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ABSTRACT

eBusiness achieves business goals using information and knowledge exchange to enable execution of inter-organizational business activities and support decision making underlying these activities. Mechanisms for knowledge transparency through standardized knowledge representation, storage, use, and sharing are essential to realize these goals. This paper addresses of knowledge integration and management for inter-organizational eBusiness processes. Building on research in Semantic eBusiness, eBusiness Processes, and knowledge management, we present a semantic knowledge integration framework for eBusiness Processes. Primary contributions of this paper include ontological engineering and knowledge representation for distributed knowledge management in inter-organizational eBusiness processes, knowledge representation for semantic knowledge management, and transparent knowledge sharing for semantic eBusiness processes. A description logics model for knowledge representation of an eMarketplace eBusiness process is presented as an illustrative example.

Keywords

Semantic Web, Knowledge Management, eBusiness process, Knowledge Representation, Ontology, Description Logics, eMarketplace.

INTRODUCTION

Knowledge is a strategically significant resource of the firm, and its creation and exchange are sources of competitive advantage (Grant 1996). eBusiness achieves business goals through information and knowledge exchange technology to enable business activities across organizations (Holsapple and Singh 2000). Prevalent inter-organizational eBusiness processes with distributed resource ownership require a holistic process view of knowledge integration to coordinate knowledge integration in collaborative inter-organizational eBusiness (Singh and Salam, Forthcoming). *Knowledge integration* is *the dynamic and seamless exchange of unambiguous, machine-interpretable knowledge resources across inter-organizational systems of business partners engaged in collaborative processes.* Current systems integration models suffer from a lack of knowledge transparency (Singh et al. 2005b).While knowledge integration can increase partners’ knowledge base and competitiveness, the key problem is how much and what knowledge should be shared, when, how, with whom, and under what conditions (Loebecke et al. 1999). There is paucity in research on distributed knowledge sharing with a unifying process perspective to share information and knowledge (Oh and Park 2003).

Semantic eBusiness is "*manages knowledge for coordination of eBusiness processes through the systematic application of Semantic Web technologies"* (Singh et al. 2005a). Here, we provide an approach to knowledge integration using existing research in Knowledge management (KM) and knowledge exchange; eBusiness processes coordination; and semantic knowledge representation. We use a Semantic eBusiness process to show the integration of *knowledge resources* involved in an eBusiness process and *process knowledge,* including process models used in eBusiness processes. Our model incorporates activity-resource based coordination mechanisms for inter-organizational processes. We use an infomediary-based eMarketplace to illustrate knowledge integration and activity-resource coordination across complex inter-organizational eBusiness processes. Key objectives of knowledge management systems (KMS) include the creation and storage, codification, coordination, and transfer of knowledge (Alavi and Leidner 2001). Developments in designing semantically enabled KMS to support Semantic eBusiness processes are thus essential. Contributions of this research to this need includes ontological engineering for complex inter-organizational business processes, including computational knowledge representation for distributed KM and semantic knowledge representation for knowledge integration and activity resource coordination in semantic eBusiness processes. Ontology supports a common vocabulary for knowledge integration in inter-organizational eBusiness process. We use Description logics (DL) as the knowledge representation formalism to express structured knowledge in a format amenable for normative reasoning by software agents. The use of DL to develop the semantic eBusiness process models allows this approach to be implementable using W3C's OWL (Web Ontology Language) and OWL-DL while maintaining theoretical robustness.

BACKGROUND

Semantic Web, Ontologies, Description Logics, and Intelligent Agents

The Semantic Web is an extension of the current Web in which information is given "*well-defined meaning*" to allow machines to "*process and understand*" the information presented to them (Berners-Lee et al. 2001). Ontologies provide a shared and common understanding of specific domains that can be communicated between disparate application systems, and therein provide a means to integrate the knowledge used by online processes employed by organizations (Klein et al. 2001). Ontology 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. Ontology documents can be created using standardized content languages like BPEL, RDF, OWL, and DAML to generate standardized representations of the *process knowledge* (Thomas et al. 2005).

Computational Ontology documents are based on DL-formalisms for knowledge-representation (Li and Horrocks 2004). DL provides formal linear syntax to express descriptions of top-level concepts in a problem domain, their relationships and the constraints on the concepts and the relationships imposed by pragmatic considerations in the domain. DL supplies the language to build composite term descriptions from primitive concepts (Baader et al. 2003). We use *SHIQ-DL* (Li and Horrocks 2004) for its expressive power and OWL-DL, is based on the SH family of DL. OWL is the W3C standardized approach for semantic web ontologies using DL as the knowledge representation mechanism. These provide the basis for developing machine-interpretable knowledge representation and computational ontologies in OWL-DL format to support knowledge integration in Semantic eBusiness.

Newell (1982) provides a functional view of knowledge as "*whatever can be ascribed to an agent, such that its behavior can be computed according to the principle of rationality*". This provides the basis for functional knowledge management using agents through explicit, declarative knowledge represented using standard knowledge representation languages. A fundamental implication is that knowledge must be available in formats that allow for processing by software agents. DL-based knowledge representation provides the formalism to express structured knowledge in a format amenable for normative reasoning by intelligent software agents. OWL documents, with domain ontologies and rules, allow knowledge sharing among agents through the standard *Web services* architecture (Iyer et al. 2005). Agents work on a distributed platform and enable the transfer of knowledge by exchanging messages through FIPA compliant agent communication languages through Web services using SOAP and XML. These technologies provide the knowledge representation and exchange mechanisms to allow for *knowledge integration*, which enable collaborating organizations to seamlessly share information and knowledge to coordinate eBusiness processes.

