Web Service for Knowledge Management in E-Marketplaces

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ABSTRACT

A common strategic initiative of organizations engaged in electronic business (e-business) is the development of synergistic relations with collaborating value-chain partners to deliver their value proposition to customers. This requires the transparent flow of problem specific knowledge to partner organizations over highly integrated information systems. Transparent exchange of information and knowledge across collaborating organizations requires technological foundations for integrating business processes using software architectures built upon industry standards. The unambiguously interpretable flow of knowledge to inform online business processes is a challenging task with significant competitive benefits for organizations that take technical initiative. Infomediary organizations can serve the e-business need for exchange of knowledge and information through value-added knowledge services to participating firms in the value chain through intelligent software systems integrated with the Web Services Architecture. We define knowledge services as the "exchange of problem domain-specific knowledge to inform decision activities of specific e-business processes, facilitated by an infomediary using intelligent software systems and the Web Services Architecture." This research presents a knowledge services framework, founded on the Web Services Architecture,*

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to enable the transparent exchange of knowledge between intelligent software systems that manage processes of organizations engaged in e-business in the knowledge-based economy. The objective is to enable informed and knowledge-based discovery of business partners from among the multitude online, and to support knowledge-rich e-business processes that cut across the value chain and deliver the value proposition to the customer.

Keywords: *Web service, knowledge management, intelligent agent, ontology, electronic marketplace.*

INTRODUCTION

Competitive forces in the digital economy require that organizations continually seek innovative solutions to streamline their business processes. Strategies such as supply chain management, collaborative product development, and enterprise resource planning have been strategically employed in the past decade to support the development of synergistic relations with collaborating organizations in the value chain in delivering the value proposition to customers. The past decade has seen significant advances in Web-based technologies for the integration of heterogeneous systems across organizations required to serve a variety of inter-organizational process needs, including collaborative product design, multi-party business transactions, and outsourced business functions. These developments provide the foundation for e-business strategy pursued by businesses of all sizes and across industries. We refer to e-business as "*an approach to achieving business goals in which technology for information exchange enables or facilitates execution of activities in and across value chains, as well as supporting decision making that underlies those activities*" (Holsapple and Singh, 2000).

Businesses operate in a knowledge-driven economy and increasingly function as knowledge-based organizations (Holsapple and Whinston, 1987). In such knowledge-rich environments, e-businesses must explicitly recognize knowledge and the processes and technologies for knowledge management and exchange across participants in their value chain (Holsapple and Singh, 2000). The role of infomediaries is well recognized in the facilitation of information sharing, exchange, and aggregation for electronic marketplaces (e-marketplaces). According to Grover and Teng (2001), infomediaries "*are to information markets in the electronic market space what intermediaries, such as wholesalers and retailers, are to physical markets in more traditional market spaces,*" (see glossary for detailed definition of an infomediary). Infomediaries play a critical role in e-marketplaces by managing information flows to support business processes required of the e-marketplace. Transparent exchange of knowledge among collaborating organizations requires a technical foundation for business process integration through standards-based software architectures. Recent developments in the Web Services Architecture (WSA) provide such a foundation using eXtensible Markup Language (XML), HyperText Transfer Protocol (HTTP), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL – http://www.wsdl.org) and Universal Description, Discovery and Integration (UDDI - http://www.uddi.org) (Gottechalk et. al., 2002). UDDI allows businesses to advertise their services to potential customers, who can query a repository and find specific service descriptions in WSDL. SOAP messages can be used to exchange information and knowledge that is represented using XML among participating firms.

E-business' need for exchange of knowledge and information can be served through infomediary organizations that provide value-added *knowledge services* to firms participating in the value chain, by adopting intelligent software systems integrated with the Web Services Architecture. We define knowledge services as *exchange of problem domain-specific knowledge to inform decision activities of specific e-business processes, facilitated by an infomediary using intelligent software systems and the Web Services Architecture.* This research presents a knowledge services framework, founded on the Web Services Architecture, to enable the transparent exchange of knowledge between intelligent software systems that manage online processes of e-business organizations. The objective is to enable informed, knowledge-based discovery of business partners from among the multitude online, and to support knowledge-rich e-business processes that span the value chain.

BUSINESS AND TECHNICAL FOUNDATIONS FOR KNOWLEDGE SERVICES

The information and knowledge flows needed to support e-business require integrative systems that support e-marketplaces in providing the mechanisms for firms participating in the value chain. Critical roles of the e-marketplace include ***discovery*** of buyers and suppliers that meet each others' requirements; ***facilitation*** of transactions to enable information flows leading to the flow of goods and services between buyers and suppliers; and ***support*** of decision processes that lead to the development of collaborative relationships between e-marketplace participants (Bakos, 1998). Infomediaries *are e-business companies that leverage the Internet to unite buyers and suppliers in a single efficient virtual market and facilitate the consummation of transactions* (Grover and Teng, 2001). Infomediaries coordinate and aggregate information flows to support e-business processes and provide value-added services to enhance the information processes of the e-marketplace through deciphering complex product information and providing independent and observed assessment of the commitment of individual buyers and sellers. This role of an infomediary is applicable to both public and private e-marketplaces.

Transparency in information flow between systems of partner organizations requires a common vocabulary to express problem-specific knowledge, as well as relevant business rules to assist autonomous system entities and decision makers in solving specific business problems. These requirements are in addition to the technical implementation platform independence currently delivered by selected Web-based technologies such as the WSA. Heterogeneous systems involved in inter-organizational e-business processes need the ability to share data, information, and knowledge. While it is evident that information is involved in the conduct of e-business, e-business employs multiple types of knowledge, of which information is one component.

