A SERVICE ORIENTED AGENT BASED MODEL FOR INTER-ORGANIZATIONAL SUPPLY CHAIN MANAGEMENT

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ABSTRACT

In the present competitive scenario Supply Chain Management (SCM) is a challenging problem which demands appropriate strategy to efficiently handle the dynamic requirements of customers. One of the key issues in managing supply chain activities is to monitor workflows across organizational boundaries so that the stakeholders operate in a concerted manner in order to achieve the goal. Integrating various processes in SCM is mainly based on information sharing and redeployment between various associated activities. In this paper we propose a Service oriented Inter-organizational Workflow (IOW) model augmented with software agents to manage the collaboration among several autonomous and heterogeneous business processes distributed over different enterprises. Considering the dynamic nature of SCM, software agents have been employed for composition and enactment of cross-organizational services.

KEYWORDS: *Supply Chain Management, workflow Management, Software Agent*

I. INTRODUCTION

In a typical supply chain raw materials are procured from suppliers and finished products are produced, shipped to warehouses for intermediate storage, and then supplied to retailers or customers. The supply chain management must take into account interactions at various levels among the stakeholders so as to reduce cost and improve service levels. The major stakeholders in a supply chain are the manufacturer/supplier, who produces/provides the products, the Customer/consumer, who purchases the products, the Retailer/distributor, who acts as a broker between manufacturer and customer to sell and deliver the right product to the right customer and purchase products from different manufacturers.

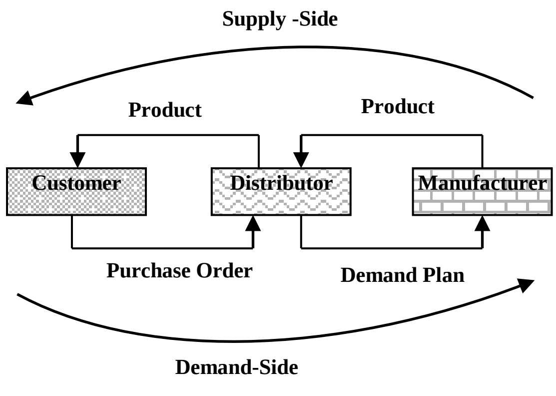


Fig. 1: Supply-side / Demand-side

The Customer places purchase order (PO) to the distributor. The distributor combines all the POs and other information from the customers and prepares a demand plan, and sends it to the manufacturer. The manufacturer in turn plans for a production schedule. Thus, all the entities in a SCM forms a close loop with supply-side and demand-side as depicted in figure 1. The Supply Chain is a network of several businesses and their relationship [1] which involves huge volume of data. In order to effectively handle the activities relating to the SCM process, workflow management technologies have been employed [4]. Further, a Service Oriented Cross organizational workflow (SCW) management approach has also been advocated to effectively deal with SCM [2].

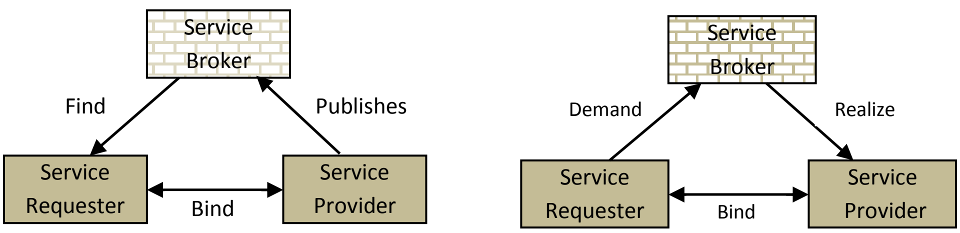
In order to address dynamic issues such as faults/breakdown in utility equipment, delays in delivery of raw materials, failure in production facility, cancellation/change in customers' orders, etc. one finds it difficult for real-time cooperation in supply chain management [3]. The dynamic and distributed nature of the Internet environment is the major challenge in achieving the necessary coordination among the stakeholders. The dynamic issue is mainly because the underlying services are constantly changing or updating. The Distributed nature is because the services are present in different physical or geographical boundaries and any possible solution must appropriately deal with the degree of distribution. Several related projects that provide a solution to address the dynamism problems associated with the cross-organizational workflow. M. Fox [6] proposes an agent-based supply chain architecture that uses independent reusable components and services which supports complex and cooperative works across organizational boundaries. Mennie and Pagurek [5] describe a Jini-based architecture for service composition. In this work, they describe an XML-based specification and process to compose services realized as Java Bean components. However, due to lack of flexible mechanisms to deal with cross-organization business activities, the technology has been continuously under observation.