Semantic Knowledge Management in Inter-organizational Process

The Resource Based View (RBV) provides the broadly accepted management perspective where organizational knowledge is a valuable resource for a firm's sustainable competitive advantage (Wernerfelt 1984). Tallman et al. (2004) show that knowledge transferability directly affects firm's performance. While cooperative inter-organizational knowledge sharing can increase their competitiveness, organizations are very selective about the nature of knowledge resources shared. Central to inter-organizational KM is the nature of the knowledge exchange, what knowledge is to be shared and under what conditions (Loebecke et al. 1999). We focus on mechanisms for knowledge representation and exchange made possible by Semantic Web technologies. Knowledge management, including knowledge exchange, transpires in the context of a business process to achieve a business objective. This requires explicit knowledge and mechanisms that allow for its appropriate exchange and use in the inter-organizational eBusiness process context. Inter-organizational eBusiness processes provide an integrative and holistic perspective to integrate *knowledge of resources* involved in a process and *process knowledge* including process models. We consider the nature of the knowledge exchange needed for collaborating organizations to achieve inter-organizational eBusiness processes objectives.

Simonin (1999) studies the impact of knowledge transfer in strategic alliances on collaborative outcomes where *knowledge ambiguity* negatively affects knowledge transfer. A survey by Davenport et al., (2001) on B2B eMarketplaces identified the lack of trust as a primary barrier for eMarketplace growth and attributed the associated risk to a need for "*information becoming more codified, standardized, aggregated, integrated, distributed, and shaped for ready use*". Tallman et al. (2004) examine the role of knowledge exchange for competitive advantage of a cluster of organizations and note that simpler, codified and less tacit *component knowledge* is amenable to knowledge exchange. We apply standardized semantic technologies to support transparent exchange of machine-interpretable and unambiguous knowledge required to develop viable inter-organizational eBusiness relationships. This allows for knowledge to be *interpreted by software and shared using automated reasoning mechanisms to reach useful inferences.* We recognize that all knowledge cannot be explicated and be effectively represented and reasoned with using decidable and complete computational techniques. This research uses an explicit definition of knowledge declarative enough for standards-based knowledge representation languages and can be processed using agent-based reasoning mechanisms to reach useful inferences. These pragmatic restrictions on knowledge are made for practical reasons to build effective and practical knowledge-based systems that are both viable and useful. We focus on *Component knowledge,* including descriptions of skills, technologies, tangible and intangible resources, consumer and product knowledge; and *Process knowledge,* typically embedded in the process models of workflow management systems as coordination knowledge for complex processes. An inter-organizational eBusiness process view of knowledge integration incorporates management of *component knowledge* and *process knowledge* for knowledge integration across inter-organizational systems.

Inter-Organizational Process and eBusiness Process Coordination

Inter-organizational processes allow collaborating organizations to provide complementary services through networks of collaborating organizations (Sawhney and Parikh 2001). Complexities of coordinating inter-organizational processes require knowledge-driven coordination structures to determine decision authority and knowledge sources (Anand and Mendelson 1997). Business processes comprise activities and require coordination mechanisms to manage their dependencies (Malone 1987). Effective coordination of business activities by managing their inter-dependencies is critical for effective inter-organizational eBusiness processes across the value-chain. Coordinating complex inter-organizational eBusiness processes requires an integrated view of the complete eBusiness process and knowledge-driven coordination to determine decision authority over distributed knowledge resources (Anand and Mendelson 1997).

Integrative IT can help streamline business processes across organizations and improve the performance of the value chain through effective coordination of processes in eMarketplaces. Dai and Kauffman (2002) review B2B eMarketplace exchanges and the research issues therein. Reduced transaction coordination costs from effective information technologies deployment partly explains the choice of markets over hierarchies by organizations to coordinate economic activities (Singh et al. 2005b). Loebecke et al. (1999) consider the effect of knowledge exchange on competitiveness and point out that *inter-organizational knowledge exchange is relevant only in the context of a market, or other form of inter-organizational exchange*. Reduced transaction costs lead to explicit coordination between organizations invested in building long-term value-adding relationships to coordinate activities (Clemons et al. 1993). We use supplier selection a primary eBusiness processes in an eMarketplace to illustrate knowledge integration and activity-resource coordination across inter-organizational eBusiness processes.

Workflows establish the logical order of execution between individual business activities in business processes within and across organizations. The Workflow Management Coalition (1996) describes business process as "*a sequence of activities with distinct inputs and outputs and serves a meaningful purpose within an organization or between organizations*". Process knowledge represents a business process in a form that consists of a network of activities and their relationships, criteria to indicate the start and the termination of the process, and information about the individual activities, including participants and data, and their coordination (WfMC, 1996). Activities are fundamental tasks that human and software agents in a system must perform to accomplish their individual and organizational, system-wide, and goals. The notion of *workflow* is a *coordinated* set of *business activities* performed by various actors or agents necessary to complete a business process (van der Aalst and Kumar 2003). Here, workflows are subsumed in process knowledge through the coordination relationships between the dependent businesses activities in an eBusiness process.

Coordination of business activities is fundamental to organizing work and managing the complexity in social systems and business organizations. Malone et al. (2003) define coordination as *managing dependencies among activities* and provide taxonomy of dependencies among activities and resources. Dependencies among multiple resources and multiple activities are summarized in Table 1.

Dependency Type	Description
Flow Dependency	A resource is the effect of one activity and a precondition of another, typical of producer/consumer dependence where a resource may either be produced by or consumed by a business activity.
Fit Dependency	Two activities result in a common resource, e.g., two or more parts must 'fit' to produce the end product; hence the notion of '*fit*' dependency among activities and output resources.
Sharing Dependency	Two activities have the same resource as a precondition.