Recently, intelligent agents have gained significant interest as model-based abstractions to enable various collaborative applications in e-business (Papazoglou, 2001). An intelligent agent is "*a computer system situated in some environment and that is capable of flexible autonomous action in this environment in order to meet its design objectives*" (Jennings and Wooldridge, 1993). Intelligence, delivered through intelligent software agents for information and knowledge flows in e-marketplaces, can help increase efficacy for its participants and reduce users' cognitive load. Liang and Huang (2000) studied the application of intelligent agents to facilitate trading and present a three-layer architecture for organizing intelligent agents for e-commerce that discusses agent types and the knowledge used by each type of agent. Recently, Yang and Chung (2003) presented an architecture specifically focused upon reducing the cognitive load of human decision makers by using software agents as intermediaries between users and information providers. It is essential that decision makers be supported through knowledge-driven interfaces and system entities that reduce cognitive load. Additionally, Kwan and Balasubramanian (2003) highlighted the need to recognize the role of *context* in the creation, exchange, and use of knowledge. Moreover, Antoniou and Arief (2001) pointed to the critical need to formalize business rules to support automated e-business processes carried out by intelligent software agents.

In this paper, we extend and enhance the concept of infomediary to provide knowledge services for the e-business processes of organizations in a knowledge-based economy. This fundamentally shifts the contribution of an infomediary from managing pure information flows to flows that incorporate knowledge, of which information is only a part. Ontologies, specification of conceptualizations (see glossary for detailed definition), allow for a common and shared understanding of the domain-specific concepts and the relations between them (Staab et. al., 2001). There is a critical role for ontologies in order for infomediaries to provide the services required of e-marketplaces in creating integrative views of information and knowledge in e-marketplaces (Singh et. al., forthcoming). Ontologies allow for unambiguous representation of domain knowledge. The choice of XML-based standard representation of ontologies allows them to be shared among integrative system components, including multiple agents responsible for various business processes. This allows for a common understanding of business concepts and process elements across multiple human and software agents through the knowledge contained in ontologies.

An e-business operates within knowledge networks (Warkentin et. al., 2001), where the timely flow of accurate knowledge and information is critical to the competitive positioning of the firm. The timely availability of problem -specific knowledge that is useful for the business problem under consideration is a useful service that extends the knowledge management processes of organizations. In addition, there is a need for an integrative architecture to deliver problem-specific, machine-interpretable information and knowledge over highly integrative systems. This research fills this gap in the literature by presenting the knowledge services architecture that builds upon and extends recent research on intelligent agents, e-business, knowledge management, and knowledge networks to enable the flow of knowledge and information among participating e-businesses in the value chain.

REQUIREMENTS FOR KNOWLEDGE SERVICES IN E-MARKETPLACE

Emerging business models are causing fundamental changes in organizational and inter-organizational business processes by replacing conflict with cooperation as a means to be economically efficient (Beam, 1998). Operationally, knowledge management (KM) is "*a process that helps organizations find, select, organize, disseminate, and transfer important information and expertise necessary for activities such as problem solving, dynamic learning, strategic planning and decision making*" (Gupta et. al., 2000). From an organizational perspective, it is the management of corporate knowledge that can improve a range of organizational performance characteristics by enabling an enterprise to be more "intelligent acting" (Wiig, 1993). A realization of the need for greater collaboration among trading partners is fueling the growth of KM to help identify integrative and interrelated elements to enable collaborations. Many organizations are developing KM systems designed specifically to facilitate the sharing and integration of knowledge for increasing collaboration to gain a competitive advantage. Transparent information and knowledge exchange across seamlessly integrated systems over globally available Internet technologies, such as the knowledge services architecture described in this paper, enable *information partnerships* among participants across the entire value chain. In addition, such functionality enhances the utility and extensibility of knowledge management initiatives of an organization by adding the ability to exchange specific and transparent knowledge-utilizing, unambiguously-interpretable, standards-based representation formats. Implementing and managing such high levels of integration over distributed and heterogeneous information platforms such as the Internet is a challenging task with significant potential benefits for organizations embracing such collaboration. Organizations can gain significant benefits from these initiatives including optimized inventory levels, higher revenues, improved customer satisfaction, increase in productivity and real-time resolution of problems and discrepancies throughout the supply chain. The vision is to achieve dynamic collaboration among business partners and customers throughout a trading community or e-marketplace through information and knowledge exchange. To accomplish the level of collaboration required for e-business integration across the value chain, businesses need a comprehensive architecture to facilitate sharing of information and knowledge between partners.

Intelligent Agents and E-Business

Intelligent software agents can be used to facilitate the discovery and integration of e-business processes and in the management of information and knowledge flows among participating firms. Intelligent agents are action-oriented abstractions in electronic systems, entrusted to carry out various generic and specific goal-oriented actions on behalf of users. The agent paradigm can support a range of decision making activity including information retrieval, generation of alternatives, preference order ranking of options and alternatives, and supporting analysis of alternative-goal relationships. In this respect, intelligent agents have come a long way from being digital scourers and static filters of information to active partners in information processing tasks. Such a shift has significant design implications for the abstractions used to model information systems, objects or agents, and for the architecture of information resources that are available to entities involved in the electronic system. Klusch (2001) points out that the specific autonomous behavior expected of intelligent agents depends on the concrete application domain and the expected role and impact of intelligent agents on the potential solution for a particular problem for which the agents are designed to provide cognitive support.

Muller (1997) identifies three minimal criteria of the application domain to apply agent technology: The application domain should: exhibit *natural distributivity*, e.g., autonomous entities, geographical distribution, distributed data; require *flexible interaction*, e.g., there is no *a priori* assignment of tasks to actors, and there are no fixed processes; and be embedded in a *dynamic environment*, e.g., our physical world, artificial worlds like the Internet, or the world of finance. E-marketplace systems (Kang and Han, 2002) are distributive, flexible, and dynamic environments that are well-suited for the application of agents. Agent-based systems may consist of a single agent engaged in autonomous goal-oriented behavior, or multiple agents that work together to exhibit granular as well as system-wide goal directed behavior. The general multi-agent system is one in which the interoperation of separately developed and self-interested agents provide a service beyond the capability of any single-agent model. Such multi-agent systems provide a powerful abstraction that can be used to model systems where multiple entities, exhibiting self-directed behaviors, must coexist in an environment and achieve the system-wide objective of the environment. Multi-agent systems can be used to enhance collaboration among supply chain partners and participate with human agents to organize, store, retrieve, search, and match information and knowledge for effective collaboration among supply chain participants.