In this work, we have used software agent technology to deal with the problems relating to dynamic and distributed nature of SCM. An agent is an autonomous and goal-oriented software entity, which can operate asynchronously and cooperatively with other agents as needed [6, 7]. Here we incorporate agents and workflow automation that provides a flexible, configurable and coordinated approach to achieve efficient and cost-effective management across the entire supply chain.

The rest of the paper is organized as follows: Section 2 provides the motivation for service oriented cross organizational workflow with respect to the integration of web services. In section 3, we focus on SCW environment and the of agent based architecture. In section 4, workflow automation through Agent-based Reflexive Processes (WARP) is introduced to support SCW. Different modelling views of WARP approach are presented in section 5. Section 6 describes different workflow operations relevant to SCM. Finally, in section 7 we conclude with a discuss on different aspects of WARP relating to automatic management of web services.

II. CROSS-ORGANIZATIONAL WORKFLOW AND WEB SERVICES

The SCW environment incorporates the interoperability of web services. For example in a SCM the stakeholders supplier, customer and manufacturer can be considered as components, which can be implemented as web services having the capability of being discovered and accessed from distributed locations. We specify these web services through Web Services Description Language (WSDL) [8] which can be invoked using the Simple Object Access Protocol (SOAP) [9].



(a) Supply_side Model (b) Customer_side Model

Fig. 2: Supply_side Model and Customer_side Model

Since we use Software agent technology, we use Web Ontology Language (OWL-S) [10] which enables users and software agents to automatically discover, invoke, compose, and monitor web-based services. Also OWL-S allows automated support for components such as agents to locate, select, employ, compose, and monitor web-based services. In addition, to advertising the specifications of distributed services universally we use Universal Description, Discovery, and Integration (UDDI) architectures [11,12]. The SCM process can be mapped into the physical world similar to the web services architecture as depicted in Figure 2(a). In this model, the three participants are service provider, service requester, and service broker, corresponding to manufacturer, customer, and supplier/distributer respectively. Here the Service provider publishes services to service broker, and the service requester can search the required services. Once a proper service is found, service requester can bind the service with provider directly. This model is from supplier/manufacturer's side we can call such a model as supply-side model. We can again propose a new model that is based on the customer's requirement. We call this as customer-side model as shown in fig. 2(b), where the service requester places its demands to a service broker. Then the service provider can browse the demand information from the customer and choose one to implement. This type of model helps in improving customer satisfaction and reducing the fulfilment time. Here the service broker support two-way service registry to manage supply and demand information.

III. SCW ENVIRONMENT AND AGENT-BASED WORKFLOW ARCHITECTURE

The SCW environment described in this paper incorporates the interoperability of general web services as shown in fig. 3. Here, the Supply chain uses distributed service from different entities - suppliers, customers and manufacturers. These entities register their offerings as web services in a distributed registry, such as a UDDI registry. Our proposed architecture of supply chain management consists of the stakeholders, namely, supplier, manufacturer, and customer. Each entity typically has its own SCM system (SCMS), Thus SCMS-Supply, SCMS-Manufacturing, and SCMS-Customer should perform all supply chain activities in a coordinated fashion [13,14].

