An Agent-Oriented Marketplace Architecture for Enterprise Integration

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INTRODUCTION

Businesses today must be fast and flexible, responsive to customers, and cost effective in their operations. They must collaborate more frequently with partners to build virtual organizations and supply-chains that reduce times-to-market and costs. *eBusiness* is the use of the Internet along with other electronic means and technologies to conduct within-business, business-to-consumer, business-to-business, and business-to-government interactions. A basic model of an *eBusiness* is the *eShop* model, which is based on providing a self-service storefront to a customer by displaying the company catalogs and product offers on a Web site. An *eProcurement* model focuses on the buying aspect of the business. A typical architecture for *eProcurement* consists of a browser-based self-service front end to the corporate purchasing system or its ERP. The supplier catalogs are presented to end-users through a single unified catalog, thereby facilitating a corporate-wide standard procurement process. Online auction models have also received much attention for automating dynamic trading. Other models are based on creating value-chain businesses, such as service provisioning of specific functions for the value chain, and electronic payments or logistics.

Although each of the above models attempts to provide an *eBusiness* solution, none of them addresses the challenge of how to create and leverage services and supply operations in a way that seamlessly integrates business entities (customers, suppliers, partners, and competitors) in a dynamic trading community. A very important and promising model is the *eMarketplace*. It supports value-chain integration and provisioning in its structure and services. The objective is to develop an *eBusiness* solution that relieves business entities of much of the burden of

participating effectively in the *eBusiness* domain. This model combines the advantages of the sell-side, the buy-side, and the value-chain models.

BACKGROUND AND LITERATURE REVIEW

There have been several recent attempts to promote *eMarketplace* models by the academic and industrial communities. For example, the Electronic Market-Place (Boll, Gruner, Haaf, & Klas,1999) is an attempt to develop a business-to-business system architecture. It is viewed as a DBMS solution to support many-to-many relationships between customers and suppliers. The Global Electronic Market system (Rachlevsky-Reich, & Ben-Shaul, et al. 1999) attempted to develop a logical market framework and infrastructure. In this system, the market provides trading mechanisms that include bids and offers. A more complex architecture for an *eMarketplace* is MAGMA (Tsvetovatyy, Gini, Mobasher, Wieckowski,1997), with its special focus on the infrastructure required for conducting commerce on the Internet. OFFER (Bichler, Beam, Segev, 1998) proposed a brokering-based architecture marketplace. A customer can search for a service either directly in the e-catalog of the supplier or use the e-broker to search all the e-catalogs of the suppliers that are registered with this broker. E-brokers employ a simple auction mechanism. MOPPET (Arpinar, Dogac, Tatbul. 2000) proposed an *eMarketplace* system as agent-oriented workflows. MOPPET viewed the market as a workflow management system carried out by several types of agents: task, scheduling, facilitator, and recovery agents.

Another approach was driven by the bottom-up modeling of market processes with self-organizing capabilities (Arthur, Holland, LeBaron, Palmer, & Tayler, 1997). The objective was to develop a computational study of economies modeled as evolving systems of autonomous interacting agents, and known as agent-based computational economics (ACE) (LeBaron, 2000; Timmers, 1999). The ACE researchers relied on computational laboratories (McFadzean, Stewart, & Tesfatsion, 2001) to study the evolution of decentralized market economies under controlled experimental conditions.

Several companies have emerged to automate logistics and re-supply within specific industrial segments. For example, Ariba (Ariba 2000) developed a marketplace based on procurement portals and dynamic exchanges for horizontal marketplaces. The SAP Service Marketplace (SAP AG) is an Internet portal for the SAP community. It provides basic online services, such as catalog browsing, matchmaking, and ordering from SAP and its partners. Other approaches were

directed to support vertical marketplaces, such as PaperExchange (Paperexchange Marketplace), which enable customers and suppliers to negotiate pricing and transact directly with one another. VerticalNet (VerticalNet® Marketplaces) also built a set of Web-based marketplaces for specific industrial segments, such as financial services, healthcare, and energy. Each Web site forms a community of vendors and customers in a specific area.

Another direction adopted by major software vendors is to develop Internet-based commerce platforms. Examples are IBM CommercePOINT (IBM Corporation CommercePOINT Payment.), Microsoft Site Server Commerce Edition (Microsoft Corporation. Internet Commerce 1998), Oracle Internet Commerce Server INTERSHOP (Intershop Communications, Inc. 1998), and Sun JavaSoft JECF (Java Electronic Commerce Framework) (Sun Microsystems). These proprietary attempts focus on providing infrastructure services, such as security payment directories and catalogs, to be integrated with existing systems and the Web.