XML-Based Standards and Web Services Architecture for Knowledge Representation and Exchange

While the popularity of the World Wide Web is partially attributable to the simplicity of HTML in usage and content presentation, HTML has limited extensibility for data description, which limits its use for content sharing by application software in distributed environments. The use of XML and related standards developed by the W3C (http://www.w3c.org) overcomes these limitations through extensible tags to describe domain-specific entities and their attributes. XML Schema (http://www.w3c.org) allows unambiguous description of XML document structure (meta-data) and their contents (data). Initiatives to develop technologies for the "Semantic Web" (Berners-Lee et. al., 2001) make the content of the Web unambiguously computer-interpretable, thereby making it amenable to agent interoperability and automated reasoning techniques (McIlraith et. al., 2001). Recently, there have been several efforts to build on Resource Description Framework (RDF) with more AI-inspired knowledge representation languages (Fensel, 2000). These initiatives are extremely promising for automating online processes through agent interoperability and automated reasoning; however, they are in rudimentary stages of development.

Web Services technology consists of components to which applications send requests for processing and data services. Web Services standards define the envelope and transport mechanism for information exchange between two entities, where the message essentially contains an XML document. The Web Services framework consists of the Web Services Definition Language (WSDL – http://www.wsdl.org) to describe Web services in XML format and provide a basis for tools to create appropriate message packets. The Universal Discovery Description and Integration (UDDI – http://www.uddi.org) allows for the creation of repositories of Web services that can be dynamically discovered over the Internet. This vision of the Web consists of services, information, and processing that can be dynamically discovered and used by human and software agents seeking specific information and processing capabilities.

The technical realization of on-demand, context-specific and useful exchange of knowledge represented in an unambiguously machine-interpretable format between collaborating organizations to integrate systems responsible for automating their online e-business processes is a challenging task (Abecker et al., 2000). It requires the explication of a commonly agreed-upon and shared set of attributes that describe context-specific information important to the system. *Ontologies provide shared and common understanding of a specific domain that can be communicated between disparate application systems, and therein, provide a means to integrate the knowledge used by online processes employed by electronic commerce organizations* (Klein et al., 2001). A system managing available knowledge must comprise facilities for creation, exchange, storage, and retrieval of knowledge in an exchangeable and usable format, and facilities to use the knowledge in a business activity (Alavi and Leidner, 1999). In recent years, advances in systems support for decision making to solve business problems have seen increased use of artificial intelligence-based techniques for knowledge representation (Yang and Chung, 2003; Staab et al., 2001; McIlraith et al., 2001). Intelligent systems incorporate intelligence in the form of knowledge about the problem domain, with problem representation and decision analytical aids to inform the decision process, provide problem domain representation, and reduce the decision maker's cognitive load.

Potentially, these technologies allow for software programs to be accessed through the Web, to provide information, automated program communication, and the discovery of services. The realization of the potential of knowledge services requires ontology and knowledge of actions to be performed. This is required to facilitate the adoption of these technologies by organizations and realize their potential. For e-business organizations, they present the potential for the automatic discovery of, and collaborations with, partners through which business relationships can be developed dynamically. This is particularly useful in business models where buyers and suppliers must dynamically discover each other and transact commercially, such as the information-based e-marketplaces (infomediaries) and supply chain relationships.

Infomediary-Based E-Marketplace: Facilitating Buyer-Supplier Interaction

Infomediaries play a critical role in e-marketplaces by managing the information flows to support business processes required of the e-marketplace. Buyers and suppliers explicate their demand or supply functions and seek market participants to meet their requirements. Discovery involves the dynamic matching of buyers and suppliers, based on current requirements. This is influenced by the experiences of other buyers and suppliers in terms of reliability and trustworthiness. Infomediaries provide valuable insight to this process through experiential transactional histories that enable reputation-based information for subsequent transactions. Once a buyer and a supplier are selected, the infomediary facilitates transactions by enabling information flows between them, which ultimately lead to the flow of tangible goods or services. The infomediary supports buyers and suppliers by providing value-added services that manage the information processes of the e-marketplace through the deciphering of increasingly complex product information, decomposing bills of materials and other enterprise resource planning documents. The infomediary also provides support of the human decision process of selecting a buyer or supplier by providing independent and observed assessment of the commitment of individual buyers and sellers. This is facilitated through the availability of transaction histories with information about the past experiences of other buyers' reliability and trustworthiness of the supplier. The core binary collaboration, illustrated in Figure 1,