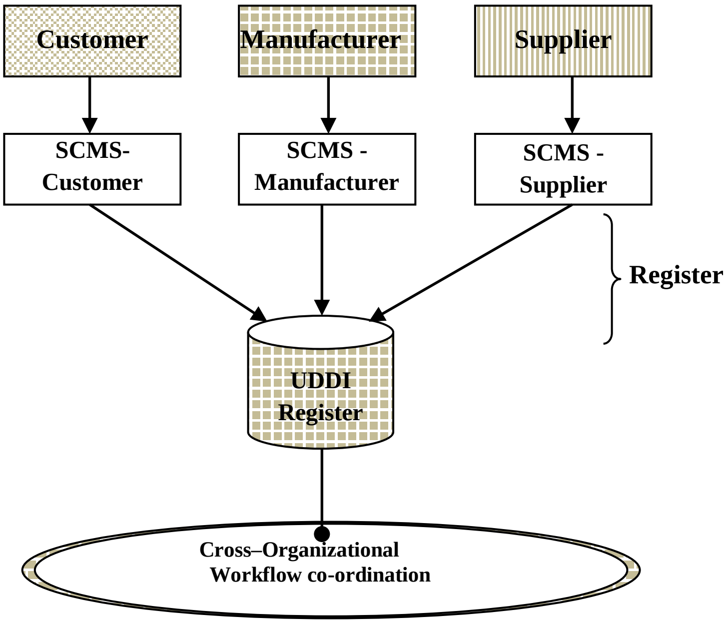


Fig. 3: SCW

IV. THE WARP APPROACH

The WARP approach [15,16] is an agent-based middleware architecture. It consists of software agents that can be configured to control the workflow operation of distributed services. The WARP architecture consists of mainly two layers, the application coordination layer and the automated configuration layer. The WARP architecture is as shown in Figure 4. In application coordination layer the workflow execution takes place by instantiating the workflow instances. The application coordination layer consists of two types of agents, namely,

i) *Role Manager Agent (RMA)* which acts as a broker for the execution of individual roles.
ii) *Workflow Manager Agent (WMA)* which acts as a broker or middle layer agent for the management and coordination of workflow process, and applicable roles.

The WMAs contain the specification and policy of the workflow process. When a new process is configured, the WMAs accept workflow representations from workflow engine as input and write workflow policies to the centralized database, which is used as the agents' knowledge base. Then the new process specifications are deployed to the RMAs. By executing one or more services RMAs fulfil their role. The actual workflow execution takes place when the workflow instances are created. At the beginning when the initiation event is written into the event server, RMAs execute one or more correct services based on its workflow role. WMAs communicate with the first role agent of RMAs via the event server. This makes RMA to invoke correct services based on localized knowledge of services and its workflow role. The WMAs do not control the workflow execution, but it adds events to bring about the non-functional changes (such as exception handling, atomicity etc.) to the workflow process.

