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Knowledge Services for eBusiness

Mark A. Gill
University of Louisville, mark.gill@louisville.edu

Rahul Singh
University of Louisville, rahul@uncg.edu

A. F. Salam
University of North Carolina at Greensboro, amsalam@uncg.edu

Lakshmi Iyer
University of North Carolina at Greensboro, lsiyer@uuncg.edu

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Mark A. Gill
College of Business Administration
University of Louisville
mark.gill@louisville.edu

Rahul Singh
Information Systems and Operations Management
Bryan School of Business and Economics
The University of North Carolina at Greensboro
rahul@uncg.edu

A. F. Salam
Information Systems and Operations Management
Bryan School of Business and Economics
The University of North Carolina at Greensboro
amsalam@uncg.edu

Lakshmi Iyer
Information Systems and Operations Management
Bryan School of Business and Economics
The University of North Carolina at Greensboro
lsiyer@uncg.edu

ABSTRACT

Dynamic value chain activities and complex decisions require the *transparent* flow of information and seamless knowledge exchange among multiple value chain participants. Advances in semantic web-based technologies offer the means to integrate heterogeneous systems across organizations in a *meaningful* way by incorporating *Ontology*, a common, standard and shareable vocabulary used to represent the meaning of system entities; *Knowledge Representation*, with structured collections of information and sets of inference rules that can be used to conduct automated reasoning; and *Intelligent Agents* that collect content from diverse sources and exchange semantically enriched information. This research applies fundamental work done in semantic web technologies including ontologies, knowledge representation, multi-agent systems and the web-services architecture to develop a system architecture that enables semantically enriched collaborative eBusiness process. We describe the feasibility of the knowledge services architecture to enable the transparent exchange of information and knowledge among agents that manage eBusiness processes to enhance online processes in an eMarketplace.

Keywords

Knowledge Management, Intelligent Agents, Knowledge Services, Ontology, Electronic Marketplace.

INTRODUCTION

eBusiness is "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). Inter-organizational collaborative business processes, which require transparent information and knowledge exchange across partner firms, are effective means for organizations to improve the efficacy of their business processes. Businesses increasingly operate in a dynamic, knowledge-driven economy and function as knowledge-based organizations. Knowledge is defined as the highest order in the continuum of data and information, as having utility and specificity in its context domain. Functionally, and in systems, the lines between useful information and knowledge are blurred (Grover and Davenport, 2001). In this research, we define knowledge as information, in the context of a specific problem domain, upon which action can be advised or taken. It is important for eBusiness to explicitly recognize knowledge along with the processes and technologies for knowledge management. eBusiness requires a knowledge services mechanism for the dynamic exchange of content and know-how among business partners.

The Semantic Web vision (Berners-Lee et. al., 2001) provides the foundation for a semantic architecture to support the transparent exchange of information and knowledge among collaborating eBusiness organizations. Recent advances in semantic web-based technologies offer means for organizations to exchange knowledge in a *meaningful* way. This requires *Ontologies,* to provide a standardized and shareable vocabulary to represent the meaning of system entities; *Knowledge Representation*, with structured collections of information and sets of inference rules that can be used to conduct automated reasoning; and *Intelligent Agents* that can exchange semantically enriched information and knowledge and interpret the knowledge on behalf of the user (Hendler 2001). It is increasingly clear that semantic technologies have potential as enablers of collaborations in eBusiness processes. The challenge for research in information systems and eBusiness is to design business models and technical architecture that demonstrate the potential of technical advancements in the computer and engineering sciences to be beneficial to business and consumers. This research applies fundamental work done in semantic

web technologies, including ontologies, knowledge representation, multi-agent systems and web-services, to develop a knowledge services architecture that supports the *transparent* flow of knowledge, *content* and *know-how*, to enable semantically enriched collaborative eBusiness.

We define Knowledge Services for eBusiness as domain specific knowledge, including domain entity ontologies and domain rules, provided by the knowledge agent to users through agents acting on their behalf, over heterogeneous information platforms via web services technology. We present domain-specific knowledge context as units of knowledge representation comprised of domain ontology that describe relevant attributes and properties of the problem domain and domain rules applicable to the specific problem domain. A problem domain may require one or more knowledge context units. The knowledge services architecture uses knowledge context units available in the knowledge repository to supply domain ontology and rules for knowledge-based decision support for online processes of partner organizations. A knowledge agent delivers knowledge services to user agents over the standard web services architecture. A schematic of the knowledge services architecture is shown in Figure 1.

