

E-Commerce Services Based on Mobile Agents

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INTRODUCTION

The Internet offers a unique opportunity for e-commerce to take central stage in the rapidly growing online economy. With the advent of the Web, the first generation of business-to-consumer (B2C) applications was developed and deployed. Classical examples include virtual shops, on-demand delivery of contents, and e-travel agency. Another facet of e-commerce is represented by business-to-business (B2B), which can have even more dramatic economic implications since it far exceeds B2C in both the volume of transactions and rate of growth. Examples of B2B applications include procurement, customer relationship management (CRM), billing, accounting, human resources, supply chain, and manufacturing (Medjahed, Benatallah, Bouguettaya, Ngu, & Elmagarmid, 2003).

Although the currently available Web-based and object-oriented technologies are well-suited for developing and supporting e-commerce services, new infrastructures are needed to achieve a higher degree of intelligence and automation of e-commerce services. Such a new generation of e-commerce services can be effectively developed and provided by combining the emerging agent paradigm and technology with new Web-based standards such as ebXML (2005).

Agents have already been demonstrated to retain the potential for fully supporting the development lifecycle of large-scale software systems which require complex interactions between autonomous distributed components (Luck, McBurney, & Preist, 2004). In particular, e-commerce has been one of the traditional arenas for agent technology (Sierra & Dignum, 2001). Agent-mediated e-commerce (AMEC) is concerned with providing agent-based solutions which support different stages of the trading processes in e-commerce, including needs identification, product brokering, merchant brokering, contract negotiation and agreement, payment and delivery, and service and evaluation. In addition, the mobility characteristic of peculiar agents (a.k.a. *mobile agents*), which allows them to move across the nodes of a networked

environment, can further extend the support offered by the agents by featuring advanced e-commerce solutions such as location-aware shopping, mobile and networked comparison shopping, mobile auction bidding, and mobile contract negotiation (Kowalczyk, Uluru, & Unland, 2003; Maes, Guttman, & Moukas, 1999).

To date, several agent- and mobile agent-based e-commerce applications and systems have been developed which allow for the creation of complex e-marketplaces—that is, e-commerce environments which offer buyers and sellers new channels and business models for trading goods and services over the Internet.

However, the growing complexity of agent-based marketplaces demands for proper methodologies and tools supporting the validation, evaluation, and comparison of: (1) models, mechanisms, policies, and protocols of the agents involved in such e-marketplaces; and (2) aspects concerned with the overall complex dynamics of the e-marketplaces.

The use of such methodologies and tools can actually provide the twofold advantage of:

1. analyzing existing e-marketplaces to identify the best reusable solutions and/or identify hidden pitfalls for reverse engineering purposes; and
2. analyzing new models of e-marketplaces before their actual implementation and deployment to identify, *a priori*, the best solutions, thus saving reverse engineering efforts.

This article presents an overview of an approach to the modeling and analysis of agent-based e-marketplaces (Fortino, Garro, & Russo, 2004a, 2005). The approach centers on a Statecharts-based development process for agent-based applications and systems (Fortino, Russo, & Zimeo, 2004b) and on a discrete event simulation framework for mobile and multi-agent systems (MAS) (Fortino et al, 2004a). A case study modeling and analyzing a real consumer-driven e-commerce service system based on mobile agents within an agent-based e-marketplace on the

Internet (Bredin, Kotz, & Rus, 1998; Wang, Tan, & Ren, 2002) is also described to demonstrate the effectiveness of the proposed approach.

BACKGROUND

In a broad sense, an agent is any program that acts on behalf of a (human) user (Karnik & Tripathi, 1998). An agent can just sit there and interact with its environment and with other agents through conventional means, such as local/remote procedure calls and asynchronous messaging, or through more advanced coordination infrastructures such as *tuple* spaces and *event*-based systems. Agents that do not or cannot move are called “stationary agents.” Conversely, a mobile agent is a program that represents a user in a computer network and can migrate autonomously from node to node to perform some computation on behalf of the user. Thus mobility is an orthogonal property of agents—that is, not all agents are mobile. Also mobile agents can interact with their environment and, notably, with other agents through mobility-aware and mobility-unaware infrastructures (Fortino & Russo, 2005). Indeed, the emergence of mobile agents was motivated by the benefits they provide for creating distributed systems. In fact, as Lange and Oshima (1999) pointed out in their seminal paper, there are at least seven good reasons to employ mobile agents: reduction of network load, overcoming of network latency, encapsulation of protocols, asynchronous and autonomous execution (“dispatch your agents, shut off your machine”), dynamic adaptation, seamless system integration, and robustness and fault-tolerance.

An agent-based e-marketplace (AEM) is a distributed multi-agent system formed by both stationary and mobile agents which provide e-commerce services to end-users within a business context. AEMs are, as previously pointed out, distributed large-scale complex systems which require tools which are able to analyze not only the AEM at the *micro* level (i.e., behaviors and interactions of their constituting agents), but also the AEM at the *macro* level (i.e., the overall AEM dynamics).

In Griss and Letsinger (2000), an agent-based framework for e-commerce simulation games has been developed by using *Zeus*, a Java-based multi-agent system developed at the British Telecom Lab. Its goal is to evaluate the potential consequences of novel combinations of market models, business strategies, and new e-services through multi-player shopping games, in which agents represent various typologies of sellers, buyers, brokers, and services.

In Wang et al. (2002), an infrastructure for Internet e-marketplaces based on the *Aglets* mobile agents that

enables real commercial activities by consumers, agents, and merchants, has been proposed. Its goal is not only to provide an advanced e-commerce service, but also to evaluate several dispatching models for mobile agents.

Bredin et al. (1998) describe a simulated environment for mobile agents which allows analyzing the market-based resource control system of the *D'Agents* mobile agent system and, in particular, the resource allocation mechanism of its resource manager using a sealed-bid, second-price auction policy.

Although useful insights about AEM micro and macro levels can be acquired by playing e-commerce simulation games and, then, analyzing the obtained results, or by evaluating real e-commerce applications, discrete event simulators are essential for evaluating how AEMs work on scales much larger than that achievable in games or in applications which involve humans. In fact, discrete event simulation is currently extensively exploited as a strategic tool in most research and application areas which are directly or indirectly related to computer science. In this context, the article proposes an approach based on discrete event simulation and shows its application to the analysis of micro-level issues of a consumer-driven AEM: validation and evaluation of services based on mobile agents for product searching and buying.

MODELING AND ANALYSIS OF MOBILE AGENT-BASED SYSTEMS

The StateCharts-Based Approach for Modeling and Analysis

The proposed approach (Fortino, Garro & Russo, 2005) consists of the following phases: high-level modeling, detailed design, and coding and simulation (see Figure 1).

The *High-Level Modeling* of an agent-based system can be supported through well-established agent-oriented methodologies (such as the Gaia methodology; Wooldridge, Jennings, & Kinny, 2000) which cover the phases of requirements capture, analysis, and high-level design. An agent-based system (AS) can be modeled as follows:

AS = <AT, LCL, act, ser, pro>, where:

AT (Agent Types) is the set of types of agents embodying activity, offering services, and interacting with each other.

LCL (Logical CommunicationLinks) is the set of logical communication channels among agent types which embody interaction protocols.

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