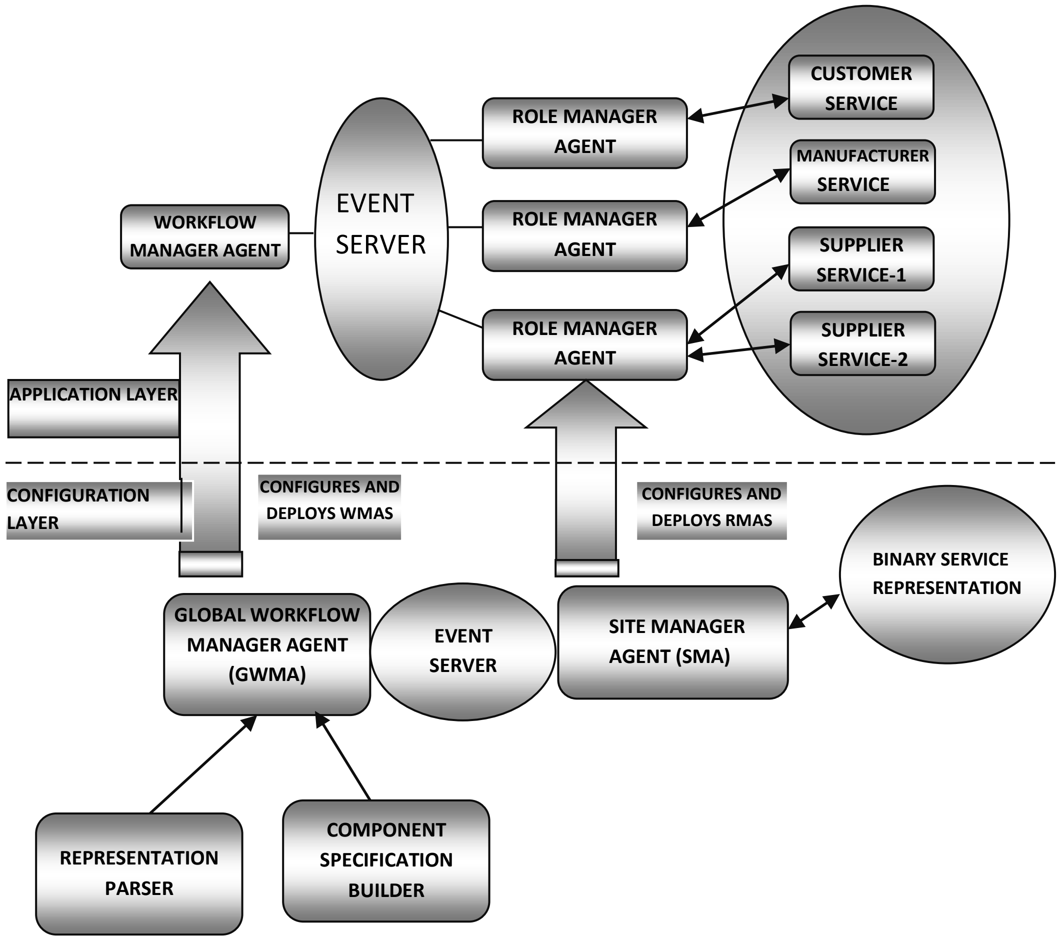


Fig 4 : The WARP architecture for SCM

The automated configuration layer consists of the Site Manager Agents (SMA) and the Global Workflow Manager Agent (GWMA). The SMAs discover the service representations from atomic service components and save the service characteristics in the service–oriented data model as illustrated in Fig. 5.

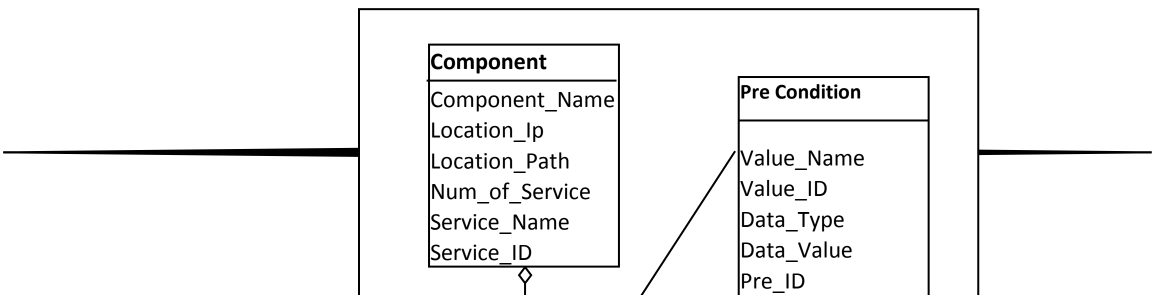


Fig.5: Service representations of atomic service components

The GWMA accepts two inputs:

i. One from SMA, the service representation
ii. Other from the workflow designer, the workflow representation, then writes the workflow policy to the centralized database

Next, the WMAs are configured by the GWMA to play specific roles. After the completion of workflow-level configuration, the RMAs are configured by the SMAs to play certain role as specified in the workflow database. In the WARP process the system takes workflow and the service-based information as input and coordinates the operation of a workflow among previously deployed and new components The WARP architecture is a reflective processes that allows it to discover new service characteristics by introspection from the existing service components. The focus of WARP is to define the components and formalize the methods to achieve semi-automated configuration.

The operation of the WARP architecture is shown in Fig. 6. In step 1 the SMA discovers service representations from the existing service component. In step 2, the SMA populates this Information into a workflow-based repository. In step 3 the workflow designer accesses the available services as Service Representation Views and creates a set of process models. In step 4, GWMA gathers information from a Workflow Designer (human) and populates this information into the same workflow-based repository. In steps 5(i) and 5(ii), the application-layer agents, WMA and RMA are self-configured and are deployed. Step 6 consists of the real-time coordination of the workflow operation.