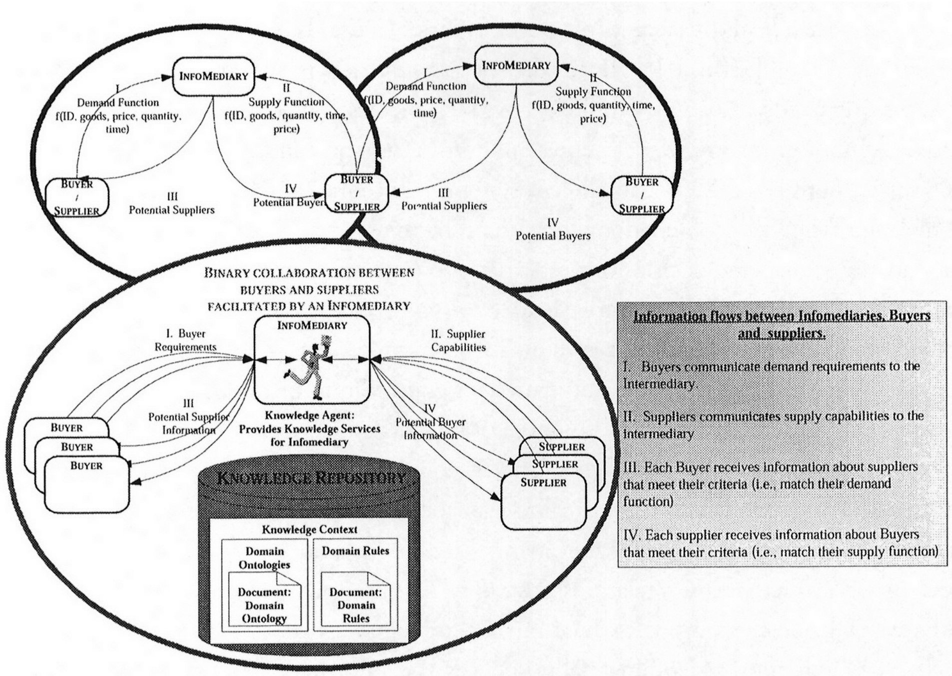

Figure 1. Infomediaries facilitate transactions between buyers and suppliers in e-marketplaces and become vital repositories of knowledge about transactions in the value chain.

represents the core process involved in the economic marketplace and provides the fundamental interaction unit, supported by most e-marketplaces with varying degrees of automation. In this article, we make no distinction between public and private e-marketplaces since both are infomediary-enabled e-marketplaces. Public e-marketplaces, such as ChemConnect (http://www.chemconnect.com/), are hosted and offered by third parties along the supply chain, while private e-marketplace are hosted by a central hub company, such as Hewlett-Packard, to create efficiencies and cost-effectiveness for participants.

An analysis of the infomediary business model shows that buyers and suppliers seek distinct goal-oriented information capabilities from the infomediary – they provide decision parameters through their individual demand or supply functions and they seek buyers or suppliers who can meet their requirements. This discovery activity involves buyers and suppliers searching for a match of their requirements, through the infomediaries-enabled e-marketplace. This discovery process may be influenced by historical information including the past experiences of other buyers' reliability and trustworthiness of the supplier (Salam et al., forthcoming). Infomediaries become vital repositories of knowledge about buyers, suppliers, their product, and their service offerings. The infomediary can provide valuable information by serving as the repository of experiential knowledge of transactional histories and the nature of exchanges among buyers and suppliers. Figure 1 illustrates a schematic for extended infomediary-based e-marketplaces. In providing decision parameters through their expressed individual demand and supply functions, participants in an e-marketplace look for the discovery of buyers and suppliers who meet their needs. The infomediary provides valuable information to this decision process by serving as the repository of experiential knowledge of transactional histories for both buyers and suppliers. To maintain and enable these knowledge services of infomediaries, transaction information from buyers and suppliers is collected to develop knowledge to inform the discovery process for subsequent transactions.

Requirements for knowledge services in e-marketplaces can be broadly identified based on the need for businesses to exchange knowledge. Unambiguous representation of domain knowledge utilizing standard-based knowledge representation formats allows ontologies to be shared among integrative system components, including multiple agents responsible for various business processes. This allows for a common understanding of business concepts and process elements across multiple human and software agents through the knowledge contained in ontologies. This knowledge exchange is only possible using ontologies, which must be developed by the infomediary and accepted by participating firms as a requirement for automated knowledge sharing. Secondly, there is a need to represent the rules for processing and interpreting transactions based on the ontologies. The third requirement is to develop a mechanism to represent ontologies and rules that allows for interpretation by both intelligent agents and human decision makers. These requirements define the systems components needed for representing, storing, managing, and using ontologies and corresponding rules for knowledge exchange among participating firms. Without integration of intelligence and knowledge across marketplaces through a knowledge services framework, the benefits of intelligent knowledge-based e-business integration remain elusive.

KNOWLEDGE SERVICES COMPONENTS

Organizations engaged in e-business processes in the knowledge-based economy are members of knowledge networks. Knowledge networks allow their participants to create, share, and use strategic knowledge to improve operational and strategic efficiency and effectiveness (Warkentin et al., 2001). Infomediaries play a vital role in the exchange of knowledge and information in these knowledge networks embedded within value chains. Knowledge services, composed and delivered through the integration of intelligent agents and the Web Services Architecture, provide a mechanism for the exchange of domain-specific knowledge to inform decision activities embedded within e-business processes weaving through these knowledge networks. To operationalize knowledge services, we need knowledge representation using standardized ontologies and knowledge context.

Knowledge Representation and Ontologies

The on-demand exchange of knowledge, specific to and useful for solving the problem under consideration, requires explicit definition of the common attributes that describe the specific entities important to the problem context. It also requires this information to be shared by system entities in a manner that allows for interpretation and the ability to infer action implication. This is required for the knowledge representation and exchange to be useful to system entities and decision makers in organizations. Recent advances in intelligent systems support increasingly incorporate intelligent techniques for knowledge representation about the problem domain with decision analytical aids to support the decision process and reduce the decision maker's cognitive burden. Ontologies represent an advance, developed in the area of artificial intelligence, to further the sharing and use of a common understanding of a specific problem that can be exchanged between application system entities on online e-business processes to provide a means to integrate the knowledge used by processes employed by e-business organizations. Ontology for this purpose describes the semantics of the constructs that are common to the online processes, including descriptions of the data semantics that are common descriptors of the domain context. Staab et al. (2001) describe an approach for ontology based knowledge management through the concept of knowledge metadata that contains two distinct forms of ontologies which describe the structure of the data itself and describe the issues related to the content of data.