Table 1. Dependencies among multiple resources and multiple activities (Adapted from Malone et al. 2003)

In *activity-resource* dependency activities have a sharing, flow or fit dependency with a resource. This notion of the coordination constructs are based on Malone et al. (2003) and are similar to those in van der Aalst and Kumar (2003). These coordination constructs are used to develop activity-resource coordination in the process knowledge representation of inter-organizational eBusiness processes.

CONCEPTUALIZATION OF SEMANTIC EBUSINESS PROCESSES

Ontologies provide representation of the semantic content of problem domain, including pertinent objects, their inter-relationships and constraints. Computational ontologies for systems contain the common syntax and semantics to be used to model and represent the artifacts in the system. Ontological analysis of a problem domain begins with concept descriptions that specify the fundamental concepts relevant to the problem domain. The inter-relationships and constraints between fundamental concepts describe the dependencies between domain concepts, primitive or derived, and provide specificity to the problem domain model. The result of ontological analysis provides knowledge representation that specifies the semantic content of the problem domain. We refer the reader to Baader et al. (2003) and Borgida et al. (1995) for a full range of DL constructors.

In an eBusiness process, agents, human or software, represents a business enterprise to perform business activities on its behalf. Business activities are coordinated through access to the resources owned by a business enterprise. Business activities are the individual activities performed by agents on individual resources. Resources, including information and knowledge owned by a business enterprise, coordinate business activities performed on them. Here we consider *information* and *knowledge* as the central resources used by agents to perform activities. An essential set of concepts fundamental to model eBusiness Processes include *business enterprise, agent, business activity, resource, coordination, information* and *knowledge*. The conceptualization for the eBusiness Process is:

In an eBusiness process, a Business Enterprise is represented by an Agent to perform Business Activities, coordinated by information and knowledge resources.

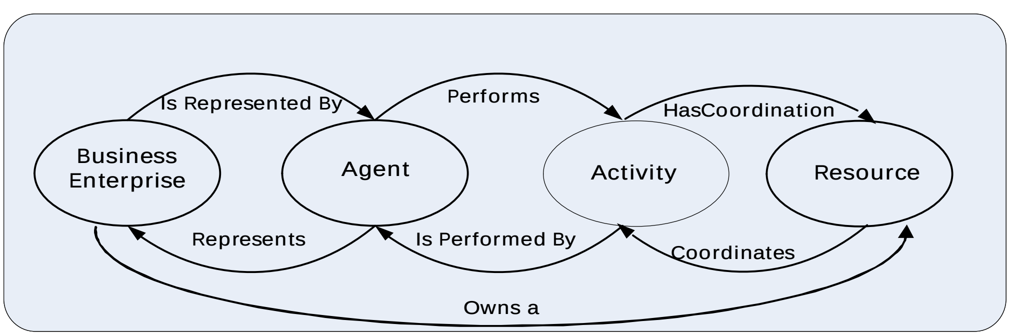


Figure 1: Concepts and Relationship conceptualization in Semantic eBusiness processes

Elementary descriptions of atomic concepts in semantic eBusiness processes include: *Business Enterprise*, *Agent*, *Business Activity, and Resource.* Elementary descriptions of the atomic relationships in semantic eBusiness processes include:

Represents ($\equiv$ *IsRepresentedBy* $^{-}$)
Performs ($\equiv$ *IsPerformedBy* $^{-}$)
Coordinates($\equiv$ *HasCoordination* $^{-}$)

These atomic concepts and relationships are used to develop axiomatic knowledge representation *terminology* to describe relationships between the concepts in the semantic eBusiness processes domain. A resource is related to an activity through a *Coordinates* relationship, where the resource coordinates business activities through various coordination mechanisms.

Resource ∃ (Coordinates . BusinessActivity)
BusinessActivity∃ (HasCoordination . Resource)

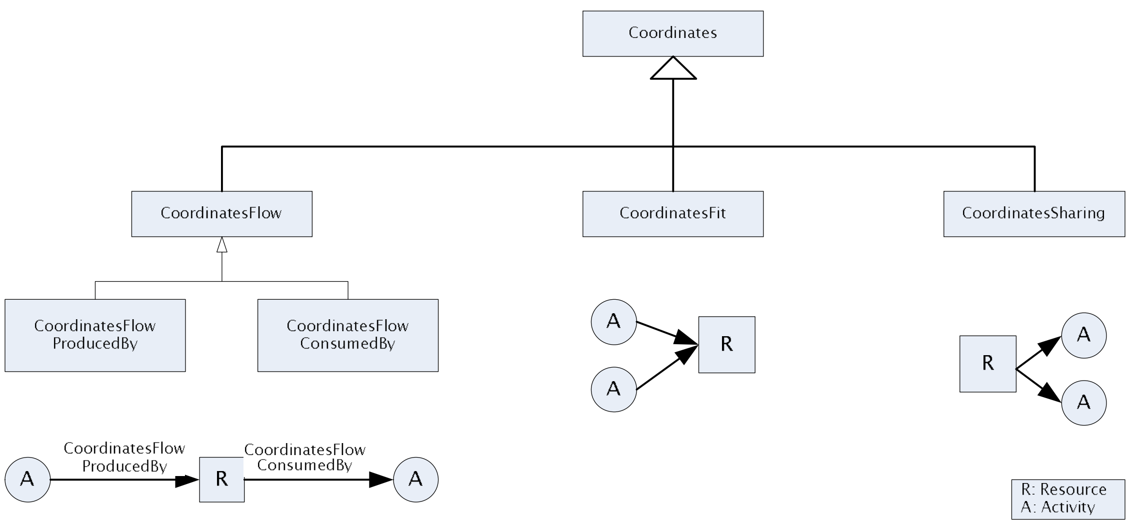


Figure 2: Relationships between activities and resources

Business Activities depend on resources and require coordination mechanisms to resolve these dependencies. This activity-resource coordination mechanism allows explicit modeling of the coordination of business activities in the eBusiness process using knowledge resources involved in the inter-organizational eBusiness processes.

