

SecCPFR – A Design Science Approach to Securing the Collaborative, Planning, Forecasting, and Replenishment (CPFR) Business Processes

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ABSTRACT

This paper addresses the lack of security and process integration of the Collaborative, Planning, Forecasting, and Replenishment (CPFR) approach. Following a design science paradigm, we develop an approach that allows for CPFR's business models to be represented using the atomic concepts of: intelligent agent, role, task, and resource. An ontological analysis and the development of the DL formalisms for the SecCPFR are presented. The proposed framework allows for the separation of duties (SOD) and permission-role assignments with semantic web technologies enabling CPFR processes to be executed in a secure and coordinated manner.

Keywords: *Design Science, CPFR, Role Based Access Control, Semantic Web, Secure CPFR*

INTRODUCTION

The “bullwhip effect”, which serially affects all the players in the supply chain, relates to the natural tendency of the supply chain to amplify, delay, and oscillate demand information (Forrester, 1958). Some of the main issues derived from the demand distortion are excessive inventory investments, poor customer service, lost of revenues due to shortages, and flawed investment decisions about capacity needs (Lee et al., 1997). Swaminathan and Tayur (2003) explain that the Collaborative, Planning, Forecasting, and Replenishment (CPFR) approach is a new and growing movement in industry to deal with demand uncertainty. CPFR aims to make pertinent information available to all member of the supply chain to improve its efficiency. In particular, seamless flow of information across the supply chain helps to coordinate and improve the accuracy of the critical demand forecasting and capacity planning information. The ultimate CPFR's goal is that buyer's purchases forecast and the seller's sales forecast match each other (Caridi et al. 2005). CPFR was developed as an industry effort to provide data models and high-level process maps for collaborative demand forecasting and planning.

According to the Voluntary Inter-industry Commerce Standards Association (VICS), several leading retailers and manufacturers have successfully adopted CPFR and have obtained benefits such as reducing working capital and fixed capital, reducing operation expensive, improved technology ROI, and growing sales (www.VICS.org). However, several barriers must be overcome to fully realize CPFR benefits. Barratt (2004) identifies the lack of information

accuracy, lack of process visibility, and fear of losing confidentiality of shared information prevent organizations from engaging in collaborative planning. In addition, CPFR guidelines do not include sharing process knowledge across partner organizations and do not consider how private and proprietary information and knowledge can be systematically and securely shared while maintaining information assurance concerns.

It has been recognized that one of the most important challenge for security researchers is how to integrate information sources across different organizations securely (Thuraisingham, 2005). In this research, we posit that CPFR business processes have a high level of inter-organizational information and knowledge sharing that demands a secure and coordinated environment to be executed effectively. Therefore, it is our research objective to enhance the security and knowledge sharing of the Collaborative, Planning, Forecasting, and Replenishment (CPFR) business processes by the application of semantic technologies. Based on the best of our knowledge, this is the first attempt to apply emerging technologies, such as semantic web technologies, to enhance the security of CPFR business processes.

To develop this research, we adopt the design science paradigm (Hevner et al., 2004; Walls et al. 1992) as a research method. Design science research addresses classes of problems that solve relevant and unsolved problems, or solve problems in a more effective and efficient manner. Design science research applies kernel theories from the knowledge domain to develop novel IT artifacts (Hevner et al. 2004). This paper is organized as follows. Section 2 presents the literature review and its analysis. Section 3 explains the conceptualization of the CPFR universe of discourse. Section 4 presents the description Logic model for knowledge representation of CPFR. Finally, we present the conclusions and future research.

LITERATURE REVIEW

In this research, we integrate streams of research in the areas of design science, access control, semantic web technologies, including intelligent agents, knowledge representation, and ontologies to enhance the security of CPFR.

Design Science Paradigm

The design science paradigm has its roots in the engineering and the sciences of the artificial (Simon 1996). Design science research addresses classes of problems that solve relevant and

unsolved problems, or solve problems in a more effective and efficient manner. In other words, design science is a fundamentally problem-solving paradigm (Hevner et al. 2004).

Benbasat and Zmud (2003) suggest that the IT artifact and its immediate nomological network should be the core of IS research. Hevner et al. (2004) highlights that the main contribution of design science research is the IT artifact per se. Several controversial IT artifact definitions exist in the literature. We refer the interested reader to Alter (2006) for a compendium of IT artifact definitions. Hevner et al. (2004, pp. 77) define an IT artifact as “constructs (vocabulary and symbols), models (abstraction and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems)”. In this research, we adopt the Hevner et al. (2004) IT artifact definition.