The performance of a particular method in modeling human decisions depends on the conformance of the method with the decision makers' mental model of the decision problem (Sung et al., 1999). Decision trees are a popular decision modeling technique with wide applicability to a variety of business problems. Their utility derives from the ability to offer a high level of interpretability unique to symbolic models. Decision trees allow for easy generation of decision rules, making them ideal for providing insights and explanations to non-technical users. Decision trees are especially suitable for decision problems that require the generation of human-understandable decision rules based on a mix of classification of categorical and continuous data (Sung et al., 1999). They clearly indicate the importance of individual data to the decision problem, and are therefore useful in reducing the cognitive burden for the decision maker. It is the task of the systems designer to select the modeling methodology and knowledge representation mechanism based upon the nature of the problem and the characteristics of the decision makers.

The knowledge services architecture presented here employs ontological descriptions of the problem domain, including the domain descriptions that describe the entities that are important to the context of the online process, and description of the rules that are employed in making decisions regarding the business context. The latter employs a decision tree representation of rules to represent knowledge about the problem domain.

Knowledge Context

Operationally, we represent knowledge using the *domain document* comprising ontological information about the problem domain and the *rules document* comprising business rules relevant to the specific business context. The domain document contains attributes relevant to the business domain problem under consideration. The rules document contains business rules that suggest and explain user actions and decision paths. In this context, users can be software agents acting autonomously on behalf of users or directly in conjunction with human users to fulfill their information requirements.

For example, a purchase decision would require information about the various attributes that describe the purchase decision, including price, quantity, and the item required by date. The problem domain also contains business rules that decide whether the purchase decision is *buy* or *don't buy.* This decision is made based upon values of these attributes for a specific instance of the decision problem. This represents contextual information about a business domain for which domain ontology and a set of business rules can be developed to model the buy-don't buy decision. Such decisions are integral to and representative of frequently occurring decision problems in e-marketplaces. The ontology representation and decision tree shown diagrammatically can be represented in XML format as shown in the XML documents in Figure 2. Thus, information regarding a business entity is represented in its attribute ontology and those attribute description are used to develop business rules that represent decisions in the given business context.

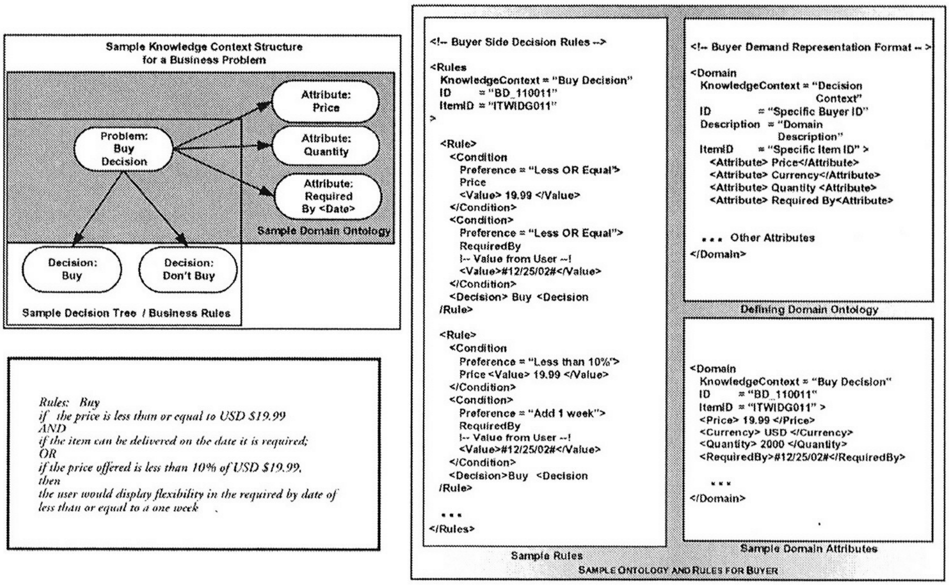

Figure 2. Domain Ontology, Business Rule and Knowledge Context for a Buyer

For example, as shown in Figure 2, a domain state can be represented through a set of specific values of the domain attributes. The Knowledge Context performs a simple matching function to match these provided attributes to the known set of rules and a rule is fired from the rule document. This results in the generation of a buy or don't-buy decision which can be explained through the set of attributes that comprise the rule. In the example shown in Figure 2, the user would be advised to buy the item "ITWIDG011" *if the price is less than or equal to USD $19.99 AND the item can be delivered on the required date; OR if the price offered is less than 10% of USD $19.99, then the user would display flexibility in the required by date of less than or equal to a one week.* Such knowledge of consumer preferences can be easily collected and codified and would provided valuable information to suppliers in developing their tactical positions in the e-marketplace. A parallel set of domain ontology and rules can be developed for suppliers seeking buyers for their goods. This knowledge architecture is extensible to multiple buyers for the same item since the buyers are essentially represented through their expressed preferences, or rules, in the context of the application.

On the supplier side, each supplier is represented in the e-marketplace by a supplier agent. A new supplier registers with the infomediary and is assigned a supplier agent to represent their behavior in the e-marketplace. A supplier agent receives ontologies for representation of their supplier's capabilities to the infomediary, comprising information on the products and services that they can deliver and additional parameters including price and delivery schedules. This may be done asynchronously and in parallel with the buyer agent communicating buyer demands to the infomediary. These information flows provide the required information for the infomediary to discover supplier capabilities with buyer needs in carrying out the discovery function. Upon discovery, suppliers receive information on buyers discovered to have requirements that match their supply capabilities. This is done irrespective of whether the buyer chooses to engage in transactions with the supplier. In other words, if a supplier is identified by the discovery agent as one whose capabilities match a certain buyer's needs, information about that buyer is communicated to that supplier's agent. This important information provides valuable feedback for a supplier to continually assess its operational capabilities and competitive positioning in the e-marketplace. Suppliers also provide feedback on completed transactions to the infomediary by communicating their level of satisfaction to the transaction agent.