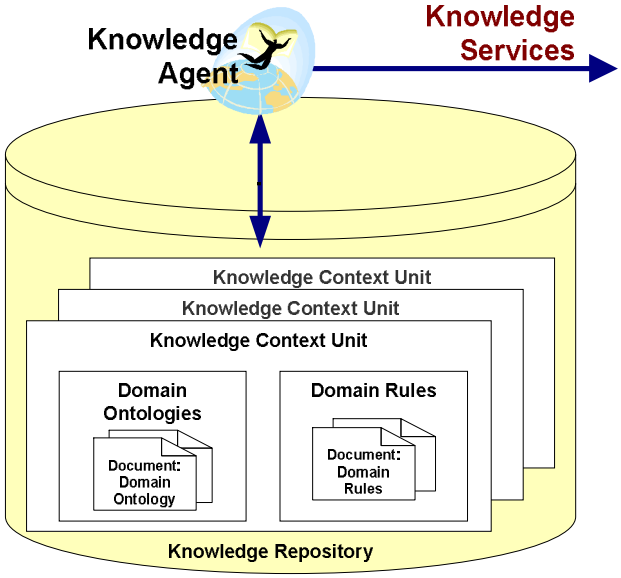

Figure 1: Knowledge Agents provide problem specific knowledge services, including domain ontologies and domain rules, to users and their agents over heterogeneous information platforms utilizing web services technology.

The inter-organizational use of integrative information technologies allows firms to create coordination structures that provide accurate market information and knowledge to inform the decision process of participants. The availability of on-demand, dynamic market information, including aggregate and individual market demand conditions and supply capabilities allows for reduced transaction costs and increased coordination of activities across organizational value chains. In addition, eMarketplaces offer value added services by leveraging industry-specific expertise and deciphering complex product information. We describe the feasibility of the knowledge services architecture to enable the transparent exchange of information and knowledge among participants in an eMarketplace. The utility of the knowledge services architecture to eMarketplace participants lies in providing domain specific knowledge, including ontologies and domain rules, in a manner interpretable by software agents that support human decision makers. This architecture provides a holistic view of semantic technologies in providing knowledge services for solving business problems. It provides business with a useful application of emergent and well-grounded technologies to improve the current state-of-the-art in eBusiness by improving the level of transparency in information and knowledge exchange, thereby increasing inter-organizational collaboration levels needed to compete in dynamic business environments.

KNOWLEDGE SERVICES IN EMARKETPLACES

eMarketplaces match buyers and sellers, facilitate transactions, and provide an institutional infrastructure for transactions to place (Bakos, 1998). Typical processes are initiated with buyer requirements that trigger a systemic search to identify qualified suppliers. This search culminates in a set of suppliers who match the needs of the buyer. The buyer then selects a supplier from the set of identified suppliers who can fulfill the buyer's demand. Such binary collaboration represents the core

process involved in an economic marketplace and provides the fundamental interaction unit that is supported by most eMarketplaces. eMarketplaces provide services to coordinate activities that facilitate transactions, thereby reducing transaction costs. Reductions in the transaction costs lead to the creation of structures that can improve transparent flow of information and knowledge required for effective collaborations between value chain partners. In addition, eMarketplaces provide information services that inform decision makers of participant organizations. The eMarketplace adds value to its network of buyers and suppliers through improved access and assistance in matching buyer needs with supplier products. eMarketplaces decipher complex product information for both suppliers and buyers and provide industry specific expertise and aggregate market conditions. The vital information role of the eMarketplace forms the basis for the development of the infomediary business model.