Kernel Theories

Kernel theories from the application domain are applied, modified and/or extended (Hevner et al. 2004) to develop the theoretical basis for design artifact. Next we present the kernel theories that are used to develop the SecCPFR design artifact.

Access Control

Sharing valuable information and knowledge resources entails the risks of possible unauthorized access and usage that may lead to foregone returns on information and knowledge assets.

Research has identified that the most common security mechanisms used to overcome information security issues are the following: authentication mechanisms, authorization, access control, data integrity and data confidentiality policies, integrity of transactions and communications, non-repudiation, end-to-end integrity and confidentiality of message, audit trail, and distributed enforcement of security policies. Here, communication security addresses confidentiality and integrity of the data transmitted as well as non-repudiation, while access control addresses authentication, separation of duty (SOD), and delegation (Joshi et al 2001; Oh and Park 2003). The main objective of access control is, based on business rules, to grant or deny the access requested from a particular user. Access control requirements vary from one environment to another. In the enterprise environment, access control must maintain high degree of information sharing and strong confidentiality (Oh and Park, 2003).

Role-Based Access Control (RBAC) models classify the elements of the system into users, roles, permission, operations, and objects (system resources). The primary benefit of RBAC over previous security mechanisms such as mandatory access control and discretionary access control is the ability of RBAC to accommodate the changing roles of users. RBAC adds *roles* as a layer of abstraction to simplify the association between *users/actors* (agents) and *permission*. Access control policies that specify users' permissions to specific system resources are defined through

the relationships between users, roles and permissions. Sandhu et al. (1996) define a family of RBAC models that include role hierarchies and constraints that allow system administrators to assign users permissions to system resources using roles. Roles are organized and managed using role hierarchies that define the inheritance structure of roles. Role hierarchies for an organization commonly reflect the organizational structures and the hierarchy of responsibility in the organization. Constraints add pragmatic consideration and exceptions to the relationships role hierarchies and are a useful tool in implementing organizational policy for access to system resources (Park et. al, 2001). Because permissions to users are assigned through roles, the administration is made easier (Bhatti et al., 2004). Role-Based Access Control (RBAC) facilitates security administration by allowing organizations to centrally manage and control access to information and processing resources. It is important to mention that the National Institute of Standards and Technology (NIST) adopted RBAC as a National Standard in 2004 (csrc.nist.gov/rbac). In this research, we posit that by integrating RBAC's separation of duties and permission-role assignments with semantic web technologies enable CPFR processes to be executed in a secured and coordinated manner.

Semantic Web

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). The Semantic Web vision comprises *Ontologies* for common semantics of representation and ways to interpret ontology; *Knowledge Representation (KR)* for structured collections of information and inference rules for automated reasoning in a single system; and *Intelligent Agent* to collect content from diverse sources and exchange data enriched with semantics (Berners-Lee et al., 2001). This vision provides the foundation for enhancing the security of CPFR. Developments in semantic technologies make semantic web content unambiguously computer-interpretable and amenable to agent interoperability and automated reasoning techniques (McIlraith et. al., 2001).

Ontology

Even though the word ontology comes from Philosophy, where it means a “systematic explanation of being”, research about ontology has become a very pervasive phenomenon in the computer science field (Guarino, 1998). In general terms, 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 (Sivashanmugam et al., 2004; Thomas et al., 2006).

Moreover, Jasper and Uschold (1999) identify that ontologies can be classified into: a) ontology for knowledge reuse; b) ontology as specification; c) ontology as a provider of common access of heterogeneous information; and d) ontology as a search mechanism. In this research, we develop ontologies that are aimed at enhancing the security and information sharing of organizations adopting or currently using the CPFR approach. Such ontologies will be used to alleviate the interoperability and semantic problems related to integrating disperse and heterogonous information systems.