Figure 3 illustrates domain ontology and rules for suppliers seeking buyers for their goods. The representation of the knowledge context for a supplier shown in Figure 3 contains a sample domain ontology from which representation of the supplier capabilities conforming to the domain ontology can be generated as shown. In addition, Figure 3 shows sample rules that may be available to the supplier agent. A matching of a set of attributes in the supply capabilities with the set of rules fires a rule from the rules document that results in a supply/don't supply decision for the supplier. In addition, this decision can be explained through a textual representation of the supply rules generated by the

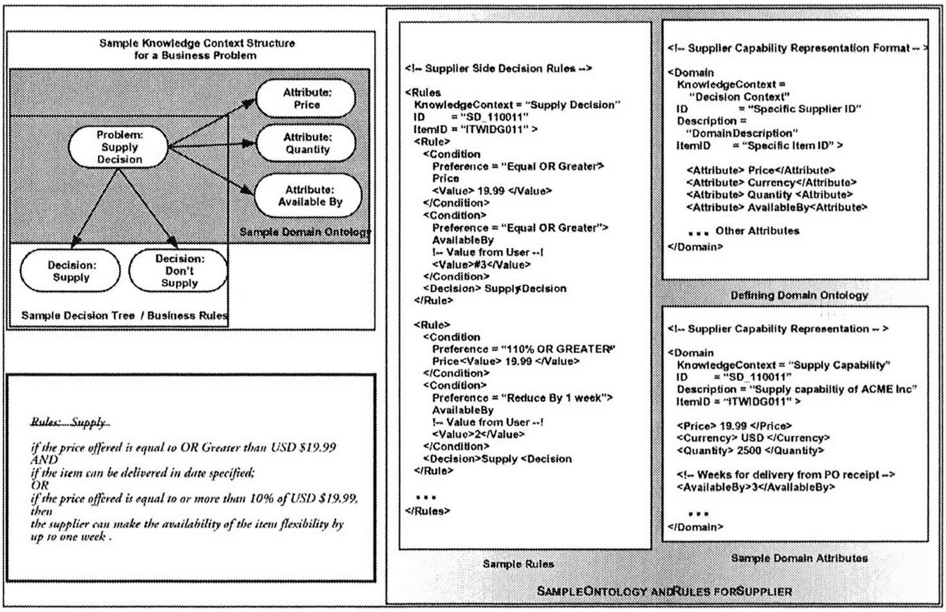

Figure 3. Domain Ontology, Business Rule and Knowledge Context for a Supplier

supplier agent, as shown in Figure 3. Supplier agents are informed of every potential buyer currently considering them for potential transactions. This information flow is provided by the infomediary and is compiled by aggregating information of all buyers evaluating the supplier for potential transactions. This information is provided to specific suppliers and represents the set of potential customers for the supplier. In addition, suppliers receive dynamic updates on potential transactions in the marketplace. Information about active transactions and potential customers provides critical demand and supply planning information for the current, upstream and downstream markets in the e-chain. In addition, this information allows suppliers to assess their competitiveness in the e-marketplace.

These representations provide the basis for the structure of a Knowledge Context that consists of domain ontology and rules that explicate advisable actions in terms of the attributes described in the domain ontology. The schematic in Figure 4 below illustrates the structure of a Knowledge Context and shows a schematic for incorporating multiple ontology and rule documents in a knowledge repository and available to users through the knowledge agent.

The Knowledge Context is actively managed through a wrapper component, called the Knowledge Context to expose its behaviors and provide a basis to instantiate multiple such components as Beans. Public methods of the Knowledge Context are presented as Web services through the knowledge agent, which manages their delivery to users and user agents. The Knowledge Context object, with its methods and contents and the interaction between the Knowledge Context object and the domain ontology and rules

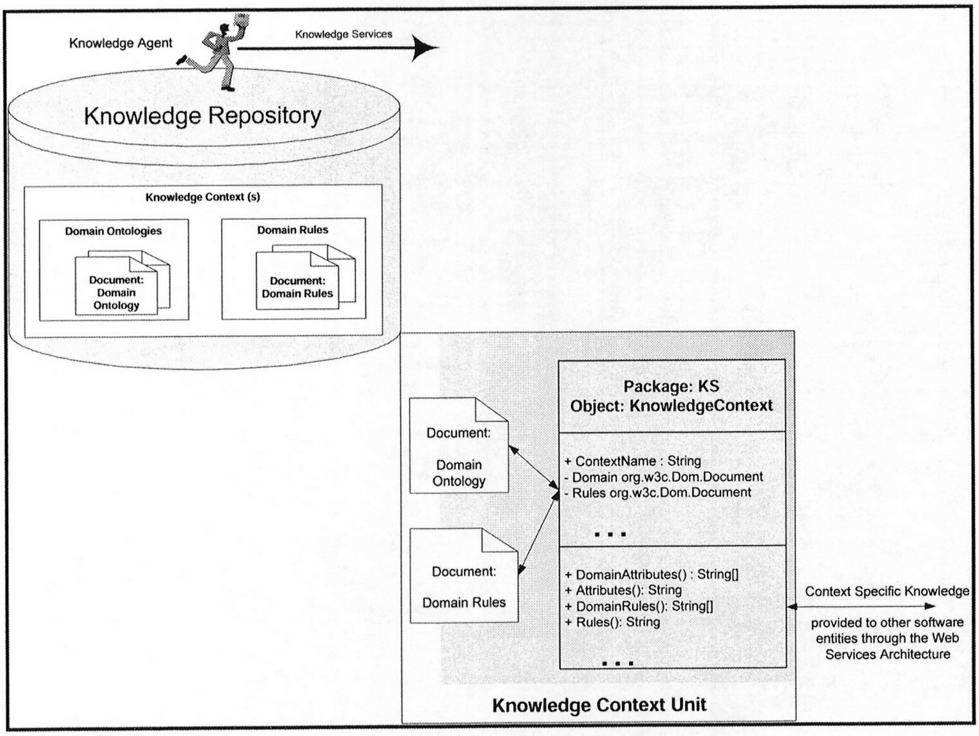

Figure 4. Multiple Knowledge Context modules constitute a knowledge repository which makes knowledge context available through a knowledge agent over the Web Services Architecture.