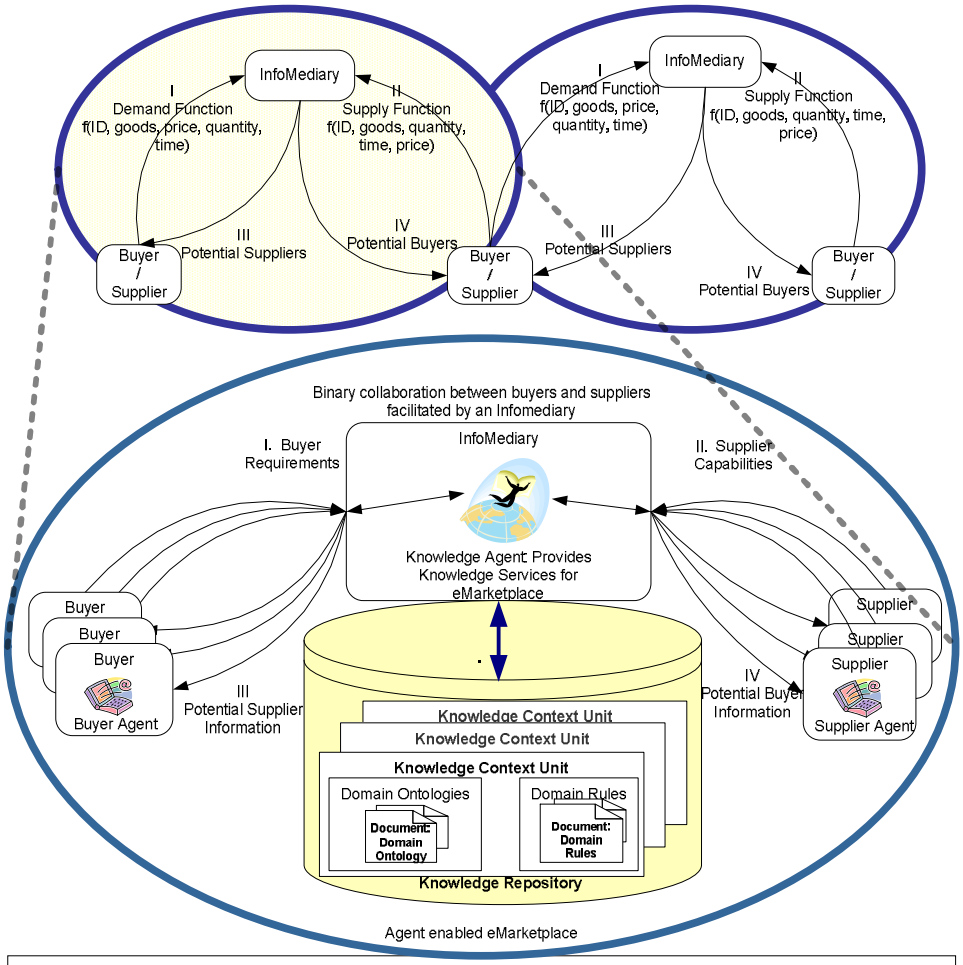

Figure 2: The role of infomediaries in eMarketplaces facilitating transactions between buyers and suppliers over multiple links in the supply chain.

Grover and Teng (2001) provide a detailed description of the value-added activities provided by infomediaries in the eMarketplace. 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 eMarketplace. This discovery

process may be influenced by historical information including the past experiences of other buyers' reliability and trustworthiness of the supplier. Infomediaries become vital repositories of knowledge about buyers, suppliers and the nature of exchanges among them. They provide independent and observed post-transaction assessment of the commitments of the individual buyers and sellers to facilitate the development of coordination structures leading to collaborative relationships in e-Supply chains. A wealth of market information is generated and exchanged through the infomediaries as they perform these functions. Infomediaries become vital resources of knowledge about the nature of exchanges in the eMarketplace that can be managed and delivered to eMarketplace participants as problem specific knowledge to enhance buyer-supplier collaborations. The infomediary can provide valuable information to business decision processes by serving as the repository of experiential knowledge of transactional histories for both buyers and suppliers. We focus on the knowledge exchange role of infomediaries through the Knowledge services architecture. To maintain and enable these knowledge services, transaction information from buyers and suppliers is collected to develop knowledge that informs the discovery process for subsequent transactions (Singh et. al., 2003). Figure 2 illustrates a schematic for information flows in extended infomediary-based eMarketplaces.

Intelligent agents have been shown to support the processing of complex information and help reduce the cognitive load of decision-makers. An agent enabled infomediary-based eMarketplace incorporates intelligence in the discovery of buyers and suppliers and in the facilitation of transactional roles. In addition, such eMarketplaces can be interconnected to share information through authenticated communications between knowledge agents that gather and share aggregate market information, using standardized ontologies, to provide secure and transparent flows of information and knowledge throughout the entire value-chain (Singh et. al., forthcoming).