The *coordinates* relationship between resource and activity is an abstract, general relationship, which is specialized by relationships where a resource may coordination activities through a *CoordinatesFlow*, *CoordinatesFit*, or C*oordinatesSharing* relationship. We utilize the relationship inheritance hierarchies, shown in Figure 2, to specify the relationships between activities and resources. In addition, the *CoordinatesFlow* is further specialized to capture the activity-resource coordination where the resource coordinates the flow of activity by either being produced by or consumed by a business activity. This inheritance hierarchy of the *coordinates* relationship allows rich and complex description of the coordination mechanisms in an eBusiness process through relationships between *Resources* and *Business Activities*:

Resource ∃
(≥0 CoordinatesFlowProducedBy . BusinessActivity)
(≥0 CoordinatesFlowConsumedBy . BusinessActivity)
(≥0 CoordinatesFit . BusinessActivity)
(≥0 CoordinatesSharing . BusinessActivity)

SEMANTIC KNOWLEDGE REPRESENTATION IN AN EMARKETPLACE

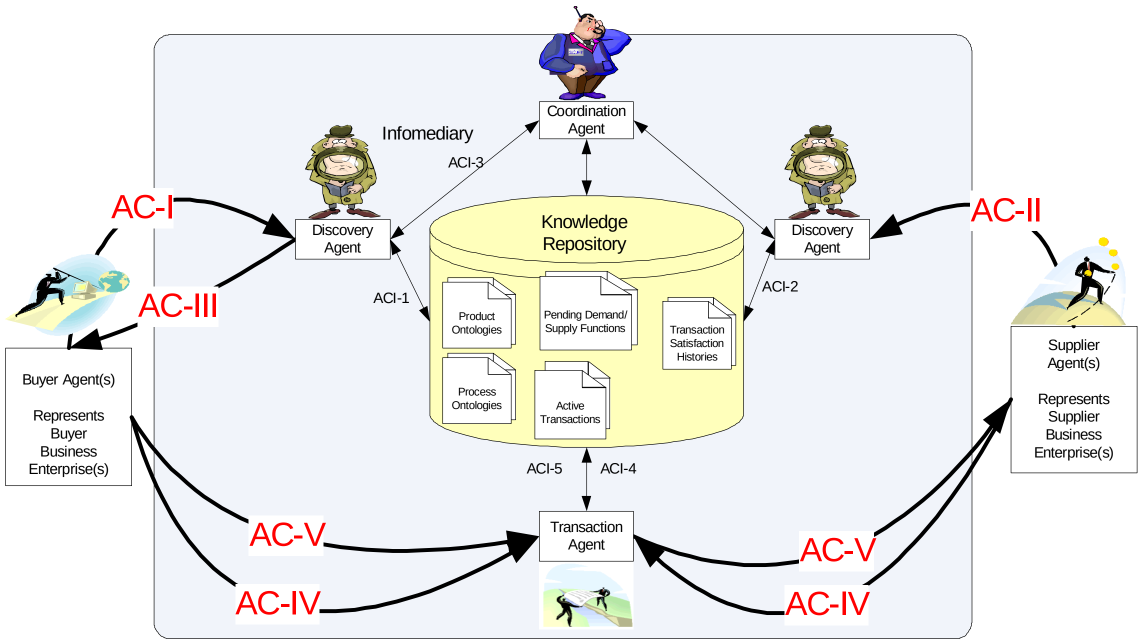
Infomediary-based eMarketplaces

An Infomediary-based eMarketplace is an advanced eBusiness exchange where infomediaries manage information and knowledge exchange to support required eBusiness processes (Grover and Teng 2001). Knowledge management in the eMarketplace provides critical input to the supplier discovery and selection decision problem while reducing the transaction and search costs for the buyer organization. Infomediaries coordinate and aggregate information flows to support eBusiness processes and provide value-added services to enhance the information processes of the eMarketplace by deciphering component knowledge of products and transactions in the eMarketplace. Infomediaries play a vital role in the exchange of knowledge and information in these knowledge networks embedded within inter-organizational value chains. 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 inter-organizational eBusiness process coordination (Singh et al. 2005b).

A common eBusiness process in an eMarketplace, supplier selection entails matching buyers' preferences of specific supplier characteristics, including supplier capabilities for product quality and production capacity. This is a *discovery activity* including matchmaking of buyer requirements and supplier capabilities by the infomediary organization. The result of this activity is the discovery of a set of suppliers capable of meeting buyers' needs. Sycara et al. (1999) discuss the role of intelligent agents in dynamic matchmaking through the comparison of features expressed in standardized knowledge representation. Li and Horrocks (2004) describe matchmaking using Semantic Web Technology and discuss the mechanisms for matching in DL-based knowledge representation. Here we develop the knowledge representation for a discovery agent to match buyer requirements with supplier capabilities in electronic supply chains and infomediary based eMarketplaces. Figure 3 shows agent communications and knowledge exchange in the eMarketplace architecture.