Selecting the language for the implementation of the ontology is one of the most crucial tasks in the ontology development process. Several ontology languages have been developed. In fact, at least 11 different languages can be identified from literature: KIF, Ontolingua, LOOM, OCML, FLogic, SHOE, XOL, RDF(S), OIL, DAML+OIL, and OWL (Gomez-Perez et al., 2004). The reader is referred to Gomez-Perez et al. (2004) for a comprehensive explanation of each ontology language. For this research, we select *SHIQ* Descriptions logics, which is equivalent to DAML+OIL, presented by Li and Horrocks (2004) to develop the ontologies for the SecCPFR.

Description Logics

Description logics (DL) are logical formalisms for knowledge-representation (Li and Horrocks, 2004; Gomez-Perez et al., 2004). A description logics is divided into two parts: 1) T-BOX, which contains intentional knowledge in the form of a terminology and is built through declarations that describe general properties of concepts; and 2) A-Box, which contains extensional knowledge, which is specified by the individual of the discourse domain (Baader et al., 2003; Gomez-Perez et al., 2004). DL provide a formal linear syntax to express the description of top-level concepts in a problem domain, their relationships and the constraints on the concepts and the relationships that are imposed by pragmatic considerations in the domain of interest. The basic description logics language is the *AL* (Attributive *Language*) which provides a minimal set of concept descriptions including atomic concept, atomic concept negation (\neg), concept intersection ($C \sqcap D$), universal value restrictions ($\forall R.C$), and limited existential value restriction ($\exists R.C$). We refer the

interested reader to Bader, et. al., (2003) for a full explanation of description logics notations, theoretical foundations and applications. In this study, we adopt the *SHIQ* Descriptions logics presented by Li and Horrocks (2004). Li and Horrocks argue that *SHIQ*'s expressive power made it to be equivalent to DAML+OIL. In addition, OWL is based on the SH family of description logics which supports Boolean connectives, including intersection, union and complements, restrictions on properties transitive relationships and relationship hierarchies.

DL-based knowledge representation provides the formalism to express structured knowledge in a format amenable for normative reasoning by intelligent software agents. In this research, we develop DL-based semantic knowledge representation including the access control constraints for CPFR demand forecasting business processes.

Intelligent Agents

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, 1998). 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 the alternative-goal relationships. 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).

Agents have been conceived to be a key technology to solve the problems related to communications in distributed environments (Liang and Huang, 2006). Recently, agent technologies have been applied in the context of supply chains (Nissen and Sengupta, 2006). Sikora and Shaw (1998) develop and validate a multi-agent framework for the coordination and integration of heterogeneous information systems. Their work illustrates how agents can be used to represent organizational functions. Nissen and Sengunta (2006) study the application of agent technologies in supply chain. In particular, they successfully demonstrate how agents can be used to automate and facilitate procurement activities and decisions in the area of maintenance, repairs, and operations (MRO). Liang and Huang (2006) develop a multi-agent-based demand forecast systems where agents share information and forecasting knowledge to control inventory and minimize the total cost of supply chain. In this research, we posit that *Intelligent Agents* can be effectively used to support CPFR business processes.

Collaborative Planning, Forecasting, and Replenishment (CPFR)

In essence, successful supply chain management involves the coordination of activities performed by independent companies in order to deliver a product or service to the end customer (Lee and Whang, 1998). However, several factors have been identified to affect the success of supply chains. Demand uncertainty has always been a topic of interest for the academic and practitioner communities. In this regard, one of the most interesting phenomena in demand forecasting is “bullwhip effect” or “Forrester effect”.

Several efforts have been made to alleviate the “bullwhip effect”. For instance, Swaminathan and Tayur (2003) explain that a new and growing movement is taken place in the industry. This new movement is known as the collaborative planning, forecasting, and replenishment (CPFR) approach. The rationale behinds CPFR is that because the information is made available to all member of the supply chain, the supply chain operations become more efficient. The key is that the forecast is coordinated and it conveys richer information. According to the Voluntary Inter-industry Commerce Standards Association (VICS), several leading retailers and manufacturers have successfully adopted CPFR and have obtained benefits such as reducing working capital and fixed capital, reducing operation expensive, improved technology ROI, and growing sales (www.VICS.org).

After analyzing CPFR’s technical guideline, we realized that such guidelines do not include sharing process knowledge across partner organizations and do not consider how private and proprietary information and knowledge can be systematically and securely shared while maintaining information assurance concerns. Similarly, Barratt (2004) identifies the lack of information accuracy, lack of process visibility, and fear of loosing confidentiality of shared information prevent organizations from engaging in collaborative planning. In next section, we illustrate how a core CPFR business process can be secured through the application of RBAC and semantic web technologies.