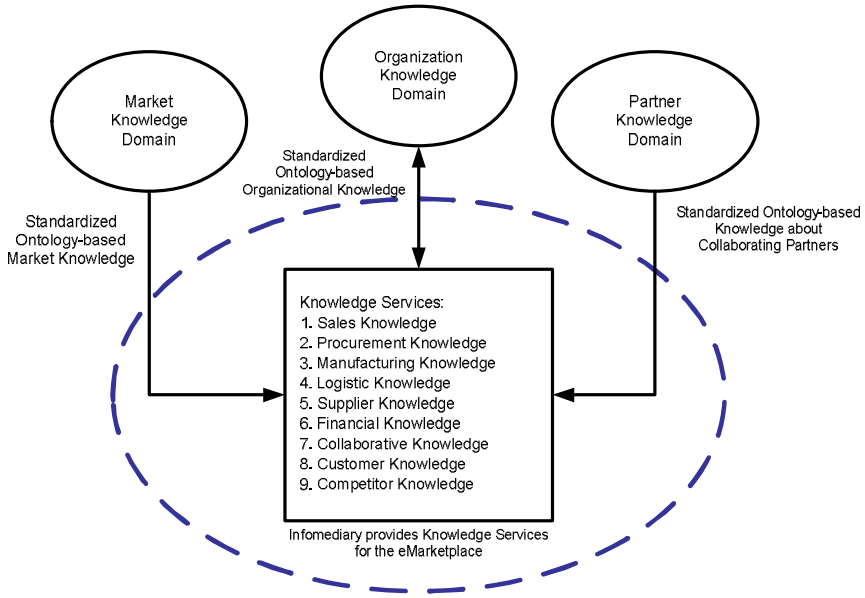

Figure 3: Integration of eMarketplace knowledge domains for knowledge services

The market knowledge domain, the partner knowledge domain and the organizational knowledge domains form the knowledge source for integration of eMarketplace knowledge available to the infomediary organization. The infomediary provides value added knowledge services to eMarketplace participants as shown in Figure 3. This information includes key market conditions such as aggregate current and potential market demand conditions compiled by aggregating current transactions and pending buyer demand functions; and product information represented in standardized and unambiguously interpretable ontologies that describe product characteristics. Relevant information from single eMarketplace is available to participants in related eMarketplaces. Participants in the eBusiness value chain can reduce the volatility in their demand forecasting and production plans by integrating standardized market demand information with their internal bills of materials and other ERP/MRP based planning tools. Such information integration in eBusiness processes of value chain participants allows the dynamic and transparent information and knowledge flows required for mitigating the intrinsic volatility in the critical demand forecasting and supply capacity planning functions. This knowledge goes beyond processing of transactional information to support a knowledge network view of the value chain where collaborating partners seamlessly share

knowledge across highly integrated systems. This feature is missing from current attempts at enabling eMarketplaces and is critically needed to achieve seamless and transparent flow of knowledge across value chain partners.

KNOWLEDGE REPRESENTATION AND EXCHANGE MECHANISM

The technical realization of on-demand, context-specific, and useful knowledge exchange among collaborating organizations in an eMarketplace requires the explication of common and shared attributes to describe context specific entities important to the system. It also requires information about the interpretation and action implications for the entities for the knowledge to be useful to decision makers in organizations. A system managing available knowledge must be composed of facilities for creating, exchanging, storing and retrieving knowledge in an exchangeable and usable format, and facilities to use the knowledge in a business activity (O'Leary 1998). 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. 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.

Ontologies, developed in the area of artificial intelligence, represent an advance to further the sharing and use of a common understanding of a specific problem. They provide a shared and common understanding of 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 eBusiness organizations (Klein et. al., 2001). 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 describes the issues related to the content of data.

Initiatives to develop technologies for the "Semantic Web" (Berners-Lee, et. al. 2001) make the content of the web unambiguously computer-interpretable to make 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). The Web Ontology Language (OWL) has been standardized by the W3C as a knowledge representation language for the semantic web. The knowledge services architecture utilizes OWL documents to represent domain ontologies and rules to allow knowledge sharing among agents through the standard web services architecture. Web Services technology provides the envelope and transport mechanism for information exchange between two entities. The knowledge services architecture uses Simple Object Access Protocol (SOAP) messages to carry relevant semantic information in the form of OWL documents between agents. Web Services framework consists of the Web Services Definition Language (WSDL – http://www.wsdl.org) that describes web services in XML format and provides the basis for tools to create appropriate SOAP messages. These technologies provide the knowledge representation and exchange mechanism to allow collaborating eMarketplace participants to seamlessly share transactional information leading to a knowledge network view of the e-supply chain.