documents is shown in Figure 4. The public behaviors of the Knowledge Context object for a given domain entity define the basis for the set of Web services that are available for a specific entity about which the knowledge repository is able to provide information. A Knowledge Context object is a Java Bean that wraps and allows programmatic access to the information contained in the domain and rules documents with public methods to show the domain entity ontology and the business rules that are pertinent to the given business domain. The Knowledge Context provides a list of the various attributes that make up the business domain in order to inform the user, or user agent, of a common description of the various attributes that are pertinent to this business entity. With access to this domain ontology, provided by the Knowledge Context, the user application can share terminology to unambiguously refer to concepts and constructs that define the business domain under consideration. The Knowledge Context utilizes an internal representation of attributes and rules that allow the object to make decisions, with information about a particular set of circumstances described in terms of specific attribute values. The Knowledge Context object incorporates behaviors that allow it to share the attributes that comprise the ontology and the rules, in SOAP envelopes through the standard Web Services Architecture.

KNOWLEDGE SERVICES ARCHITECTURE AND KNOWLEDGE EXCHANGE

Knowledge services are domain-specific knowledge provided by the Knowledge Agent to users, through their agents, over heterogeneous information platforms using Web services as a foundation. Knowledge services are delivered through the Knowledge Agent to share domain-specific knowledge by presenting the returned parameters of the Knowledge Context object's methods to distribute domain context information and business rules as knowledge services. The Knowledge Agent performs the role of the manager for all services through the knowledge repository. It actively manages the information that is made available through the repository by managing the UDDI of service provided by the Knowledge Context objects. The Knowledge Agent represents the external interface through which users and user agents make requests for knowledge services provided by the knowledge repository. Figure 5 below shows a schematic for the presentation of knowledge services to the user agents.

Ease of interpretation of the exchanged content between agents requires uniformity of content on the structure and nature of requests between the knowledge agent and user agents. This implies that all exchange between the Knowledge Agent and the User Agent must conform to formats agreed upon *a priori* to their actual exchange. This is a principle contribution of ontologies and namespaces to the ability of Web services to deliver stan-

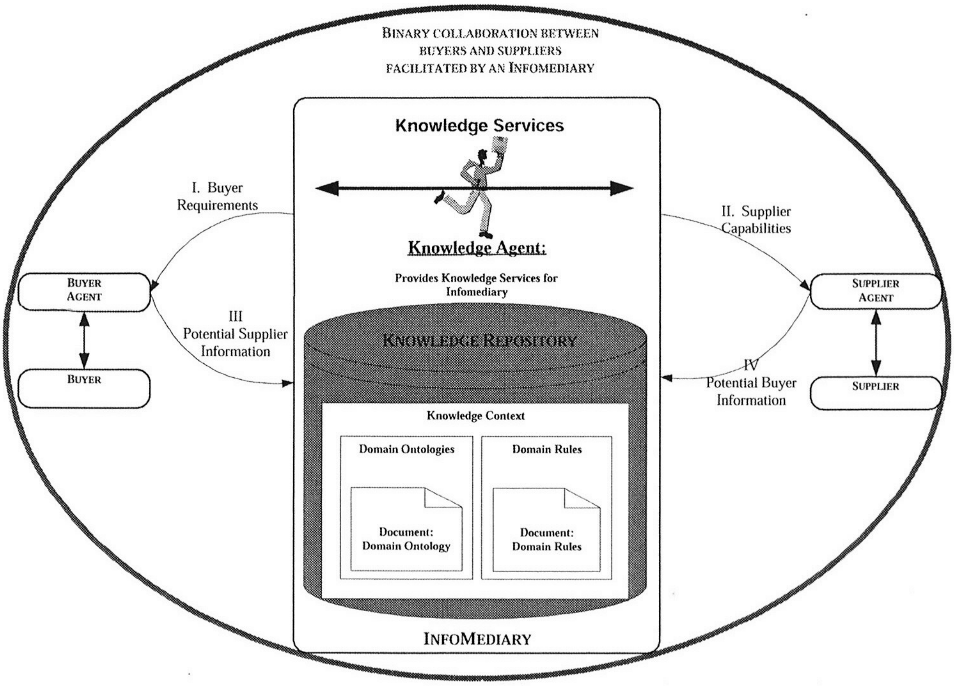

Figure 5. Knowledge Services are delivered by the Knowledge Agent to User Agent through Web Services to collect and provide domain-specific knowledge.

dardized content. The infomediary provides the buyer and supplier agents with the ontologies to allow buyers and suppliers to represent themselves in the e-marketplace to ensure interoperability among partners by enforcing a standard representation for all information exchange. Demand requirements of buyers and the supply capabilities of suppliers are made known to the knowledge repository, uniquely identified through the common item that they wish to purchase or provide. The buyers and suppliers are identified in the repository using unique identifiers that are assigned to them when they register their details with the repository. At this time, the repository interface requires the registrant to identify the product of interest to them, and makes the meta-data and ontology for that item available to them. Receipt of buyer demand requirements triggers discovery activity that involves matching buyer demand with supplier capabilities. In addition, the knowledge repository retrieves reputation-based ratings for every matched supplier and provides information on matched suppliers to the user agent.