DESIGN OF SECURE CPFR (SECCPFR)

Kishore et. al (2006) investigate the characteristics of the multi-agent-based integrative business information systems (MIBIS) universe based on the literatures in both the integrative business information systems (IBIS) and multi-agent systems domains. They propose eight minimal ontological foundation constructs for the MIBIS universe of discourse, including *goal*, *role*, *interaction*, *task*, *information*, *knowledge*, *resource*, and *agent*. Likewise, (Singh and Salam,

2006) proposed that essential set of concepts fundamental to model eBusiness Processes are: *business enterprise, agent, business activity, resource, coordination, information and knowledge.*

Being consistent with previous research in MIBIS, eBusiness Processes, access control, and based on the CPFR's business processes, we proposed that CPFR's business models can be represented using the following atomic concepts: *agent, role, task, and resource.* Figure 1 shows the different atomic concepts and their relationships for the SecCPFR.

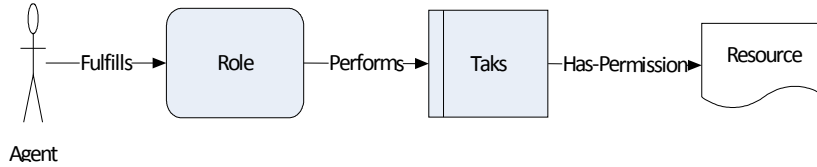


Figure 1. SecCPFR's Atomic Concepts- Universe of Discourse

A SecCPFR business process can be formulated as a quadruplet $SecCPFR=f(Ag,RI,T,R)$; where, *intelligent agents* (Ag) represent business organizations and fulfill roles (RI) and are capable of performing *tasks* (T) that consume and/or produce information *resources* (R) needed to achieve a CPFR business goal. We formalize the definition of the atomic concepts of SecCPFR as follows:

- Definition 0:** *Be= Business enterprises* are represented by agents
- Definition 1:** *Ag=Intelligent agents* perform activities on behalf of business enterprises to enact eBusiness processes
- Definition2:** *RI= Based on access control policies, Resources* allow *Activities* to be performed on them.
- Definition 3:** *Activities= Activities* require access to *Resources* in order to perform business tasks
- Definition 3.1:** *Activities* have permission to read, create, delete, and write *Resources*
- Definition 4:** *R= Resources* are either consume or produce by *Activities*
- Definition 4.1:** *Resources* permit *Activities* to read, create, delete, and write them

Here, *information* and *knowledge* are central resources. They are used by actors in business enterprises to perform their assigned tasks in order to accomplish their goals. To prevent unauthorized access to resources (information and knowledge), the proposed framework grants or revokes permissions based on the roles assigned to each intelligent agent and the tasks that the resources allow to perform on them.

The Description Logics for SecCPFR's Atomic Concepts are presented in table 2.

Atomic Concept	Description	Description Logics
Agent	An Agent concept represents a Business Enterprise and fulfills a Role for the Business Enterprise.	$Agent \subseteq$ $(\geq 1 Represents \cdot BusinessEnterprise) \wedge$ $(\geq 1 Fulfills \cdot Role)$
Role	A Role concept is fulfilled by an Agent and performs at least one Business Activity	$Role \subseteq$ $(\geq 1 IsFullfilledBy \cdot Agent) \wedge$ $(\geq 1 Performs \cdot Task)$
Task	A Task is performed by a Role, has at least one permission to a Resource, coordinates Resources and has a Begin Time and End Time.	$Task \subseteq$ $(\geq 1 hasLabel \cdot StringData) \wedge$ $(\geq 1 isPerformedBy \cdot Role) \wedge$ $(\geq 1 hasPermission \cdot Resource) \wedge$ $(\geq 1 isCoordinatedBy \cdot Resource) \wedge$ $(= 1 hasBeginTime \cdot DateTimeData) \wedge$ $(= 1 hasEndTime \cdot DateTimeData)$
Resource	A Resource is a thing owned by exactly one Business Enterprise and permits Business Activities to perform operations on it and coordinates Business Activities	$Resource \subseteq$ $(= 1 hasID \cdot StringData) \wedge$ $(\geq 1 Permits \cdot Task) \wedge$ $(\geq 1 Coordinates \cdot Task)$