Proposed Semantic Knowledge Integration Architecture for an Infomediary-Based eMarketplace

An agent enabled infomediary-based eMarketplace provides the discovery of buyers and suppliers and facilitates transactions (Singh et al. 2005b). Such an eMarketplace provides the basis for creating ad-hoc coordination structures and collaborative mechanisms for transactions through the eMarketplace mechanisms (Iyer et al. 2005). The above two studies emphasize the role of agents to facilitate information transparency in eMarketplace. The focus of our research is to develop semantic, DL-based knowledge representation to enable knowledge integration and activity-resource coordination in a multi-agent infomediary-based eMarketplace.



<u>Inter-Organizational Agent Communications</u>

<u>(External to Infomediary):</u>

AC-I: Buyer Needs (Demand function) *f(ID, goods, price, quantity, time)*

AC-II: Supply Capability – Supply Function *f(ID, goods, price, quantity, time)*

AC-III: Information on Suppliers that meet Buyer Requirements

AC-IV: Information Flow for a Transaction, including transaction details between buyer and supplier, facilitated by the Infomediary

AC-V: Post Transaction Information from Buyer and Supplier Agents to Transaction Agent of Infomediary, reporting on level of satisfaction with the transaction.

<u>Infomediary Agent Communications</u>

<u>(Internal - Within the Infomediary):</u>

ACI - 1: retrieve ontology from repository for buyers

ACI - 2: retireve ontology from repository for suppliers

ACI - 3: Suppliers that meet Buyer Requirements

ACI - 4: Transaction details between buyer and supplier sent to repository. Move a transacitonID from pending to Active state.

ACI - 5: Post Transaction Information from Transaction Agent of Infomediary, sent to repository.

Figure 3: Agent communications in an intelligent-agent infomediary-based eMarketplace architecture

In an infomediary-based eMarketplace, buyer, supplier, and infomediary are described as:

Buyer ⊆ *(BusinessEnterprise) ∧* *(=1 HasID . StringData) ∧* *(≥ 1 HasAddress . Address) ∧* *(≥ 1 HasDescription . StringData) ∧* *(≥ 1 HasReputation . StringData) ∧* *(≥ 1 IsRepresentedBy . BuyerAgent) ∧* *(≥ 1 Has TransactionSatisfactionHistory . StringData)*	*Supplier ⊆* *(BusinessEnterprise) ∧* *(= 1 HasID . StringData) ∧* *(≥ 1 HasAddress . Address) ∧* *(≥ 1 HasDescription . StringData) ∧* *(≥ 1 HasReputation . StringData) ∧* *(≥ 1 IsRepresentedBy . SupplierAgent) ∧* *(≥1 HasTransactionSatisfactionHistory.StringData)*	*Infomediary ⊆* *(BusinessEnterprise) ∧* *(= 1 HasID . StringData) ∧* *(≥ 1 HasDescription . StringData) ∧* *(≥ 1 HasAddress . Address) ∧* *(≥ 1 IsRepresentedBy . RegistrationAgent) ∧* *(≥ 1 IsRepresentedBy . DiscoveryAgent) ∧* *(≥ 1 IsRepresentedBy . TransactionAgent)*

Agents that represent these entities are described as:

BuyerAgent ⊆ *(SoftwareAgent) ∧* *(=1 Represents . Buyer) ∧* *(≥1 Performs . ObtainsOntology) ∧* *(≥1 Performs.CommunicateBuyerNeeds) ∧* *(≥1 Performs.ReceiveDiscoverdSuppliers) ∧* *(≥1 Performs.CommunicateContract) ∧* *(≥1 Performs.ReceiveContract) ∧* *(≥1 Performs . AuthorizesTransaction) ∧* *(≥1Performs.CommunicatesSatisfactionLevel)*	*SupplierAgent ⊆* *(SoftwareAgent) ∧* *(=1 Represents . Supplier) ∧* *(≥1 Performs . ObtainsOntology) ∧* *(≥1Performs.CommunicatesSupplierCapabilities) ∧* *(≥1 Performs.ProvideSupplierAgreement) ∧* *(≥1 Performs . CommunicatesSatisfactionLevel)*	*DiscoveryAgent ⊆* *(SoftwareAgent) ∧* *(=1 Represents.Infomediary) ∧* *(≥1 Performs.DiscoverSuppliers) ∧* *(≥1 Performs.RequestSupplierAgreement) ∧* *(≥1 Performs ReceiveSupplierAgreement)* *TransactionAgent ⊆* *(SoftwareAgent) ∧* *(=1 Represents.Infomediary) ∧* *(≥1 Performs.InitiateTransaction)*

Ontological Engineering for Infomediary enabled Buyer/Supplier Discovery Process

Buyer agents present buyer needs to the eMarketplace by communicating buyer requirements and buyer preferences for a supplier from a set of matched suppliers. The discovery agent uses the buyer needs to discover a set of suppliers to meet buyer requirements and match the buyer preferences. Discovered suppliers are communicated to the buyer through the buyer agent. It is noteworthy that the process of supplier discovery is an iterative process that culminates with the buyer's selection of a supplier. A typical workflow for the supplier discovery eBusiness process is shown in Figure 4.