KNOWLEDGE SERVICES ARCHITECTURE COMPONENTS

We operationalize knowledge representation in the knowledge services architecture as knowledge context units that have two components: the *domain document* that contains ontological information about the problem domain including its attributes and properties; and the *rules document* that contains epistemological knowledge about the business process represented in the form of domain rules.

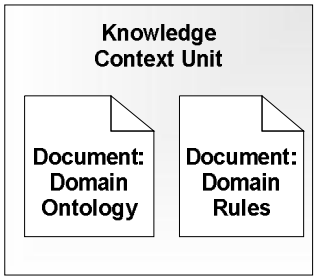

Figure 4: A Knowledge context unit is comprised of domain specific knowledge including domain ontology and domain rules.

Together, these components comprise the knowledge context with information about problem domain entities, the explication of their attributes, and information that can advise actions in the context of the specific decision problem under consideration. An individual knowledge context is illustrated in figure 4.

The domain-specific knowledge contained in the knowledge context units, including the domain ontology and rules documents, must be actively managed to allow multiple instance representations and specific information to be made available to users of the knowledge. Each knowledge domain consists of multiple knowledge context units. For example, the supplier knowledge domain is comprised of multiple supplier knowledge context units, where each knowledge context unit represents the known information about an individual supplier. Depending on the requirements of the individual decision problem, the knowledge agent constructs the individual knowledge context units from the available ontology instances for each supplier. Additional knowledge context units, pertinent to the decision problem, are available to the knowledge agent from knowledge context units available in additional knowledge domains as shown in Figure 5. For example, an e-Procurement or supply decision problem may require information from the supplier, procurement and the logistics knowledge domains. For this specific decision problem, the knowledge agent constructs a decision problem domain that consists of a set of knowledge context units that are specific and relevant to the decision problem under consideration. The construction of a problem specific decision problem domain from the available knowledge domain by the knowledge agent assigned to this particular e-Procurement decision problem is shown in figure 5.

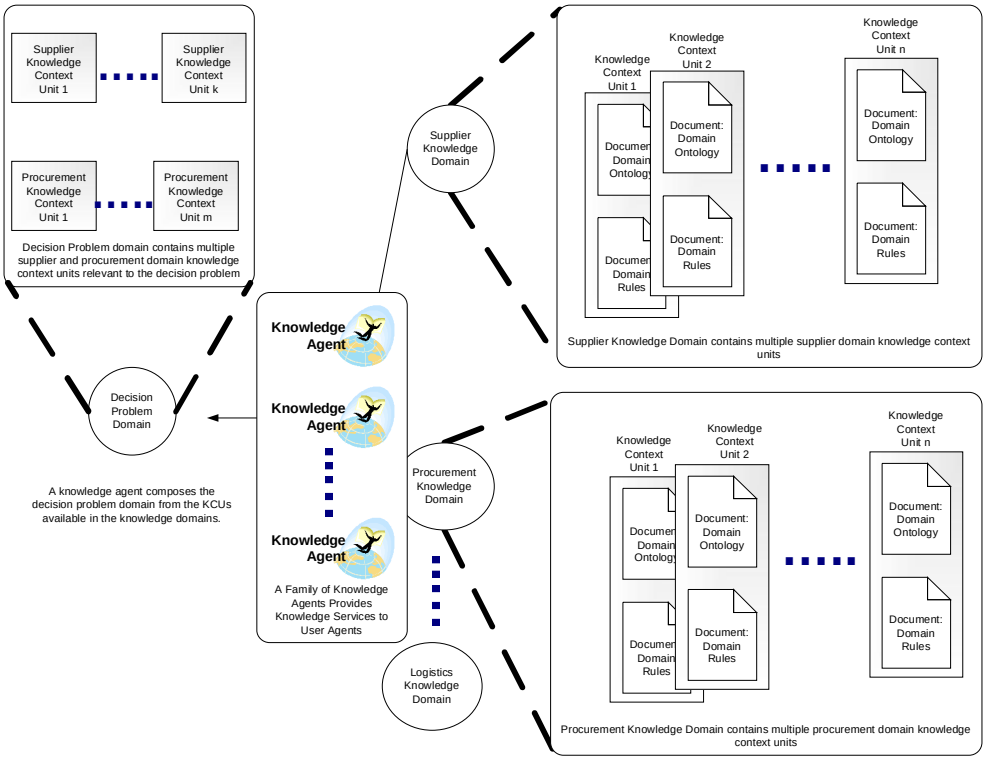

Figure 5: A knowledge agent can dynamically compose the knowledge required for a decision problem from the available knowledge context units

