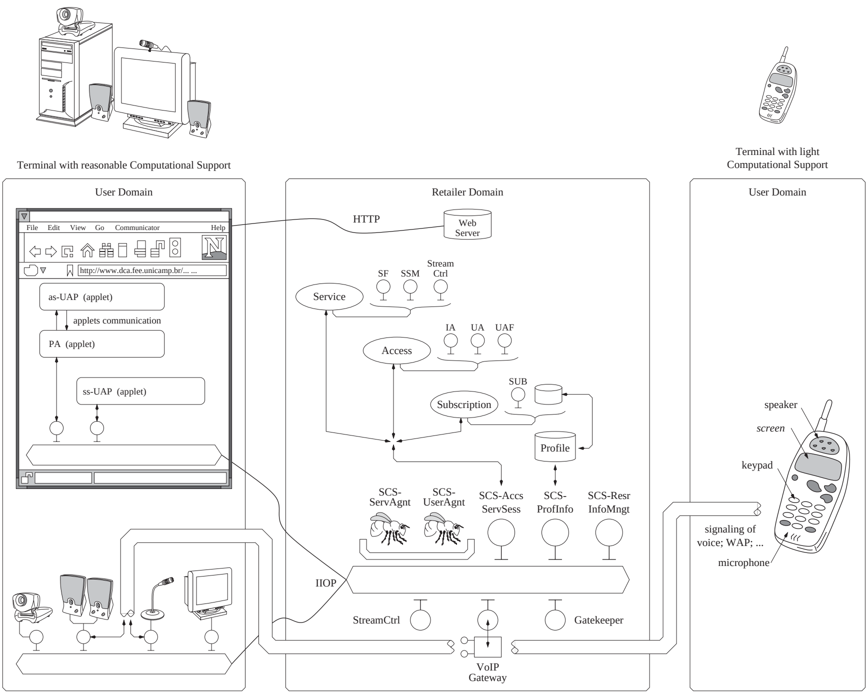

Fig. 3: Technological aspects of the developed prototype.

Figure 3 presents the components described above. At the user terminal, the TINA components are implemented as Java applets and downloaded at the user terminal (Web browser) on demand. The communication session components employs the Java Media Framework (JMF) for Java-based terminals, or `vat` otherwise. The former supports both audio and video streams, while the latter supports only audio streams.

The remaining components of Fig. 3 are CORBA objects implemented in Java. The user agent and service agent components were implemented in Java above the *Voyager* platform.

Scenario for Validating the Proposed Architecture

Consider a video-conference established between two users using a Java-enabled Web browser as terminal. With the service in progress, one of the users decides to continue from another terminal on a network owned by a different retailer.[1].

This scenario is simulated in Fig. 4. User #1 employs the terminal "Itaparica" at a network operated by the "Rocas" retailer. User #2 employs the terminal "Angra" at the same network. This user then moves to the terminal "Mocooca" on a network operated by the "Botafogo" retailer. If this new terminal does not present the same computing infrastructure of the previous one, the service must be adapted.

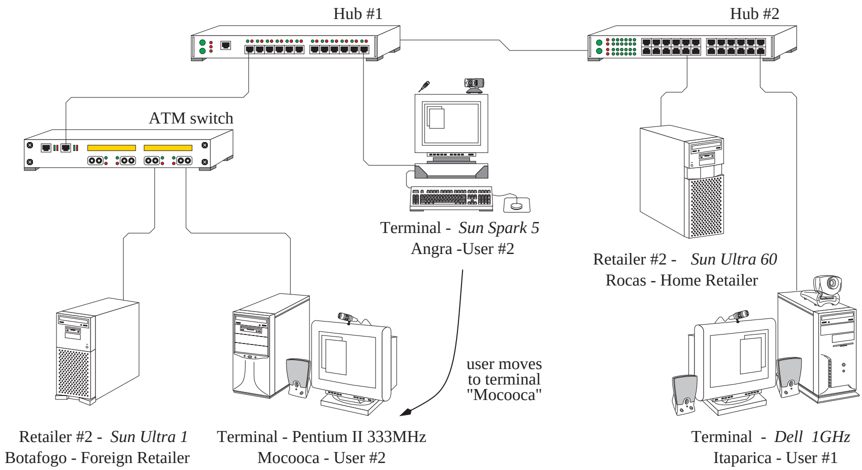

Fig. 4: User #2 requests a service to "Rocas" from "Botafogo".

After the User #2 has moved he/she contacts the retailer "Botafogo" using his/her personal identification. As shown in Fig. 5, the graphical interface allows the user to establish a new access session. After the login and download of some components on the user's terminal, the interface shown in Fig. 6 is made available. Through this interface, the user can identify him/herself by providing name, password, and the domain the user wishes to contact for services.

When an access session is established, it is assumed that the domains can establish a trusted relationship. The DPE can offer some of the security mechanisms needed by this relationship (for instance, a secure connection). Two items should be considered in order to guarantee the security and privacy in a federation of retailers: **a.** the user authentication should occur at the user's home retailer; **b.** the user's personal data should be encrypted for privacy before transmitted to the home retailer. Once established the access session (Fig. 7), the retailer "Botafogo" informs the local services that it can offer or the choice of another retailer.

If the user selects services from his/her home retailer, the retailer "Botafogo" asks the user agent in the home retailer ("Rocas") to migrate. This agent evaluates which services could be adapted, considering the terminal capacities, the retailer's infrastructure, and the user profile. After migration, the user agent obtains information about the user,

[1]For instance, the user decides to change terminals, from a Web browser on a desktop computer to a cellular phone.

Fig. 5: Initial contact with a retailer.