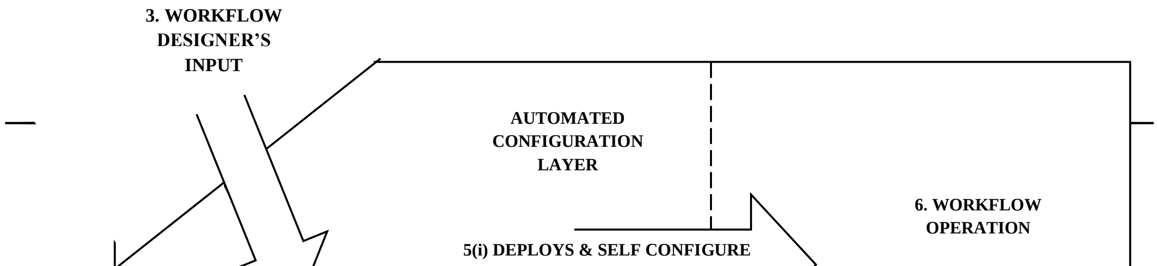


Fig.6: WARP architecture operation for a SCM

V. DIFFERENT MODELLING VIEWS OF WRAP APPROACH

The WRAP is a middleware agent architecture where the configuration requires the coordination between a workflow designer and many software agents. The configuration process mainly consists of (i) specification of various component based service and (ii) specification of workflow processes. WARP uses bottom up approach where service representations are introspected from pre-existing services while humans enhance these representations with location and interaction-based information. In WRAP the services and their interaction can be modelled from three perspectives (i) visual, (ii) message, and (iii) database (for persistence). We use Unified Modelling Language (UML) to model services and their interaction in the visual form and to model the messages we use XML. Finally we use a relational format for persistence storage.

5.1. Visual Modelling

Here we use UML to model different roles played in the workflow, workflow structure, the control/message flows and also the exception handling cases. Let us consider the workflow process in a supply chain management scenario. The WRAP architecture contains agents which introspect the existing atomic components and develop a base model. We consider few supply chain related services as shown in fig.7 with which the agents begin their initial modelling. These are considered as web services which are depicted as class diagrams as shown below.

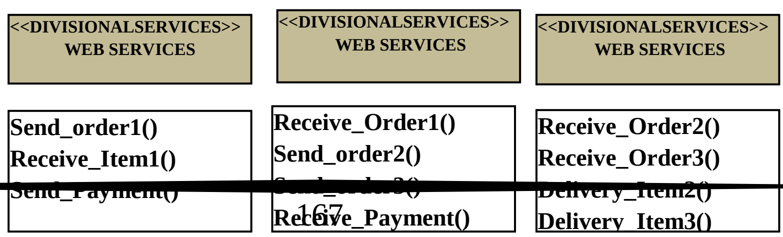


Fig.7: Service Representation View

The first human action in WRAP architecture is to model all the available roles. These roles must be mapped to different services to realize them. The three main roles in SCM are customer interface, manufacturer interface and supplier interface. This model is shown in fig.8 using UML class diagrams, where roles are associated to their corresponding services

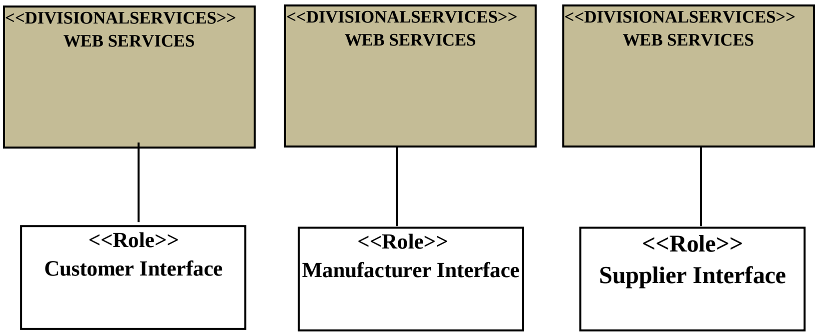


Fig. 8: Role Association View

Roles are joined together to form a workflow. A workflow is named and modelled as a UML class, called in our case as “supply chain”. Fig.9 shows all the roles associated with the workflow process in a typical SCM.