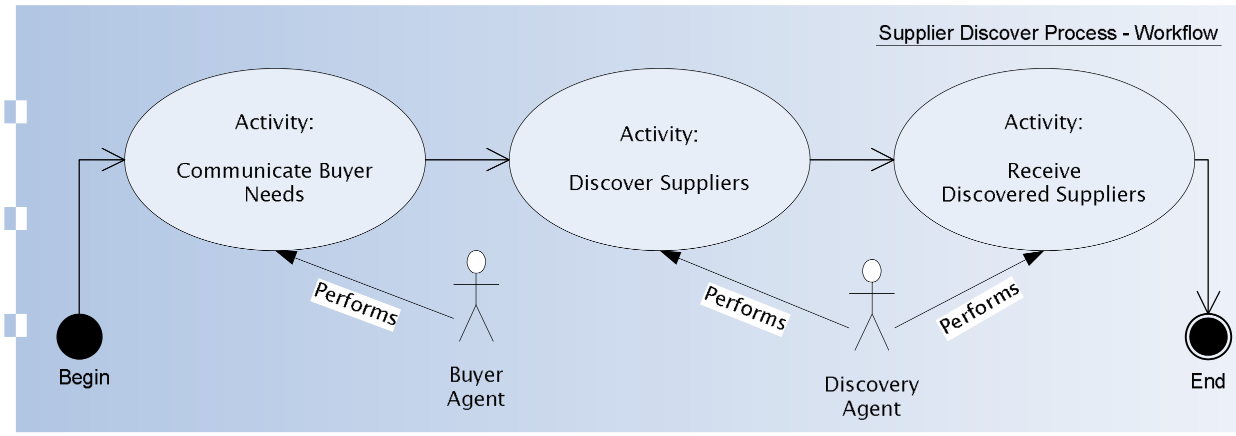


Figure 4: A typical workflow for the supplier discovery eBusiness process in an infomediary-based eMarketplace

The representation of buyers demand conforms to the ontology described above to ensure interoperability of agent interactions. A semantic map that conforms to the DL-based conceptualizations of the eBusiness process knowledge presented earlier for the supplier discovery eBusiness process is shown in Figure 5.

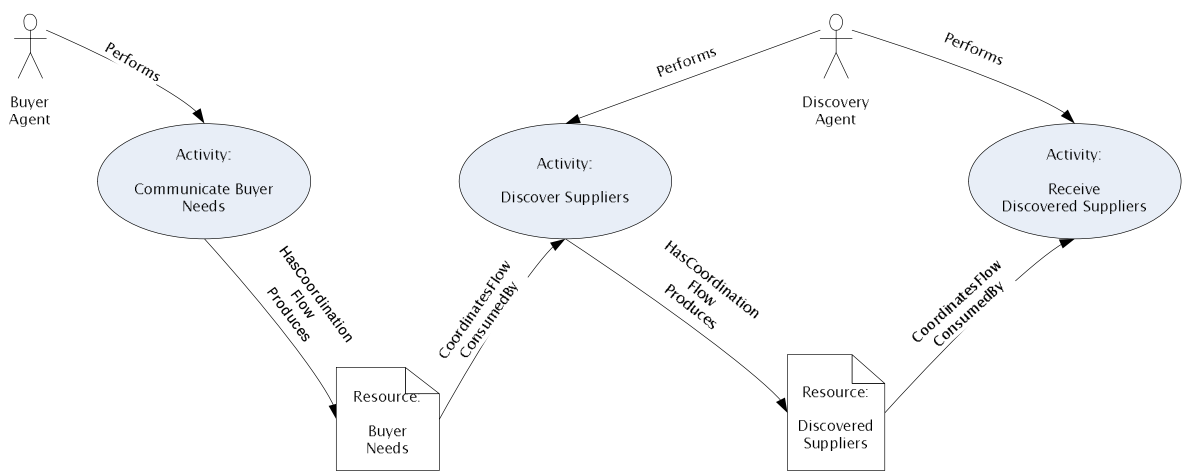


Figure 5: Semantic activity-resource coordination in the supplier discovery eBusiness process

The DL descriptions to represent the buyer's needs, including buyer requirements and buyer preferences, supplier capabilities, and supplier reputation are presented below. It is important to highlight that these demand requirement characteristics are intended to serve as examples and they are not exhaustive. Buyers communicate their needs to the eMarketplace using standardized ontology for specifying the *Buyer Needs.*

$$\begin{aligned} BuyerNeeds \subseteq\ & (Resource) \wedge \\ & (= 1\ hasCharacteristics\ .\ BuyerID) \wedge \\ & (= 1\ CoordinatesFlowProducedBy\ .\ ComunicateBuyerNeeds) \wedge \\ & (= 1\ CoordinatesFlowConsumedBy\ .\ DiscoverSuppliers) \end{aligned}$$

The buyer agent *Communicates Buyer Needs* to the eMarketplace to coordinate the supplier discovery activity.

$CommunicateBuyerNeeds \subseteq (BusinessActivity) \wedge$

(= 1 IsPerformedby.BuyerAgent) ∧
(= 1 HasCoordinationFlowProduces.BuyerNeeds)

Communicating Buyer Needs by the Buyer Agent has a coordination flow relationship with the Buyer Needs resource by producing the Buyer Needs to the Discovery Agent. The discovery agent performs the *Discover Suppliers* activity.

DiscoverSuppliers ⊆ *(BusinessActivity)* ∧
(= 1 IsPerformedby.DiscoveryAgent) ∧
(= 1 HasCoordinationFlowConsumes.BuyerNeeds) ∧
(= 1 HasCoordinationFlowProduces.DiscoveredSuppliers)

The *Discover Suppliers* activity produces a set of discovered suppliers that meets *Buyer Needs.*

DiscoveredSuppliers ⊆ *(Resource)*
(≥ 0 hasCharacteristics . Supplier) ∧
(= 1 CoordinatesFlowProducedBy . DiscoverSuppliers) ∧
(= 1 CoordinatesFlowConsumedBy . ReceiveDiscoverdSuppliers)

The *DiscoveredSuppliers* resource is produced by the discover suppliers activity through the matchmaking algorithms and coordinates the *ReceiveDiscoveredSuppliers* activity of the buyer agent.