In our research work, we view *eMarketplace* as a cooperative distributed system that integrates participating business entities, including consumers, suppliers, and other intermediaries. This architecture enables and facilitates common economic services and commerce transactions between the buyers and sellers, such as brokering, pricing, and negotiation, as well as cross-enterprise integration and cooperation in an electronic supply-chain. In this architecture, the *eMarketplace* exists as a collection of economically motivated software agents.

DESIGN ISSUES AND TRENDS

As *eBusiness* grows and becomes viable in the real world, its corresponding *eMarketplaces* must expand to support a broader base of services ranging from baseline interaction and directory services to specialty services, such as dynamic trading, cooperative supply-chain integration, and management. In this new *eMarketplace* environment there are significant interactions among the systems deployed by the participating business units of an enterprise, their customers, and other businesses. Therefore, designing *eMarketplaces* requires embodying greater levels of business knowledge within the *eMarketplace* transactions, activities, and service definitions. Additionally, it requires a greater degree of communication, coordination, and cooperation within and among the business entities and their systems in the *eMarketplace*. In other words, the *eMarketplace* architecture represents an integrated body of people, systems, information, processes, services, and products.

Enterprise Model and Ontologies

At the heart of the integration architecture for an *eMarketplace* is a model of the enterprise. It is an abstract representation of the structure, activities, processes, information, resources, people, behavior, goals, rules, and constraints of the *eMarketplace*. From an operational perspective, the enterprise model captures what is planned, what might happen, and what has happened. Therefore, it supplies the information and knowledge necessary to support the operations of an *eMarketplace*. An appropriate *eMarketplace* architecture should support enterprise-modeling ontologies. An ontology is a vocabulary along with some specification of the meaning or semantics of the terminology within the vocabulary. The objective is to provide a shared and common understanding of a domain that can be communicated to people, application systems, and businesses. In an *eMarketplace* model, ontologies are integrated or related to support reasoning among the elements of the model.

Market Structure and Economy Model

An important aspect of the *eMarketplace* is the economic model of its structure. A market structure governs the trading process and defines the formal rules for market access, traders' interactions, price determination, and trade generations. In classical economic theory there are several market models for specific trading situations and structural behaviors. In the commodity market model, various suppliers and consumers participate to trade goods/services (commodity) of the same type. The market price is publicly agreed upon for each commodity independent of a particular supplier. All consumers and suppliers decide whether and how much to buy or sell at each agreed-upon price. The challenge in this market structure is to deploy a pricing methodology that produces price adjustments that bring about market equilibrium (i.e., equalizes supply and demand). In an auction-based market, each participant (both consumers and suppliers) acts independently and contracts to buy or sell at a price agreed upon privately. An auction-based *eMarketplace* is a form of centralized facility, or clearinghouse, by which costumers and suppliers execute trades in an open and competitive bidding process.

There are many situations where effective coordination cannot be entirely determined by the market forces. In bargaining, both customers and suppliers have their own objective functions and they negotiate with each other as long as their objectives are met. The participants can engage in direct negotiations with each other using their respective bargaining strategies to arrive

at a "fair" price for a particular item. This market structure does not support a specific negotiation protocol; rather, the participants will use an unrestricted bidding protocol. A major challenge in this structure is how to enable any participant to determine the "fair" price.

Supply-Chain Integration and Management

An *eMarketplace* can be treated as a physically and logically distributed system of interacting autonomous business entities. Yet, there is a need for well-accepted interoperability standards, which must be meshed for supply-chain integration to meet business demands. Conceptually, a supply chain manages coordinated information and material flows, production operations, and logistics of the *eMarketplace*. It provides the *eMarketplace* with flexibility and agility in responding to customer demand shifts without conflicts in resource utilization. The fundamental objective is to improve coordination within and between various participant business entities in the supply-chain. In an *eMarketplace* setting, supply-chain management can be viewed as a cooperative distributed problem-solving activity among a society or group formed by autonomous business entities that work together to solve a common problem (Smirnov & Chandra, 2000). The group is responsible for coordination throughout the supply chain, whereas each member provides specialized expert knowledge and product and process technology to the supply chain. The decision-making process is centralized for the group, but decentralized for the local decisions of each member.