Fig. 6: Access session in the terminal.

current terminal and resources of hardware and software that can be used on the current retailer. Obtained the necessary information to the evaluation, the agent produces a list of services that can be adapted (Fig. 8). This list is passed to the assess and service session component in a standardized way (through a IDL interface). This component translates this information in a form compatible with the retailer's network and user terminal (for instance, through recorded voice messages).

Once a service is chosen, the foreign retailer requests the migration of the corresponding service agent. This agent interacts with the user agent in order to gather information about the resources to be allocated, the infrastructure available at the foreign retailer, and parameters for service configuration. After the service agent concludes the adaptation process and the resources needed for the service are committed, the user agent and the terminal receive the status signal that the service session has been established. From now, the service could be controlled by an computer-human interface available at the user terminal.

The service was established initially as a video-conference on terminals "Itaparica" and "Angra", both with full computational capabilities for audio and video. As one of the users moved to a terminal without video capturing and Java capabilities ("Mocooca"), the service was adapted to this new terminal. In this case, the original video-conference service (Fig. 9) was downgraded to an audio-conference (Fig. 10). This situation simulates the right hand side of Fig. 3. In this example, the adaptation process consists in destroying the audio and video streams at "Angra" followed by the establishment of an audio stream on "Mocooca". The audio endpoint on "Mocooca" employs a local resource, the `vat` tool, since this terminal does not have computing power enough to support Java.

In terms of performance, the time interval to contact the user agent is about 2 seconds. Migration time for both user and service agents is about 3 seconds. Most of this time is spent in serialization and deserialization of Java code, not in transferring this code over

Fig. 7: Access session established.

Fig. 8: Services that can be adapted.

the network. The time interval of the user agent processing was about 100 milliseconds. All of these time intervals may increase if the knowledge base incorporated to the agents increases. The authors believe that these performance figures may be improved by one or even two orders of magnitude through code optimization and hardware upgrading.

Evaluation of the Proposed Service Architecture

The architecture has the following positive aspects. Firstly, it preserves the retailer's legacy subscription and access systems. These systems are integrated to the new environment through CORBA. Another point is that service software is distributed and adapted on demand through mobile agents. Mobile agents, in this context, allow the decentralization of control and management of service, bringing these activities as close to the user as possible. The proposed architecture also preserves the positive aspects of the TINA architecture, but simplifies the requirements for establishing a federation of retailers. Finally, as the retailer can supply additional resources for the services, terminals with limited computing resources can be employed (for instance, all the control of a conference can be placed at the retailer's computing infrastructure, not at the terminal as prescribed by TINA).

No matter the positive aspects listed above, some points still need investigation and improvement. Mobile agent technology is maturing fast, but performance and security are still weak points. Moreover, solid and well accepted standards are needed for true agent mobility among different platforms.

Another point that still needs to be addressed is scalability. As the number and size of agents increase, the amount of computing power at the retailer's domain needed for agent migration may became prohibitive. Of course, this will impact on scalability. A possible solution is to employ a cache scheme where Java classes belonging to migrated

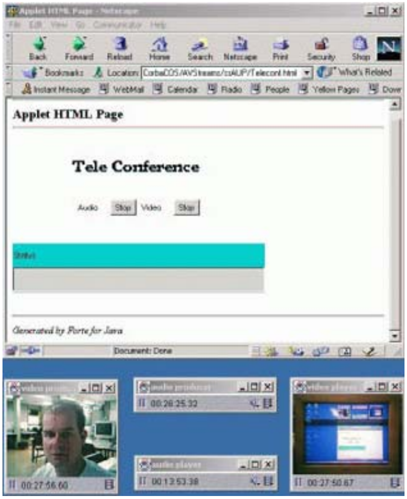

Fig. 9: Tele-conference service.

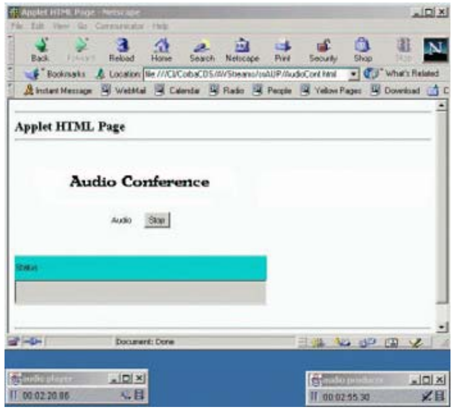

Fig. 10: Audio-conference service.

agents are stored locally. When a new agent of the same kind migrates, most of its code will be found at the destination node. This scheme works similarly to Web caching and contributes to scalability in the same way.

Reliability and performance are also key aspects in telecommunication services. Being more and more software intensive, these services impose reliability and performance constraints not fulfilled by the implemented prototype. As such, these issues need to be assessed in a more comprehensive way.

Finally, another drawback, perhaps the most severe one, is the need of a federation of retailers for supporting ubiquity. Commercial interests may inhibit such a federation.

5 Concluding Remarks

Personal mobility demands new strategies for service design and deployment. As users are allowed to access the service from multiple retailers, networks, and terminals, service mobility and service adaptation are tightly close to personal mobility. From the authors' viewpoint, intelligent mobile agents is a technology that will play a key role in personal and service mobility. Mobile agents can bring the service (or part of it) close to the user, adapting the service to the current user's need and environment.

This paper proposed a "TINA-like" service architecture based on mobile agents. Being much simpler when compared to full TINA specifications, this architecture is easily extended by incorporating new operations at the RP-Retl reference point. These operations can be supported either by fixed objects or mobile agents.

Acknowledgements

This research is supported in part by FINEP(1588/96). The authors thank Antônio T. Maffeis for his help in the implementation of the scenario described in section 4.

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