The eMarketplace facilitates transaction-level information flows between buyers and sellers in order to fulfill its role as an enabler of transactions. In addition, it serves a knowledge role due to its unique position as a repository of knowledge about buyers, suppliers and the nature of exchange between them (Grover and Teng, 2001). The knowledge required to automate online processes requires complete ontologies of the data used to describe the exchange in addition to the explication of domain rules that can be applied to express preferences of buyers and sellers engaged in the eBusiness process. The knowledge specification of an eBusiness process using ontologies includes the description of the shared context, with descriptions of the various attributes of the item being bought or sold, descriptions of the various organizational entities engaged in the sale and descriptions of the attributes used to describe the entities. The knowledge services architecture presented here employs ontological descriptions of the entities that are important to the problem context of the online process and description of the rules employed in making decisions regarding the business context.

A common e-Procurement supplier selection decision requires information about various attributes that describe the purchase decision, including price, quantity, and the date by which the item is required. The problem domain also contains domain rules that decide whether the decision is a *buy* or *don't buy* based on requirements and decision preferences of the buyer organization. The decision is made based upon values of decision attributes for a specific instance of the decision problem and such decisions are integral to and representative of frequently occurring decision problems in eMarketplaces. Decision problems of this nature have a *local dimension*, encompassing decision attributes that are specific to the decision-making organizations; and a *global dimension*, which entails factors that effect the selection of an optimal solution to the decision problem. In the selection of a supplier, or set of suppliers, the local dimension of the decision problem entails the individual buyer's preferences regarding specific supplier characteristics, including supplier capabilities for product quality, production capacity and reputation. The global dimension of the problem domain, including suppliers, logistics providers, warehousing providers and other entities represented in the eMarketplace, affect the composition of the set of suppliers that satisfy the preferences identified in the local dimension of the decision problem.

