

# Mobile Agent–Based Information Systems and Security

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## INTRODUCTION

The rapid expansion of information and the high demand for timely data delivery have triggered the development of a large number of wireless information systems that enable users to access data from anywhere at anytime. These applications must face three major challenges: the limited bandwidth of wireless medium, intermittent network connectivity, and the fact that portable devices have limited CPU power, memory, and energy sources. Traditional distributed system design methods, such as the client/server-based computational model, cannot meet the aforementioned challenges very well. In contrast, a relatively new distributed system design paradigm, the mobile agent-based computation model, provides natural solutions to these problems. In this article, we will introduce the concept of mobile agent-based computing, review some examples of existing agent-based information systems, and discuss security issues that are related to them.

## BACKGROUND

An *agent* is a computer program that acts autonomously on behalf of a person or organization (Lange & Oshima, 1998). A *mobile agent* is an agent that can move through the heterogeneous network autonomously, migrate from host to host, and interact with other agents (Gray, Kotz, Cybenko, & Rus, 2002). Agent-based distributed application design is gaining prevalence because it provides a single framework that allows a wide range of distributed applications to be implemented easily, efficiently, and robustly.

Mobile agents have many advantages (Lange & Oshima, 1998). We only highlight some of them that are closely related to distributed information system design.

- **Support Disconnected Operation:** Mobile agents can roam the network and fulfill their tasks without the owner's intervention. Thus, the owner only needs

to maintain the physical connection during submission and retraction of the agent. This asset makes mobile agents desirable in the mobile computing environment where intermittent network connection is often inevitable.

- **Balance Workload:** By migrating from the mobile device to the core network, the agents can take full advantage of the high bandwidth of the wired portion of the network and the high computation capability of servers/workstations. This feature enables mobile devices with limited resources to support functions beyond their original capability.
- **Reduce Network Traffic:** Mobile agents' migration capability allows them to handle tasks locally instead of passing messages among the data sources. This implies fewer messages and, consequently, reduced chances for loss of messages and the overhead of retransmission.

One should note that the agent-based computation model also has some limitations. For instance, the overhead of mobile agent execution and migration can sometimes overshadow the performance gain obtained by reduced communication costs. In addition, the ability to move and execute code fragments at remote sites could introduce serious security implications.

## MAIN THRUST OF THE CHAPTER

### Mobile Agent-Based Information Systems

Papastavrou, Samaras, and Pitoura (2000) proposed the DBMA-Aglet Framework for World Wide Web distributed database access. The system uses mobile agents, between the client and the server machine, as a means of providing

database connectivity, processing, and communication. The DBMS-Aglet Multidatabase Framework is an extension of the DBMS-Aglet Framework that can perform parallel execution over multiple databases. In this framework, a coordinator DBMS-Aglet is responsible for creating and dispatching multiple DBMS-Aglets to different data sources. Finally, the coordinator DBMS-Aglet compiles the results and returns it to the client. The authors claimed that the DBMS-Aglet Framework allows the aglet to be portable, light, independent, autonomous, flexible, and robust.

Vlach, Lana, Marek, and Navara (2000) implemented a system called Mobile Database Agent System (MDBAS). The system intends to integrate heterogeneous databases under one virtual global database schema to transparently manage distributed execution. The MDBAS aims to preserve local autonomy and execute distributed transactions using the two-phase commit protocol. Based on the experiences gained in the development of MDBAS, the authors claimed that mobile agent technology will play an important role in the software industry in a short time.

Babaoglu, Meling, and Montresor (2002) proposed a Java-based multi-agent system, called Anthill, which is a framework for peer-to-peer (P2P) application development, deployment, and testing. Anthill adopts the concept of swarm intelligence (Kennedy & Eberhart, 2001), where there is no central coordination of activity and the collection of simple agents of limited capability achieves intelligent collective behavior. Performance evaluation of Anthill was done by using 10,000 queries collected from the Internet. Simulation results confirm that the performance of the system, in terms of the success rate for each search request and the number of hops necessary for the first reply to a search request, improves over time because of the learning and adaptive capabilities of agents.

The VIPAR (Virtual Information Processing Agent Research) system is a multi-agent system that uses agents and ontology to automatically monitor and manage newspaper articles in a manner comparable to humans (Potok, Elmore, Reed, & Shelton, 2003). It includes 13 information agents that manage 13 different newspaper sites. Results show that VIPAR can efficiently handle information gathering, analysis, and summarization tasks that are critical to the Virtual Information Center (VIC) at the U.S. Pacific Command. The deployment of such a system can drastically reduce the cost of these labor and resource intensive processes.

MAMDAS stands for Mobile Agent-based Mobile Data Access Systems (Jiao & Hurson, 2004). Its design aims to alleviate two major difficulties in large-scale mobile data access systems: heterogeneity and mobility of data sources and/or users. Experimental results have shown that under the same underlying multi-database configuration, the mobile agent-based computation mode can achieve better performance and robustness than the traditional client/server-based model. In addition, the authors also pointed

out that, from a software engineering point of view, the use of mobile agents can significantly improve modularity and reusability and simplify the management of large complex systems. Therefore, the authors believe that mobile agent-based programming is an excellent solution to distributed information system design.

Spyrou, Samaras, Pitoura, and Evripidou (2004) also share the view that mobile agent technology has great potential in wireless computing applications. The authors proposed a general framework for dynamically configuring applications through the deployment of mobile agents. They believe that the use of mobile agents enhances the applicability of different software models to mobile wireless computing, and it makes applications more light-weight and tolerant to intermittent connectivity. The proposed framework was illustrated through a wireless Web-based data access application. Their simulation results show that, in the wireless environment, for average size transactions, the deployment of mobile agents provides a performance improvement of approximately a factor of 10.

## Security Issues

Despite the advantages that mobile agents have demonstrated in building flexible distributed information systems, the success of mobile agent-based systems will depend on the development of robust security defense mechanisms. Due to the mobility and autonomy of mobile agents, designing such security mechanisms is a challenging task.

Within the scope of security, three key issues have been identified for mobile intelligent agent systems (Chess, 1998):

- Protection of the agent against malicious hosts;
- Protection of the host against malicious agents;
- Protection of the network communication.

Ideas from the distributed computing and operating systems can be borrowed to address the second issue (Farmer, Guttman, & Swarup, 1996; Greenberg, Byington, & Harper, 1998), and techniques such as the Secure Socket Layer (SSL) can resolve the third problem. However, protecting agents against malicious hosts is a new and difficult problem that is specific to mobile agents. In the following subsections, we will first summarize the security threats in mobile agent-based systems and then, briefly review solutions that have been proposed in the literature for both host and agent protection.

## Security Threats in Mobile Intelligent Agent Systems

Types of attacks are often categorized as follows: damage, denial of service, unauthorized access, harassment, masquerade, and repudiation. These attacks may be launched by

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