Foundation Architecture for Integration

The architecture of the *eMarketplace* provides the foundation to integrate and leverage the participants' resources, such as applications and databases. Traditionally, the foundation technology that enables enterprises to connect resources together is known as *middleware*. Mainstream middleware solutions focus on integration at the data-level. There are several commercial middleware products and standards, such as OMG CORBA™ (Object Management Group, Inc. 1995), J2EE™ (Java™ 2 Platform, Enterprise Edition), and .NET (which has superseded DCOM, the Distributed Component Object Model), that focus on providing infrastructure tools and frameworks of integration. Enterprise application integration (EAI) is a trend that has recently emerged in designing middleware technology with an objective to ease the burden and lower the costs of application integration. However, different EAI solutions are developed to accommodate different levels of integration requirements. Object-level integration

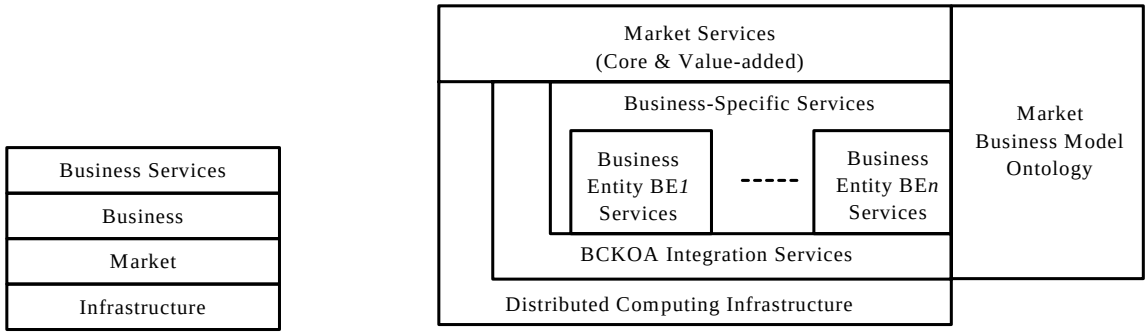
provides synchronization of data between different applications or databases. Business process-level integration extends the object-level by supporting multiple, distributed, and heterogeneous applications. Finally, cross-enterprise process-level integration involves multiple, distributed, heterogeneous business-process applications across different enterprises. While EAI solutions focus on technology-centered integration, other approaches focus on integration as an architectural aspect. One approach is a mediator-based architecture (Wiederhold, 1992), which comprises a layer of "intelligent" middleware services to link data resources and applications, such as integrating data from multiple sources in a way that is effective for the client application. Another approach is the facilitator (Genesereth, 1992), in which integration is based on the principle that any system (software or hardware) can interoperate with any other system without the intervention of human users or their developers. This level of automation depends on supporting ontologies to describe the resources. Facilitators use metalevel information in converting, translating, or routing of data and information.

FUTURE TRENDS: AGENT-ORIENTED *eMARKETPLACE*

The development of an architecture for an *eMarketplace* requires a new design paradigm, improved integration architectures, and services. In this architecture, the *eMarketplace* is a cooperative distributed system composed of economically motivated software agents that interact cooperatively or competitively, find and process information, and disseminate it to humans and to other agents. The architecture also supports common economic services and commerce transactions, such as pricing, negotiation, and automated supply chains, as well as cross-enterprise integration and cooperation.

Fundamentally, integration can be viewed as an abstraction level at which a distributed system environment can be described as a collective coherent universe of cooperative entities. In a cooperative distributed system, integration is captured at the foundation architecture that supports all the entities' individual architectures, and therefore, the complete computing environment. Here we describe a business-centric knowledge-oriented architecture (BCKOA) for cooperative distributed systems. The main elements of BCKOA include domain services, integration services, and a domain ontology. Furthermore, BCKOA provides three families of integration services: ontology and semantic integration services; coordination and cooperation services; and wrapping services. Based on our premise that an *eMarketplace* is a coherent

service-oriented universe, the BCKOA based *eMarketplace* is shown in Figure 1 (b), which builds upon the abstraction architecture of the *eMarketplace* in Figure 1 (a) (Ghenniwa 2001).