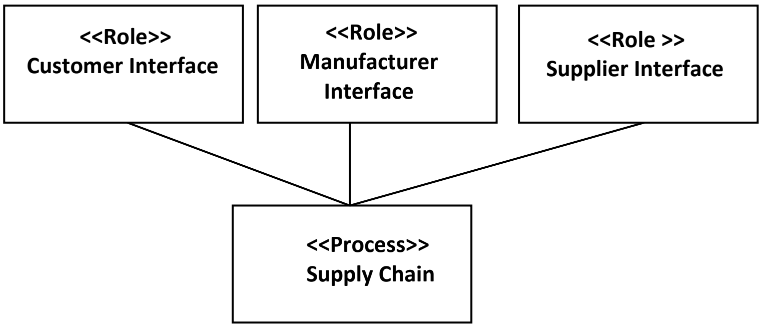
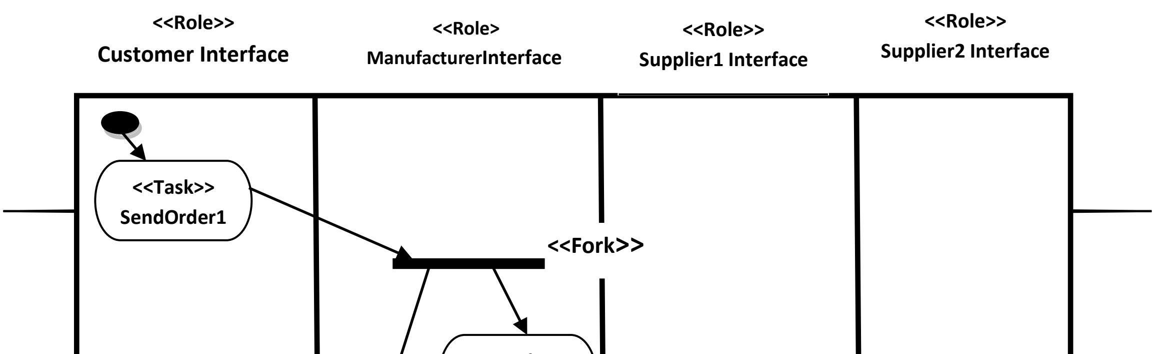


Fig.9: Role Join View

In visual modelling the control flow and the message flow views are the main focus of attention in the workflow coordination. These models are depicted as UML activity diagrams, both for control flow and message flow. The Role Collaboration view shown in Fig. 10 shows different roles played and their services that must be executed throughout the workflow. In this workflow, we have different control flow branches. Activity diagrams show workflow schema with forks that allow for multiple Paths.



As the workflow executes, the Message Collaboration View shows how the information is exchanged between various roles. The classes that represent the dataflow can map to complex XML schemas. This model is shown in Fig.11. The workflow model detailed above shows the information required to model a workflow of web services. Thus, by using visual modelling the interpretation is much clear compared to textual interpretation.