ReceiveDiscoverdSuppliers ⊆ *(BusinessActivity)* ∧
(= 1 IsPerformedby . BuyerAgent) ∧
(= 1 HasCoordinationFlowConsumes . DiscoveredSuppliers)

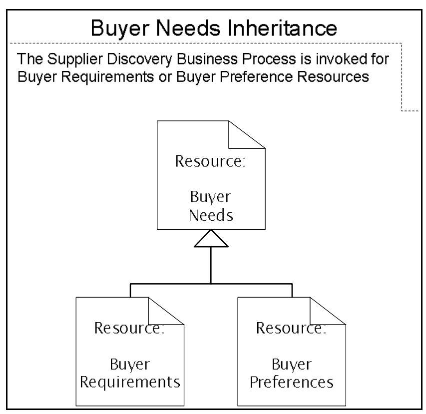


Figure 6: *Buyer Needs* is an abstraction for the *Buyer Requirements* and *Buyer Preferences* involved in the supplier selection eBusiness Process

The *BuyerNeeds* resource abstracts the specialized *Buyer Requirements* and Buyer Needs as shown in Figure 6.

BuyersNeeds ⊆ *(Resource)*
BuyersRequirements ⊆ *BuyerNeeds*
BuyerPreferences ⊆ *BuyerNeeds*

Buyer Requirements are buyer needs that specify buyers' demand function.

BuyersRequirements ⊆ *BuyerNeeds*
(= 1 hasCharacteristics · ProductName) ∧
(= 1 hasCharacteristics · ProductType) ∧
(= 1 hasCharacteristics · PriceType) ∧
(= 1 hasCharacteristics · Currency) ∧
(= 1 hasCharacteristics · Quantity) ∧
(= 1 hasCharacteristics · Quality) ∧
(= 1 hasCharacteristics · NeedByDate)

Buyer Preferences specify buyer preferences of suppliers and additional preference criteria for the buyer enterprise.
BuyerPreferences $\subseteq$ *BuyerNeeds*

(≥ 0 hasCharacteristics · PreferredSupplierReputation) ∧
(≥ 0 hasCharacteristics · PreferredDeliveryMethod) ∧
(≥ 1 hasCharacteristics · PreferredMinPrice) ∧
(≥ 1 hasCharacteristics · PreferredMaxPrice) ∧
(≥ 1 hasCharacteristics · AllowedLeadTime)

This inheritance hierarchy of *Buyer Needs* specialized into the *Buyer Requirements* and the *Buyer Preferences*, provides a basis to utilize the supplier discovery workflow using either type of the buyer needs resource. The hierarchy illustrates the ability to specify meta-knowledge of processes and instantiate the individual workflows using multiple types of resources that inherit from the same parent resource used in the process knowledge specification.

Ontological Engineering for Infomediary Enabled Contractual Agreement eBusiness Process

The discovery process culminates in the buyer enterprise indicating a chosen supplier and communicating a proposed contractual agreement to the infomediary. If the supplier accepts the proposed contractual agreement, then it becomes a binding contract, the buyer is notified and the transaction is initiated by the transaction agent. The activity-resource coordination semantic map for this complex inter-organizational eBusiness process, involving the buyer, supplier and the infomediary business enterprise is shown in Figure 7.

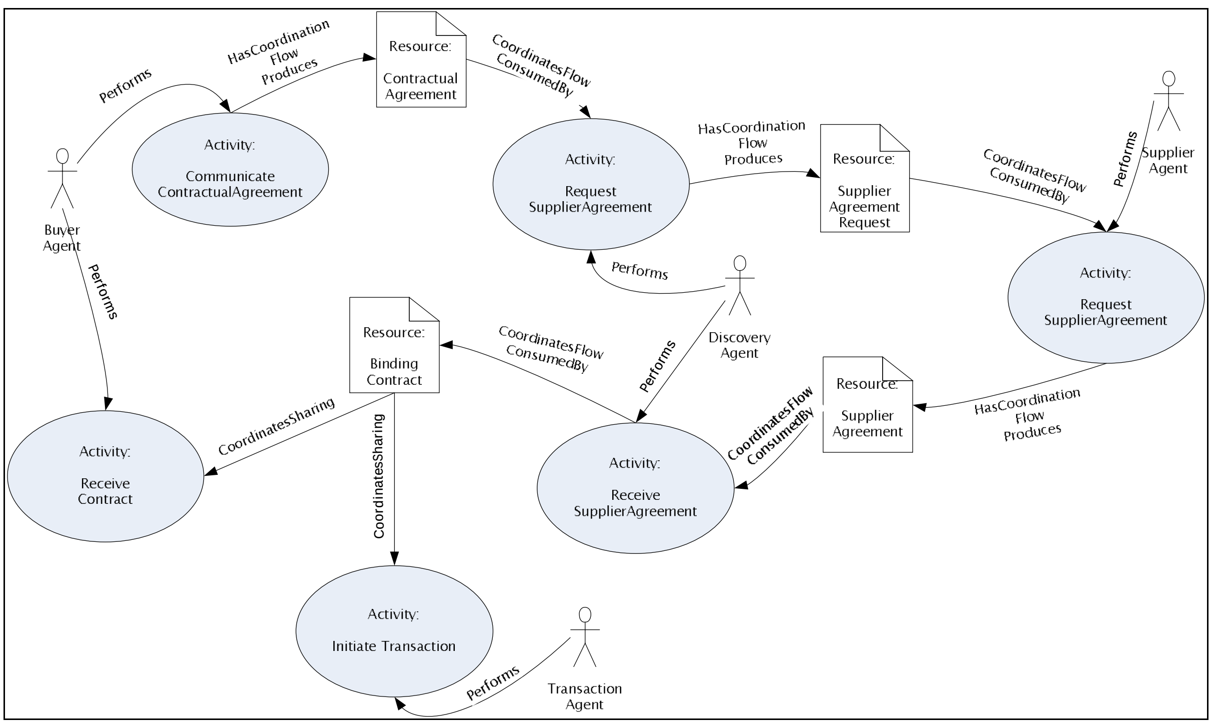


Figure 7: Activity-Resource coordination of the Contractual agreement process

The eBusiness process is initiated by the buyer agent performing the *Communicate Contractual Agreement* activity that produces the *Contractual Agreement* resource for the infomediary organization.

