Collaborating Multiple 3PL Enterprises for Ontology based Interoperable Transportation Planning

Muhammad Ali Memon[1], Agnès Letouzey[2], Mohammed Hedi Karray[3], Bernard Archimède[4]

[1,2,3,4]University of Toulouse, INP-ENIT, 47 Avenue d'Azereix, BP1629, F-65016 Tarbes Cedex,
[1]muhammad-ali.memon@enit.fr, [2]agnes.letouzey@enit.fr,
[3]mohamed-hedi.karray@enit.fr, [4]bernard.archimede@enit.fr

Abstract. Today enterprises have to distribute their final products to far away consumers. It is difficult and not cost effective for these enterprises to manage their own transport vehicles. Thus, they outsource their transportation tasks to third party logistics (3PL) companies. These 3PL companies take transport orders from several clients and try to group them in the vehicles to utilize their resources at maximum. An issue of interoperability arises, when 3PL companies have to process different transport orders arriving from several clients in different formats and terminologies. Secondly, how 3PLS will collaborate with other 3PL companies following different working standards and also for collaboratively delivering transport orders which single 3PL cannot deliver alone due to its limited operational geographic area. Interoperability to achieve collaborative transportation planning is our concern in the context of this paper. Interoperability is a key issue for collaboration, especially in case of heterogeneous environment, when entities trying to collaborate have different ways of functioning and follow certain standards specific to their organizations. So the objective of this paper is to present a distributed and interoperable architecture for planning transportation activities of multiple logistics enterprises aiming at a better use of transport resources and by grouping transport orders of several manufacturers for each effective displacement.

Keywords: Interoperable and Distributed Scheduling, Multi-Agent Systems, Collaborative Transportation Planning, Third Party Logistics, Ontology

1.1 Introduction

More often, companies wishing to reach the far away customers could not possibly purchase their own fleet of vehicles to transport their goods. These companies contact third party transportation companies to ship their products, same as a courier company. This need led emergence of Third Party Logistics enterprises (3PL)[3]. In that case, suppliers can outsource their complete transportation tasks to 3PL enterprises and then these 3PLs take charge of whole transportation process. To fulfil customers' demands and improve the performance of supply chains, 3PL must manage its own resources and collaborate with other 2PL (carriers) and 3PL companies to reach far away customers at lower price. Additionally these 3PLs will group together several transport orders sharing similar origins or destinations in vehicles to deliver them collectively. Eventually minimizing number of transport travels and minimizing environmental pollution. This collaboration involves a good understanding of exchanged information between clients and 3PL and between 3PLs, especially about locations, product constraints, vehicles type, etc.

Clients will generate their transport orders by their own specific ways, which will not be understandable by 3PLs. There is a need of an interoperable mechanism which can transform the information for that 3PL in an understandable form. This transformation should deliver correct information and without any distortion. Similarly for communication in case of multiple 3PLs, they need an intermediate mechanism to understand each other's working methods in order to collaborate. One solution is to let each entity work in its own manner by using their terms, but defining them using their local ontologies and let interoperable service utilities (ISU) handle the transformations on the basis of common semantics [9,16]. Thus, the schedule of all transport orders has to be achieved by several interoperable scheduling systems.

The work presented in this paper proposes ontology based interoperable framework to support collaborative transport planning for 3PL enterprises in distributed manner. The objective is to describe the I-POVES Interoperable (Path Finder, Order, Vehicle, Environment, and Supervisor) for improving collaboration and interoperability between 3PL enterprises and clients. After a state of the art on the latest research on interoperability for transportation planning, we describe the interoperable architecture of the POVES model and the associated ontologies. Finally, we conclude with future work.

1.2 State of the art

Several approaches have been proposed to solve transportation planning problem. Sauer and Appelrath [7] proposed a centralized approach with a global scheduler, which schedules transportation planning activities. They model the problem by a 5-tuple (R, P, O, HC, SC), where R denotes the set of required resources, P the set of products, O the set of actual orders and HC and SC the sets of hard and soft constraints, respectively. They use a rule-based approach and heuristics to produce several scheduling strategies. This approach is centralized

and is limited to the planning of transportation activities of a single enterprise. The need for confidentiality limits the scope of centralized approaches.
Baykasoglu and Kaplanoglu [1] proposed a multi-agent approach to address collaborative transportation problem. This approach is based on cooperation between transport order agents and truck agents, which proposes grouping multiple orders together in a vehicle. In this approach, transport order agent is bound to accept the proposition from one truck agent, which provides a nonstop delivery from origin to destination. However, in reality a truck rarely alone transports a transport order. A transport order requires, most often, several trucks.

Takoudjou R. et al [10] propose a multi-agent heuristic to address the transport problem with transhipment. Their methodology is decomposed in four steps. In first step, they calculate PDP (pickup and delivery solution) without transhipment/ Cross Docking solution for all random requests. In second step, they try to optimize the PDP solution with VND (Variable Neighbourhood Descent method) using Path Relinking. In the third step, they calculate PDPT (PDP with transhipment) solution, compare it with PDP solution and keep the best one. This whole procedure is repeated to the number of iterations. This work makes an assumption that number of vehicles is not fixed and if no vehicle can satisfy a request because of the noncompliance with the constraints (vehicle capacity, time windows, etc.), a new route is created with a new vehicle to welcome the considered request. It is not realistic to create a new vehicle each time a transport order needs one. Moreover, this method calculates PDP solution without transhipment improves it by optimizing it and then destroys the PDP solution to obtain PDPT solution with transhipment. In further studies a simulation framework is presented by Sprenger and Mönch [8] for assessing the performance of cooperative transportation planning and isolated transportation planning. Mes et al. [6] study the interaction between intelligent agent strategies for realtime transportation planning. A multi-agent theoretical approach on dynamic transportation planning is given in [2].