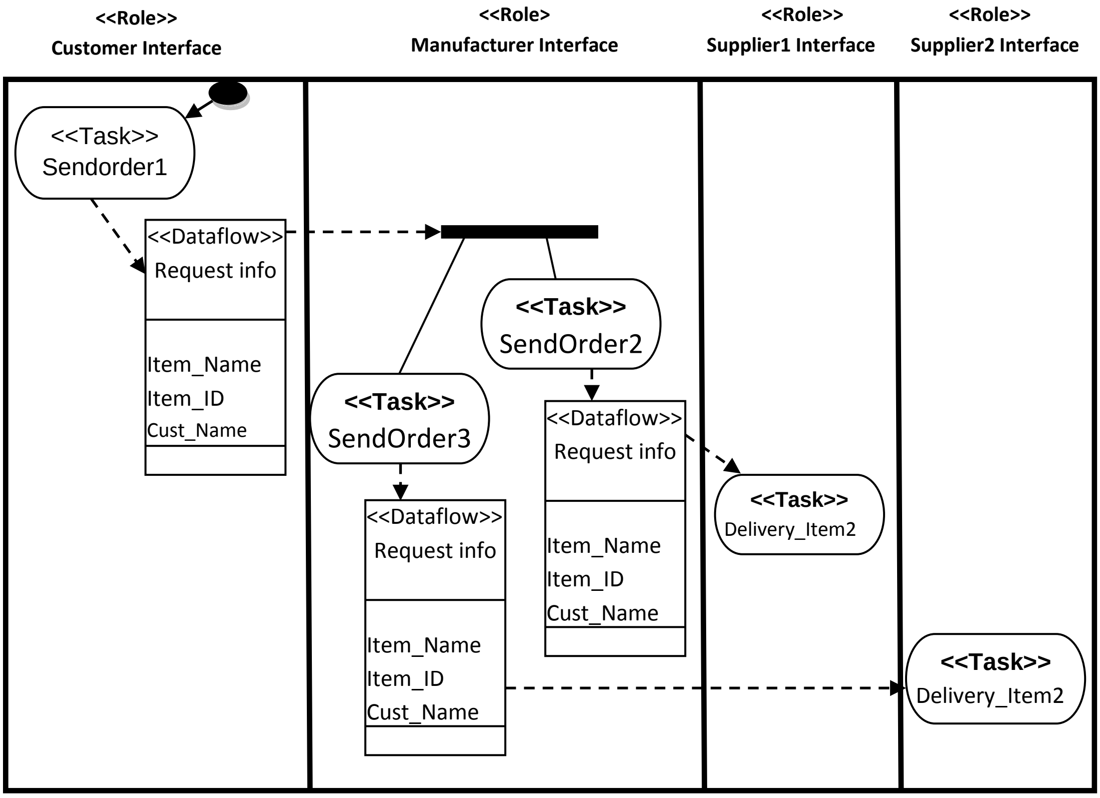


Fig.11: Message Collaboration View

5.2. Message and Relational Modelling

In the following section we map these representations to XML messaging form and relational model. Fig. 12 shows the relational format based on the workflow terminologies. This relational format contains underlying service representations, workflow information flow and workflow control flow.

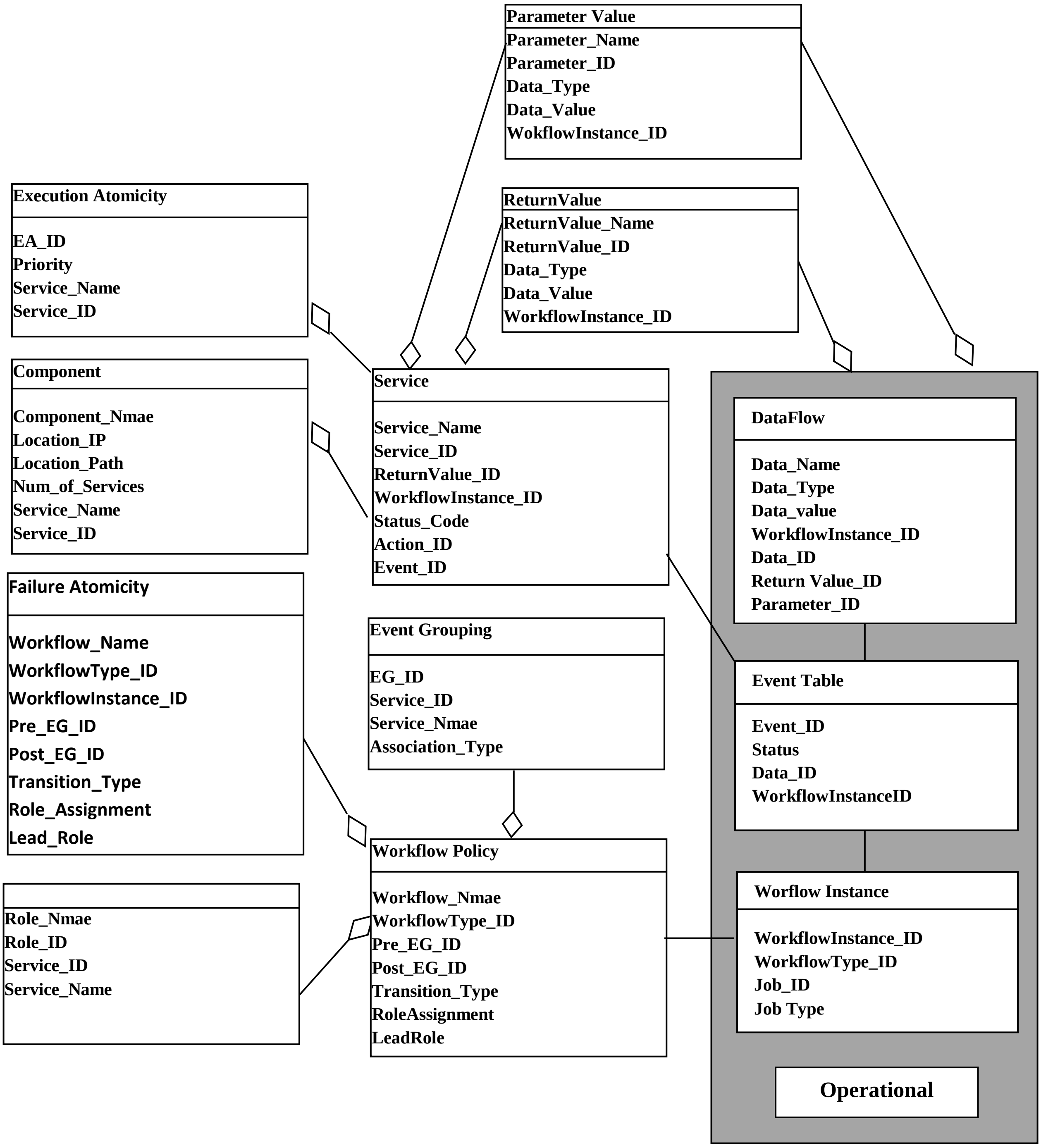


Fig. 12: Relational Format for Workflow Model

In fig. 13 we show how in a supply chain management process the underlying service representations, workflow information flow and workflow control flow mix together to receive the orders sent by customers and fulfil customer needs. Here the manufacturer depends on the raw materials supplied by two suppliers namely, supplier1 and supplier2.