Table 2. The Description Logics for SecCPFR's Atomic Concepts (Adapted from Singh and Salam 2006)

An Illustrative Example of SecCPFR

Even though all CPFR business processes are important, we select the core business process of *Create Order Forecast* to initially evaluate our design artifact. We illustrate how the atomic concepts of the Universe of Discourse can be used to enhance and model the security of CPFR. *Create Order Forecast* process has been identified as strategic and tactical process (Caridi et al., 2005) and involves and requires high degree of collaboration, security, and integration. Figure 3 depicts the dataflow of the *Create Order Forecast* process. The *Create Order Forecast* dataflow describes the information exchanged in an initial order forecast for products within a planning period. (CPFR Technical Specifications, VICS 1999).

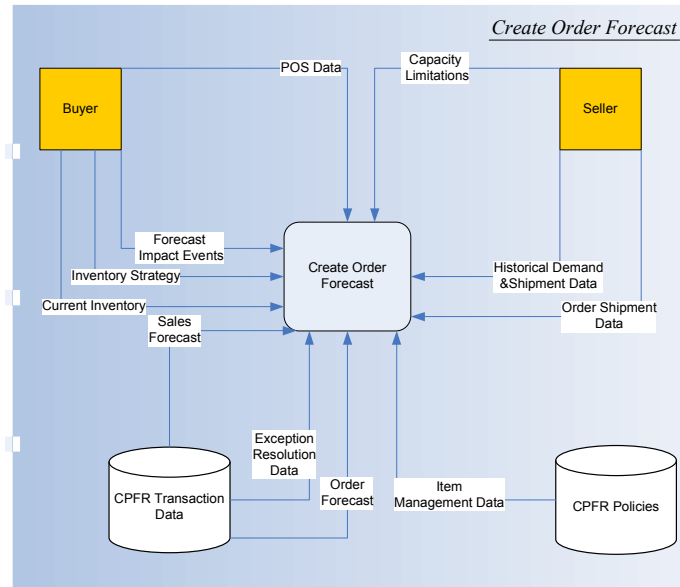


Figure 3. *Create Order Forecast* Data Flow (Adapted from CPFR Technical Specifications, VICS 1999)

An analysis of those business processes allows us to identify the following atomic concepts:

- i) Agents: Buyer agent, Seller agent
- ii) Tasks: Communicate POS Data; Communicate Forecast Events; Communicate Inventory Strategy; Communicate Current Inventory; Communicate Order; Communicate Capacity Limitation; Communicate Historical Demand & Shipment; Communicate Order Shipment Data; Create Order Forecast;
- iii) Resources: POS Data, Forecast Impact Events, Inventory Strategy, Current Inventory, Sales Forecast, Exception Resolution Data, Order Forecast, Capacity Limitation, Historical Demand & Shipment Data, Item Management Data.

Buyer agents and Seller agents represent Sellers and Buyers respectively in the *Create Order Forecast* process. Figure 4 shows how the *Create Order Forecast* process can be mapped using the atomic concepts of SecCPFR.