(a) Abstraction layers for *eMarketplace* **(b) BCKOA-based *eMarketplace***

Figure 1: Use of BCKOA for the Architecture of an *eMarketplace*

All services (business, market, and integration) in a BCKOA-based *eMarketplace* usually involve complex and nondeterministic interactions, often producing results that are ambiguous and incomplete. Auctions and *ad hoc* service integrations are some examples. In addition, the dynamic nature of the environment requires that the components of the system be able to change their configuration to participate in different, often simultaneous roles in *eMarketplaces*. These requirements could not be accomplished easily using traditional ways of manually configuring software. For this domain, we strongly believe that agent-orientation is a very promising design paradigm for integration. In fact, such a paradigm is essential to model an open environment such as an *eMarketplace*, especially considering the multiple dynamic and simultaneous roles a single business-entity may need to participate in given *eMarketplace* sessions.

Agent technology provides the next step in the evolution of paradigms for computational modeling, programming methodology, and software engineering (Huhns, 2003; Huhns, 2001). The first principle of agenthood is that an agent should be able to operate as a part of a community of cooperative distributed systems, including human users. In our view, an agent model such as Coordinated Intelligent and Rational, Agent (CIR-Agent) (Ghenniwa, & Kamel, 2000), can be described as an individual collection of primitive components that provide a focused and cohesive set of capabilities. In the context of a BCKOA-based *eMarketplace*, an agent has a role that is related to a specific service category and is able to coordinate, cooperatively or competitively, with the other agents, including humans. An agent's role can be

categorized as user-interface, business-specific service, business-entity service, market service, or integration service.

User interface agents play an important and interesting role in many applications. The main functionality of user interface agents is to support and collaborate with users in the same work environment to achieve the users' goals.

Business-specific service agents are specialists that provide a collection of business-services available in the *eMarketplace*. Performing the functionality of a business service is typically the cooperative integration of several agents including business-entity agents and market service agents.

A business-entity service agent may be a representative in the *eMarketplace* for some functionality that is based on legacy applications or libraries, such as a product catalogue Web site. Market service agents are specialists that provide a collection of functions for the generic *eBusiness* in an *eMarketplace* environment in which a single entity (usually an agent) can perform its tasks in the *eMarketplace*.

Market service agents are horizontal, in the sense that they are used in several business domains by several business entities. Examples of core services are dynamic trading services, such as commodity market and Vickery auctions (Wellman, 1993; Varian, 1995), and supply-chain integration and management. The commodity market service governs the trading behavior of the participant business entities in the session. This service recognizes three types of agents, namely, market-mediators, consumers, and suppliers. Consumers and suppliers are roles assigned to agents of type business-entity service or user interface. These roles are assigned upon registration with the market session. Each market session is assigned to a mediator to coordinate the actions taken by consumers and suppliers in a way that will eventually clear its respective market. An alternative market session is the auction market. It recognizes three types of agents representing suppliers, an auctioneer, and buyers. However, the trading process mainly involves the auctioneer and buyers (or bidders). Each bidder agent declares its valuation function to the auctioneer. Under the general Vickery mechanism, it is in the interest (the dominant strategy) of the bidder to report its true valuation function.

Agent-based supply-chain integration and management, in an *eMarketplace*, is a cooperative distributed problem-solving service. Using this service, business participants need only describe

their supply processes using OAG standard business documents and UML interaction diagrams. The methodology, summarized in Figure 2, uses—and begins to formalize—the business object documents (BODs) that OAG and RosettaNet are standardizing. It provides a basis for the convergence of multiple standards for supply-chain management, which could become ready-to-use technology by different participant business entities in the *eMarketplace*.

Integration agents are specialists that provide a collection of integration functions for a cooperative distributed system in which a single entity (agent, component, object, etc.) can perform its tasks. Integration services are used by several distributed entities.