Through the aggregation of transactional information flows, the knowledge agent can create knowledge on the volume of authorized transactions in an e-marketplace, along with information that a supplier is under consideration by a buyer to indicate current product demand in the marketplace. Information about the match between supplier capabilities and buyer requirements provides vital planning information for participant organizations. Additionally, this indicates committed and uncommitted supply capacities in the e-marketplace. For example, a supplier that is frequently evaluated, yet infrequently chosen by a buyer's analysis of historical transactions in the e-marketplace will inform competitive positioning strategies pertinent to pricing or the revaluation of product-service mix development. Knowledge provided by the knowledge services architecture includes key market conditions, such as the aggregate demand volume in the e-marketplace from aggregating current transactions, potential volatile aggregate demand from the aggregate of pending buyer demand functions, and product information represented in ontologies that describe product characteristics. In addition, suppliers can use this information to dynamically assess their production plans by such market knowledge with their internal bills of materials and other ERP/MRP planning tools in an integrative manner. These information flows, coordinated through the knowledge services architecture, increase the amount of market knowledge available and serve to mitigate the risk associated with demand and capacity planning in volatile market conditions for participants of infomediary-based marketplaces. The intelligent e-marketplace enables transparent information flows and provides intelligent assistance to decision makers in participant organizations for the core process involved in the economic marketplace supported by most infomediary-based e-marketplaces. Further, knowledge services provide the mechanisms needed for the exchange of domain-specific knowledge to inform decision activities embedded within e-business processes.

CONCLUSIONS AND FUTURE RESEARCH

Recent developments in e-business focus on the development of collaborative value chains between organizations to deliver value to customers. The transparent flow of information and problem specific knowledge across collaborating organizations, over systems that exhibit high levels of integration, is required in order to enable such strategies. The knowledge services architecture presented here applies domain ontologies, Web services, and multi-agent systems in developing a mechanism to deliver context-specific domain knowledge to partner organizations. We show the development of knowledge services for electronic commerce as domain-specific knowledge available over heterogeneous information platforms through Web services technology, using a multi-agent systems framework. This is illustrated through the application of the knowledge services architecture to infomediary-based e-marketplaces. This example attempts to capture much of the core business processes involved in a typical supply chain network, while remaining general enough to allow for further research.

Our on-going research examines the extension of this core model to e-marketplaces that are interconnected and exposed to each other through authenticated monitoring agents that gather and share market-related information in providing information transparency throughout the entire e-supply chain. Integrative technologies allow firms to create coordination structures that mitigate the risk inherent in dynamic market conditions through the availability of accurate information and specific knowledge for the planning process to e-marketplace participants. Additionally, these technologies allow organizations to coordinate activities and exchange information, including demand conditions and supply capabilities, across collaborating firms in upstream and downstream marketplaces. Buyers benefit from reduced transaction costs, greater choice of alternatives, and cheaper prices; while suppliers benefit from better access to buyers and better information to key business processes including demand and capacity planning, product development, and collaborative product design. Such knowledge-infused processing capability is missing from e-marketplaces and is critically needed. It is clear that information transparency in the entire supply chain is a required component. The growing complexity in information sources and business processes requires an alliance of mechanisms for the *ad hoc* availability of knowledge, to supplement human analysis, intuition, and judgment. The knowledge representation required to automate transactional process is a useful research endeavor to enable semantic e-business. Integrative flow of knowledge to inform e-business processes is a challenging task with significant potential competitive benefits for organizations that exhibit technical and managerial leadership.

Our future research will address the use of knowledge services and intelligent agents to monitor developments in multiple infomediary-based e-marketplaces to make the entire e-supply chain transparent and reduce the cognitive load on human decision makers by enabling a knowledge-rich environment. The exploration of business realms such as virtual communities to test and refine the architecture presented here is an interesting and useful avenue for future research. In addition, implications of efforts such as the semantic Web, ebXML, and enhanced Web services on knowledge-based collaborative architectures such as those presented here hold much promise for academics and professionals alike.

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Glossary of Key Terms and Concepts

Documents. XML-based data representation containing both a logical and a physical structure. Physically, the document is composed of units called entities, which refer to other entities in the document. A document begins in a "root" or document entity. Logically, the document is composed of declarations, elements, comments, character references, and processing instructions, all of which are indicated in the document by explicit markup. (Source: Extensible Markup Language (XML) W3C Recommendation 6 October 2000; http://www.w3.org/TR/REC-xml#sec-documents)

Infomediary. A Company that leverages the use of Internet to unite buyers and sellers in an efficient virtual marketplace to facilitate the consummation of transactions. Infomediaries "*are to information markets in the electronic market space what intermediaries, such as wholesalers and retailers, are to physical markets in more traditional market spaces*". Infomediaries play a critical role in e-marketplaces by managing the information flows to support business processes required of the e-marketplace (Grover and Teng, 2001).

Intelligent Agent. A computer system situated in some environment and that is capable of flexible autonomous action in this environment in order to meet its design objectives (Jennings and Wooldridge, 1993).

Knowledge Agent. An Intelligent Agent that helps to manage the distribution of knowledge services and interacts with user agents.

Knowledge Context. The domain document contains ontological information about the problem domain and the rules document that contains business rules relevant to the specific business context.

Knowledge Repository. A centralized repository for knowledge that is available to all the entities in the architecture.

Knowledge Service. Domain-specific knowledge, including domain entity ontologies and business rules, provided by the knowledge agent to users, through their agents, over heterogeneous information platforms via Web services technology.

Ontology. The specification of conceptualizations, used to help programs and humans share knowledge. In this usage, ontology is a set of concepts - such as things, events, and relations - that are specified in some way (such as specific natural language) in order to create an agreed-upon vocabulary for exchanging information. (Source: www.whatis.com)

"In the context of knowledge sharing, I use the term ontology to mean a *specification of a conceptualization*. That is, ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents. This definition is consistent with the usage of ontology as set-of-concept-definitions, but more general. And it is certainly a different sense of the word than its use in philosophy." (T. R. Gruber, 1993; Source: http://www-ksl.stanford.edu/kst/what-is-an-ontology.html)

User Agent. An Intelligent agent that represents the user in the architecture. In the current architecture, buyer agents and supplier agents are examples of user agent.

Web Services: Web services are services that are made available from a business's Web server for Web users or other Web-connected programs.