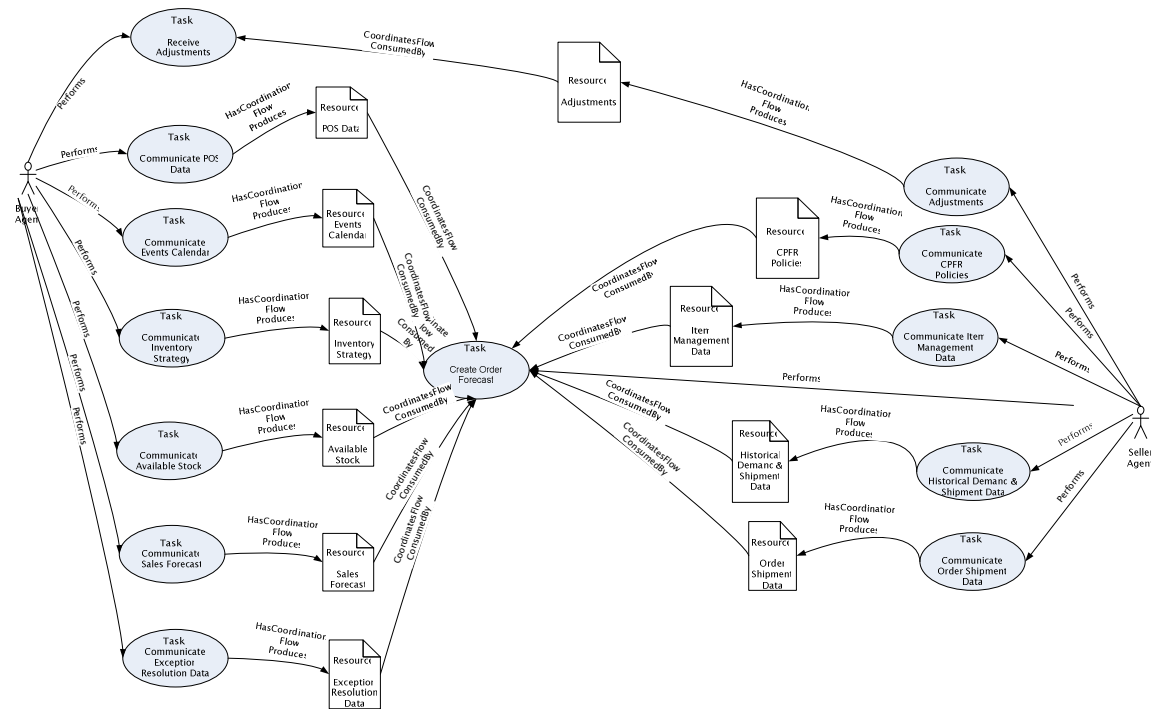


Figure 4. Semantic activity-resource coordination in *Create Order Forecast* Process

After mapping the core business processes of CPFR, it is clear that the security knowledge does not form part of the CPFR technical specifications. Here, CPFR is enhanced by incorporating the roles-activities permissions needed to perform planning and forecasting activities. Using the RBAC model (Sandhu et al., 1996), we show, in Table 3, the role-activity-resource permissions for CPFR's *create order* business process. In addition, based on the universe of discourse, the semantic activity-resource coordination depicted in Figure 4, and the VICS-CPFR data model, we develop the Description logics (DLs) to represent the buyer and seller characteristics along with all the resources involved in the processes of Create Order Forecast.

Role	Fulfilled by	Business Activity	Permission Type (Write, Read, Create, Delete)	Resource
BuyerRole	Buyer Agent	Communicate POS Data	Read/Write	POS Data
		Communicate Forecast Events	Read/Write	Forecast Impact Events
		Communicate Inventory Strategy	Read/Write	Inventory Strategy
		Communicate Current Inventory	Read/Write	Current Inventory Data
		Communicate Order	Read/Write	Order

SellerRole	Seller Agent	Communicate Capacity Limitation	Read/Write	Capacity Limitations
		Communicate Historical Demand & Shipment	Read/Write	Historical Demand & Shipment Data
		Communicate Order Shipment Data	Read/Write	Order Shipment Data
		Create Order Forecast	Read/Write	Order Forecast Sales Forecast Exception Resolution Data Item Management Data POS Data Forecast Impact Events Inventory Strategy Current Inventory Capacity Limitations Historical demand & Shipment Data Order Shipment Data
			Create/Write/Read	Order Forecast

Table 3. RBAC for role-activity-resource permissions for the CPFR's *Create Order* business process

Next, we provide the ontological engineering using DL-based definitions for the activity resource coordination for CPFR. We utilize DL as the knowledge representation formalism for expressing structured knowledge in a format that is amenable for intelligent software agents to reason with it in a normative manner. Understanding the inherent relationships among business processes within and between organizations is a key topic of the information systems field. The use of standard description logics in developing semantic models allow this approach to be a truly implementable framework using W3C's OWL(Web Ontology Language) and OWL-DL without losing theoretical robustness. It is important to highlight that these demand requirement characteristics are intended to serve as examples and are not exhaustive.