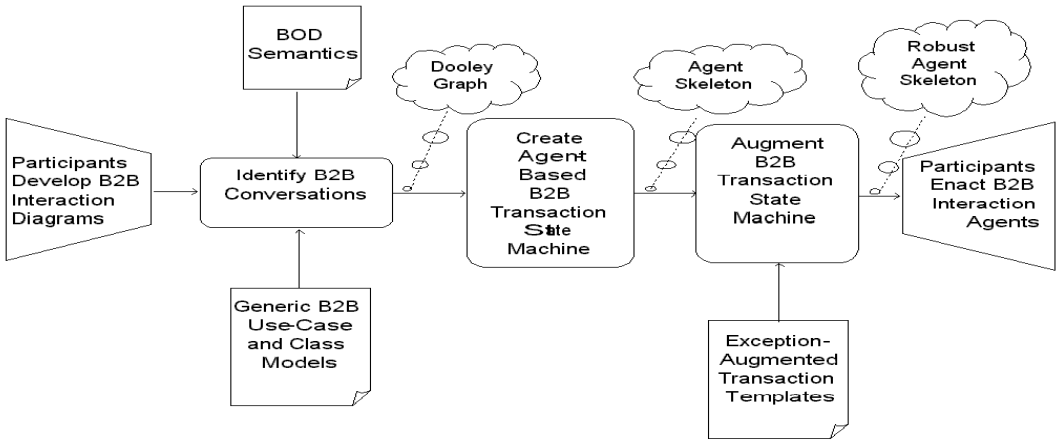


Figure 2. Agent-Based Coordination Methodology for B2B Automation

To validate and experiment with our analyses and foundations described in the previous sections, we have developed a prototype of an agent-oriented BCKOA for an *eMarketplace* with virtual business entities. They register with the *eMarketplace* for both purchase and sales services. Both services use a BCKOA-based computation environment. Individual customers or business-entity personnel in the *eMarketplace* can participate in the market through their user interface agents. Similarly, an agent in the eMarketplace represents each business-entity service. These agents provide thin, intelligent, autonomous interfaces for the business-entity services, which might be based on legacy applications. The implementation utilizes the JADE platform (Bellifemine e*t al* 1999), which is a software framework to develop agent applications in compliance with the FIPA specifications (The Foundation for Intelligent Physical Agents 1998) for multiagent systems. Although our implementation takes advantage of the JADE platform and FIPA specifications, the architecture of the economic market structure and the application agents is based on the CIR-Agent model and BCKOA.

CONCLUSIONS AND FUTURE WORK

This chapter presented state-of-the-are research on developing an agent-oriented architecture for an *eMarketplace* that provides intelligent enterprise integration. The objective is to establish an engineering foundation for an *eMarketplace*. To this end, several business and design issues have been discussed and analyzed for *eMarketplaces*. This chapter has emphasized an agent-based business-centric and knowledge-oriented approach. An agent-oriented architecture provides an abstraction of the domain entities and applications independent of any specific technology. An *eMarketplace* supports several types of agents, namely, user-interfaces, business-specific services, market services, and integration services. In continuing the research, our main concern will be investigating the computational effectiveness of agent-oriented *eMarketplaces* as well as exploring the appropriate techniques to support secure, reliable, and effective transactions.

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Terms and Definitions

eBusiness: The use of the Internet along with other electronic means and technologies to conduct within-business, business-to-consumer, business-to-business, and business-to-government interactions.

eMarketplace: An electronic marketplace. It is a business model for a particular kind of eBusiness, which aggregates potentially large numbers of business partners (including buyers, sellers, and intermediaries) and allows them to interact according to a variety of market structures, such as a commodity market, an auction, or an exchange. The result can be significant cost savings.

Market Structure: Governs the trading process and defines the formal rules for market access, traders' interactions, price determination, and trade generations.

Commodity-Based Market: A form of a market in which various suppliers and consumers participate to trade goods and services, i.e., commodities, of the same type. The market price is publicly agreed upon for each commodity independent of any particular supplier. All consumers and suppliers decide whether and how much to buy or sell at each agreed-upon price.

Auction-Based Market: A form of centralized facility or clearinghouse by which consumers and suppliers execute trades in an open and competitive bidding process.

Agent Orientation: The next step in the evolution of computational modeling, programming methodologies, and software engineering paradigms. Aspects of agent orientation include both cooperative and competitive interactions, knowledge, economic and logical rationality, and learning, all of which are useful for designing distributed computations in open dynamic environments.

Enterprise Integration: Refers to the plans, methods, and tools aimed at modernizing, consolidating, and coordinating software applications among a group of businesses or organizations that interact as consumers and suppliers. Enterprise integration might involve developing a total view of the organizations' businesses and applications, seeing how existing applications fit into the new model, and then devising ways to efficiently reuse what already

exists while adding new applications and data. Enterprise integration is done for the mutual benefit of all organizations involved.

Ontology: A representation of knowledge specific to some universe(s) of discourse. It is an agreement about a shared conceptualization, which includes conceptual frameworks for modeling domain knowledge and agreements about the representation of particular domain theories.

Supply-Chain Management: All services that help an enterprise manage its procuring, purchasing, warehousing, distributing, consuming, and monitoring the supplies it utilizes in its operation. They enable management to receive the information needed for making decisions along the chain from acquiring raw materials to manufacturing products to distributing finished goods to retailers. The services consist of consulting, project design, compliance reporting, deployment of resources, and product qualification along the entire chain.