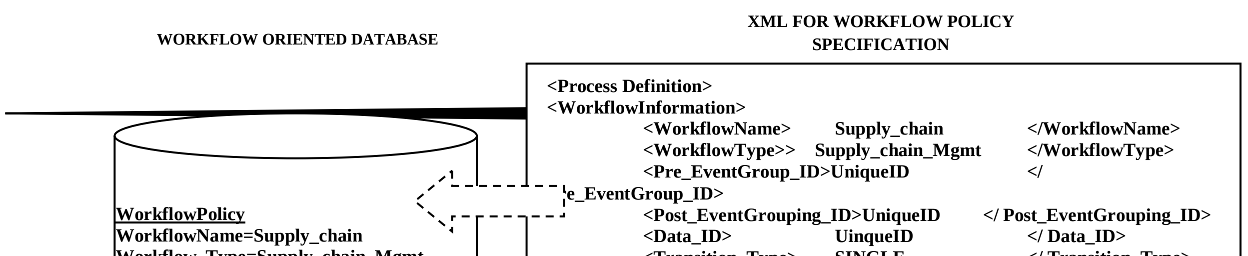


Fig.13 Integration of Three Models Prospective

VI. WORKFLOW OPERATION OF ON-LINE SERVICES

Fig 14 shows the sequence of workflow operations of different WRAP agents. At the beginning when a new job event or service completion event occurs, it initiates the workflow instance and the WMA takes this event, builds a workflow policy with a unique ID based on its Task Object that contains Event-conditions-Action rules. The WMA then broadcasts an event that initiates the workflow. Then the RMAs coordinate to play each role so as to complete the workflow advertised by the WMA. As the RMA is reflexive in nature, it waits till some of the service completion as registered in the event server (tuple space) is reported. Once these services complete their task the RMA invokes some of the services by introspection. When the introspected services are completed it sends a completion event.

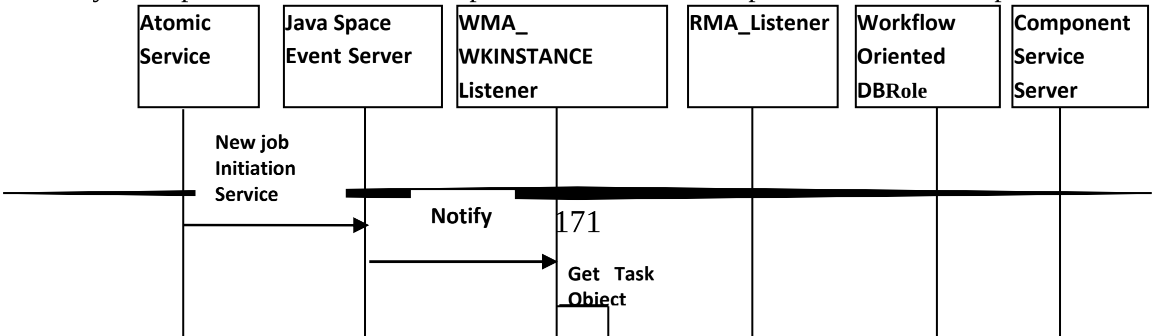


Fig. 14: Sequence Diagram for workflow operation of WRAP agents

VII. CONCLUSIONS

In this paper we have analysed the workflow inherent in a supply chain that involves multiple organizations. In the presence of multiple stakeholders it is imperative that various processes are to be properly coordinated in order to efficiently handle supply chains. We have modelled the application scenario as a set of service providing entities. The workflow among these entities has been monitored by software agents such that agents capture each and every event associated with the SCM process and act suitably in response to different types of events. The proposed model helps in achieving coordination among the stakeholders of the SCM process. We continue to work on formalizing the interaction among various stakeholders in a supply chain process.

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