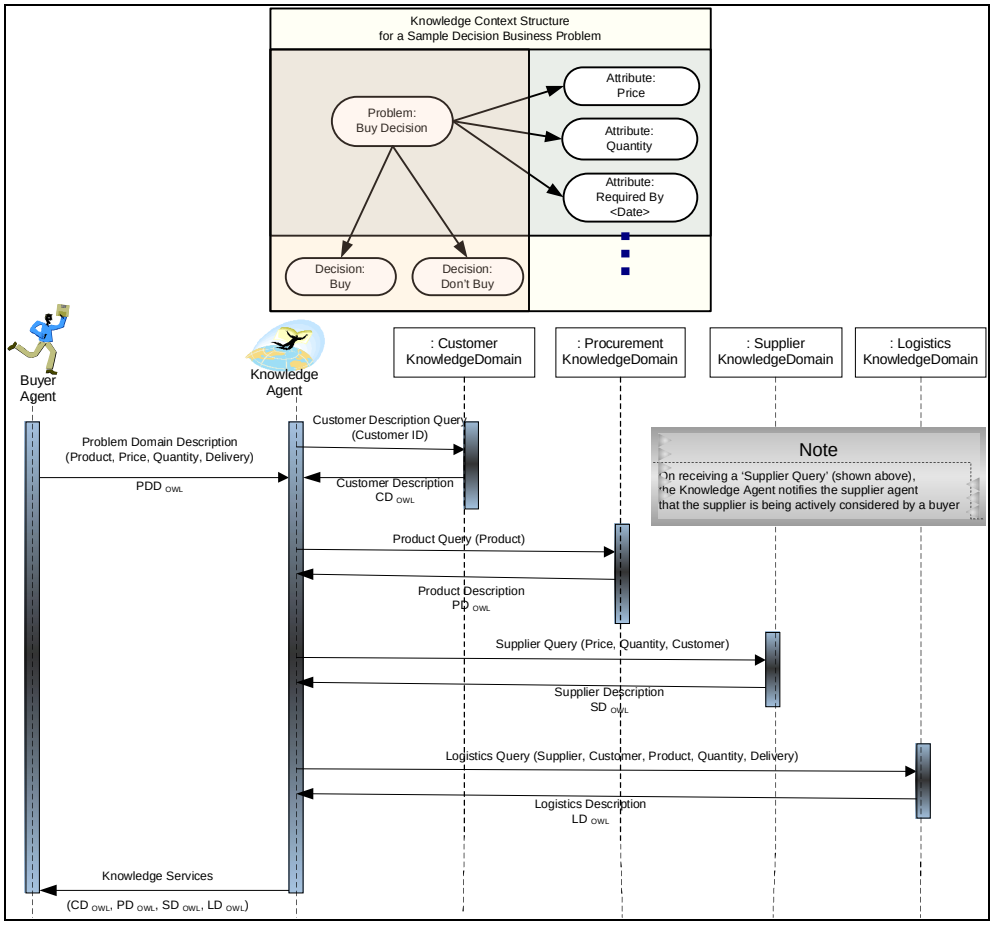

Figure 6: Interaction Diagram and Knowledge Context Requirements for a typical e-Procurement supplier selection decision.

For example, while a set of individual suppliers may be capable of meeting the local dimension criteria, they may not be able to meet the logistical requirements, may not be part of the preferred list of suppliers or may not be able to comply with the preferred set of financial requirements of the buyer organization. In such a situation, knowledge of the global dimensions provides essential input to the decision problem context while reducing the transaction and search costs for the buyer organization. Otherwise, the transaction cost for each buyer organization would include costs of evaluating individual suppliers, logistics and transportation companies, warehousing providers, among other organizations. In addition, the buyer organization would incur costs of setting up ad-hoc coordination structures that integrate across these companies while optimizing the decision problem on an individual basis. Thus, an eMarketplace that provides knowledge services reduces transaction costs of buyers by informing the global dimension of the local decision problem. Such an eMarketplace provides the basis for creating ad-hoc coordination structures and collaborative mechanisms for specific transactions through the eMarketplace mechanism, thereby allowing for the flexibility and dynamics in business processes required to compete in a dynamic competitive environment.

In an eMarketplace, individual buyers and suppliers provide representations of their needs for products or services in the form of their respective demand and supply functions. A buyer is represented in the eMarketplace through a buyer agent. The buyer agent has a detailed view of the local dimensions of the decision problem through the preferences of the buyer organization. The buyer agent lacks knowledge of the global dimension of the decision problem domain. The knowledge agent provides knowledge of the global dimension of the problem domain as a knowledge service from the eMarketplace. The description of the buyer's decision problem contains individual decision criterion that is used by the buyer agent to communicate buyer preferences to the knowledge agent, using a common ontology. The knowledge agent identifies the knowledge domains that are pertinent to the decision problem, through the attributes specified by the buyer agent. It performs localized searches in each pertinent knowledge domain to identify the relevant knowledge domain entities that satisfy the preference criteria of the decision problem as shown in Figure 5. Figure 6 shows an interaction diagram of such a knowledge service provided by the eMarketplace through the knowledge agent and lists the individual knowledge components that comprise the global dimension of the decision problem under consideration. The knowledge agent communicates the global dimension of the decision problem to the buyer agent as the knowledge service.

The buyer agent, upon receiving knowledge services from the knowledge agent, has a complete view of the decision problem, including the local and global dimensions, and can make better and more informed decision about the problem domain. This provides a more effective, knowledge-based decision support to the user for complex, multi-dimensional decision problems.

SUMMARY

Recent developments in eBusiness 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, knowledge representation web services, and multi-agent systems to develop a mechanism to deliver context specific domain knowledge to partner organizations. We demonstrate the development of Knowledge Services for eBusiness, 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 semantic knowledge services architecture to infomediary-based electronic market places. In addition, such eMarketplaces 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. Such knowledge infused, semantic processing capability is missing from current eMarketplaces and is critically needed to overcome the requisite information integration for transparent information and knowledge exchange across inter-organizational systems. 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 use of knowledge services and intelligent agents to monitor developments in multiple infomediary-based eMarketplaces makes the entire e-Supply chain transparent and reduces the cognitive load on human decision makers by enabling a semantically enhanced, knowledge rich environment. Development of tools and methods to interpret domain ontologies and support comprehensive dynamic decision making to support e-business processes is an interesting and useful avenue for further research. In addition, research related to the development of trust on semantic web technologies is essential to ensure its successful adoption.

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