CommunicateContractualAgreement $\subseteq$ *(BusinessActivity)* ∧
(= 1 IsPerformedby.BuyerAgent) ∧
(= 1 HasCoordinationFlowProduces.ContractualAgreement)

ContractualAgreement $\subseteq$ *(Resource)* ∧
(= 1 hasOwner· Buyer) ∧

(= 1 CoordinatesFlowProducedBy. CommunicateContract) ∧
(= 1CoordinatesFlowConsumedBy.RequestSupplierAgreement)

The *Contractual Agreement* resource is consumed by the *Request Supplier Agreement* activity performed by the discovery agent of the infomediary. This activity produces the *Supplier Agreement Request* resource sent to the supplier business enterprise.

RequestSupplierAgreement ⊆ (BusinessActivity) ∧
(= 1 IsPerformedby.DiscoveryAgent) ∧
(= 1 HasCoordinationFlowConsumes. ContractualAgreement) ∧
(= 1 HasCoordinationFlowProduces. SupplierAgreementRequest)

The supplier agent consumes the *Supplier Agreement Request* resource to coordinate the *Provide Supplier Agreement* activity and produce the *Supplier Agreement* resource, which in turn is consumed by the *Receive Supplier Agreement* activity of the discovery agent.

SupplierAgreementRequest ⊆ (Resource) ∧
(= 1 CoordinatesFlowProducedBy. RequestSupplierAgreement) ∧
(= 1CoordinatesFlowConsumedBy.ProvideSupplierAgreement)

ProvideSupplierAgreement ⊆ (BusinessActivity) ∧
(= 1 IsPerformedby.SupplierAgent) ∧
(= 1 HasCoordinationFlowConsumes.SupplierAgreementRequest) ∧
(= 1 HasCoordinationFlowProduces.SupplierAgreement)

SupplierAgreement ⊆ (Resource) ∧
(= 1 hasOwner· Supplier) ∧
(= 1 CoordinatesFlowProducedBy. ProvideSupplierAgreement) ∧
(= 1CoordinatesFlowConsumedBy.ReceiveSupplierAgreement)

ReceiveSupplierAgreement⊆ (BusinessActivity) ∧
(= 1 IsPerformedby.DiscoveryAgent) ∧
(= 1 HasCoordinationFlowConsumes.SupplierAgreement) ∧
(= 1 HasCoordinationFlowProduces.BindingContract)

The *Receive Supplier Agreement* activity of the discovery agent produces the *Binding Contract* resource.

BindingContract ⊆ (Resource) ∧
(= 1 hasOwner· Buyer) ∧
(= 1 CoordinatesFlowProducedBy. ReceiveSupplierAgreement) ∧
(= 1CoordinatesSharing.InitiateTransaction)∧
(= 1CoordinatesSharing.ReceiveContract)

The *Binding Contract* resource has a coordinates sharing relationship with the *Initiate Transaction* activity of the transaction agent and the *Receive Contract* activity of the buyer agent.

InitiateTransaction ⊆ (BusinessActivity) ∧
(= 1 IsPerformedby.TransactionAgent) ∧
(= 1 HasCoordinationSharing.BindingContract)

ReceiveContract ⊆ (BusinessActivity) ∧
(= 1 IsPerformedby.BuyerAgent) ∧
(= 1 HasCoordinationSharing.BindingContract)

According to Grosof and Poon (2004), a contract may be partial, complete, proposed or final. We utilize an inheritance hierarchy of the contract resource and note that a binding contract is an equivalent concept of the final contract.

SUMMARY AND DIRECTIONS FOR FUTURE RESEARCH

By integrating research in Semantic Web technology, eBusiness Processes, and knowledge management, we present a framework for semantic knowledge integration for eBusiness Processes. We first presented ontological engineering and knowledge representation for distributed knowledge management in inter-organizational eBusiness processes and developed the central concepts to model eBusiness Process. Our primary focus is on knowledge representations and semantic architecture for knowledge management for automated inter-organizational eBusiness processes over seamlessly integrated systems. Our general framework in this paper uses DL formalism as a sound theoretical grounding. This forms the basis for the development of machine interpretable knowledge representation in the OWL-DL format. We then showed a description logic model knowledge representation of the intelligent infomediary-based eMarketplace as an illustrative example.

Information and knowledge resources are inherently distributed within and across organizations. Innovation and discovery rest upon the ability of the organizations to share and use information that are owned and made available by partner organizations in the information and knowledge sharing network. In this context, research that helps with knowledge integration and management is critical. Another important aspect of concerns within the realm of shared knowledge domain is enhancement of security considered in (Singh and Salam, Forthcoming). The development of semantic knowledge integration and architecture using a holistic eBusiness process perspective brings the added benefit of a much needed knowledge integration framework for eBusiness process implementations that incorporate semantic knowledge management in inter-organizational eBusiness Processes. In addition to research on developments in technologies and architectures that support Semantic eBusiness processes, research efforts to understand human systems that are the core of any knowledge driven activity is needed. Since, it is the human systems that decide what is knowledge and what is not, studies, in conjunction, that look at how to manage knowledge-based organizations where knowledge resources are distributed across human and software systems will then be meaningful.

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