Due to space limitation, we only provide the DL for Buyer Agent and its role; Seller Agent and its role; POS Data, and Communicates *POSData*:

A buyer agent represents a buyer business enterprise as it follows:

$$\begin{aligned}
 BuyerAgent \subseteq & \\
 & (=1 \text{ Represents. Buyer}) \wedge \\
 & (=1 \text{ Fulfills. BuyerRole})
 \end{aligned}$$

A buyer can only perform the tasks associated with the *BuyerRole* as it follows:

$$\begin{aligned} \text{BuyerRole} \subseteq & \\ & (=1 \text{ isRepresentedBy} . \text{BuyerAgent}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicatePOS}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicateForecastEvents}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicateInventoryStrategy}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicateCurrentInventory}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicateOrder}) \end{aligned}$$

A seller agent represents a seller business enterprise as it follows:

$$\begin{aligned} \text{SellerAgent} \subseteq & \\ & (=1 \text{ Represents} . \text{Seller}) \wedge \\ & (=1 \text{ Fulfills} . \text{SellerRole}) \end{aligned}$$

A seller can only perform the tasks associated with the *SellerRole* as it follows:

$$\begin{aligned} \text{SellerRole} \subseteq & \\ & (=1 \text{ isRepresentedBy} . \text{SellerAgent}) \wedge \\ & (=1 \text{ Performs} . \text{CreateOrderForecast}) \wedge \\ & (=1 \text{ Performs} . \text{GenerateOrder}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicateCapacityLimitation}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicateHistoricalDemandShipment}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicatesOrderShipment}) \wedge \\ & (=1 \text{ Performs} . \text{CommunicatesReceiveOrder}) \end{aligned}$$

Buyers communicate their POS Data using standardized ontology for specifying the resource.

$$\begin{aligned} \text{POSData} \subseteq & (\text{Resource}) \wedge \\ & (=1 \text{ hasID} . 1) \wedge \\ & (=1 \text{ CoordinatesFlowProducedBy} . \text{CommunicatePOS}) \wedge \\ & (=1 \text{ CoordinatesFlowConsumedBy} . \text{CreateOrderForecast}) \wedge \\ & (=1 \text{ Permits} . \text{CommunicatePOS}) \wedge \\ & (=1 \text{ Permits} . \text{CreateOrderForecast}) \end{aligned}$$

The buyer agent communicates *POSData* to coordinate the *Create Order Forecast* activity.

$$\begin{aligned} \text{CommunicatePOSData} \subseteq & (\text{Task}) \wedge \\ & (=1 \text{ IsPerformedby} . \text{BuyerRole}) \wedge \\ & (=1 \text{ HasCoordinationFlowProduces} . \text{POSData}) \wedge \\ & (=1 \text{ HasPermissionRead} . \text{POSData}) \wedge \\ & (=1 \text{ HasPermissionWrite} . \text{POSData}) \end{aligned}$$

Using Protégé (www.protege.stanford.edu), we develop the T-BOX for SecCPFR design artifact. We use tools like Protégé and Racer (www.racer-systems.com) to verify the conformance to DL formalism and modeling requirements and model consistency of the DL for the SecCPFR. Protégé generates OWL-DL for schema and instance level documents for verification and implementation of semantic knowledge representations

that can be used by intelligent agents to reason and make inferences. DL-based knowledge representation provides the formalism to express structured knowledge in a format amenable for normative reasoning by intelligent software agents, which provide the foundation for semantic interoperability among heterogeneous systems.

CONCLUSIONS AND FUTURE RESEARCH

Following a design science paradigm, we integrate research streams in the areas of access control and Semantic Web technologies to develop a theoretically grounded approach to enhance the security of CPFR business processes. Based on RBAC (Sandhu et al., 1996), a national security standard adopted by the National Institute of Standards and Technology (NIST) and the ontological foundation constructs for the multi-agent-based systems (MIBIS), we proposed the universe of discourse for the SecCPFR. Our universe of discourse, represent the CPFR's business models using the four atomic concepts: *agent*, *role*, *task*, and *resource*. SecCPFR enhances CPFR business processes by providing systematic mechanisms that prevent unauthorized access to information resources, provide non-repudiation mechanisms, and allow for segregation of duties. Our general framework in this paper uses description logics as the theoretical basis. This framework was presented using DL formalism for theoretical soundness. This forms the basis for the development of machine interpretable knowledge representation in the OWL-DL format.

Finally, we showed a description logics model knowledge representation of the business process of *Create Order Forecast* of CPFR as an illustrative example. All DL knowledge representations presented in this paper have been developed, validated and checked for consistency using Protégé and Racer. As future research, we plan to map and develop the DL formalisms for all the CPFR business processes and to perform simulations and experiments to demonstrate the validity of the proposed framework.

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