Above mentioned papers are interested only for transportation planning and do not take into account the interoperability aspect. Following papers discuss the interoperability for exchanging information. Niarki and kim[13] propose an ontology based personalized route planning system which uses multi–criteria decision making from user/ decision maker. Whether, a certain route is better than other strongly depends on environmental situations and user preferences. In addition to these criteria, the impedance of road plays a very important role in route planning. Impedance factors involved in determining the travel time are the volume of the traffic, the type of the road, the road width, number of junctions and turns etc. This approach models the decision making criteria using ontology and apply an impedance function in route finding algorithm to find the personalized route for the user(s).

Paul Davidson et al[14] have developed an adapter based open source freeware to exchange information between business systems. System was tested on two case studies for improving transport activities for small medium enterprises, based in Sweden. S. Smith and M.Becker [11,12] propose an ontology based toolkit for constraint based scheduling system called ozone. The ozone ontology provides a framework for analysing the information requirement of a given target domain, and a structural foundation for constructing an appropriate domain model. We here are interested to use the aspect of interoperability for solving collaboration problem in transport planning domain.

1.3 P.O.V.E.S. MULTI-AGENT MODEL

1.3.1 Description of model

The POVES multi-agent model (Fig. 1.1) is developed for collaborative transportation planning activities. It is inherited from SCEP multi-agent model, which is being used with success for manufacturing planning since years. Limitations restricted SCEP for transportation planning [4], due to that POVES emerged after overcoming these limitations. POVES introduces an indirect cooperation between two communities of agents, Order agents called (O) and vehicle agents called (V), leading to a high level of co-operation. Each order agent manages one transport order from first party logistics (1PL). Each vehicle agent manages one vehicle of the organization. A supporting agent "Path Finder" elaborates for a transport order the traveling route between pickup and delivery locations. The cooperation between order agents and vehicle agents is performed synchronically through the background environment agent E. The supervisor agent S controls the model functioning. The detail working procedures and functioning of POVES model is given in [5].

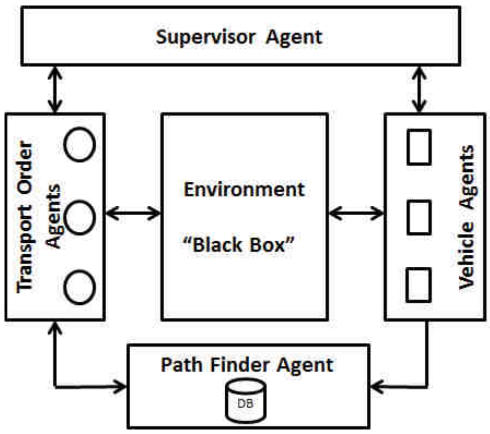

Fig. 1.1 POVES model

1.3.2 Limitations of the model

This model is well suited for transportation planning in case of only single 3PL enterprise with a fleet of its own vehicles. However a single 3PL enterprise operates in a limited region and it is unlikely possible that it can fulfil TO entirely. It is more often that, TOs have to be delivered to faraway clients in a region outside the reach of this 3PL. It must collaborate with other 3PL enterprises that operate in other regions to make the delivery of the products to faraway clients. Moreover, if more than one 3PLs operating in the same region entirely or partly, they will increase the chance of TO delivery on time, as one of either must have a vehicle available to deliver the order on time. Additionally in POVES, TOs arrive from several clients, but these TOs should be in the same format that should be compliant with the format understandable by Path Finder agent to find the elementary activities. In reality, customers generate their TOs in different formats that are not interoperable by the 3PL enterprises, because each of the customers has its own way of interpreting and representing locations, paths, etc. Similarly, each of 3PL enterprises defines their elementary activities and vehicle parameters according to their own methods and formats. There is need of some intermediary mechanism that could understand all the formats in order to produce better results, which is currently not available in the POVES previously presented. For these reasons POVES model must be evolved.

1.4 Interoperable-POVES

In order to take into account limitations in the preceding section, we propose an evolved version of POVES model shown in Fig 1.2. In this model, we add ontologies and interoperable service utilities (ISU) in order to achieve interoperability to treat different formats. Ontology provides a shared vocabulary (terminologies), which can be used to model a knowledge domain. Each customer who generates TOs, defines them using the terminologies from their local ontology. Similarly, each transporter (3PL) has also its local ontology to define its elementary activities and vehicle parameters, which is comprehensible only by this transporter. In addition to that, we add a global ontology, which provides a federation of concepts. Those concepts map with the concepts of all the local ontologies on the basis of common semantics [16]. Global ontology has consistent and coherent information and has standard and shared terminologies.

Furthermore, in order to work on that global ontology standard terminologies, we require interoperable service utilities, which will be used for matching and translation of terminologies from local ontologies to global ontology and vice versa. In I-POVES, virtual customer presents an ISU that will match and translate the enterprise's "Customers local ontologies" terminologies to global ontologies' terminologies and then communicate with Path Finder to find the route. Path Finder finds a route based on the terminologies of global ontology. Then, virtual customer will send computed route tasks to environment for planning. Similarly, virtual 3PL is also an ISU that will retrieve the tasks from environment. Those tasks are represented in the form of global ontology standard and translated and sent into the format of local ontologies for respective 3PLs by ISU. After 3PL planning, virtual 3PL sends back to the environment propositions received by 3PLs after translating them from transporter's local terminologies to global ontologies. Virtual 3PL will also translate the elementary activities of each 3PL and their vehicle parameters and send them to Path Finder to update its database before commencement of the planning process, each time Path Finder agent is activated.

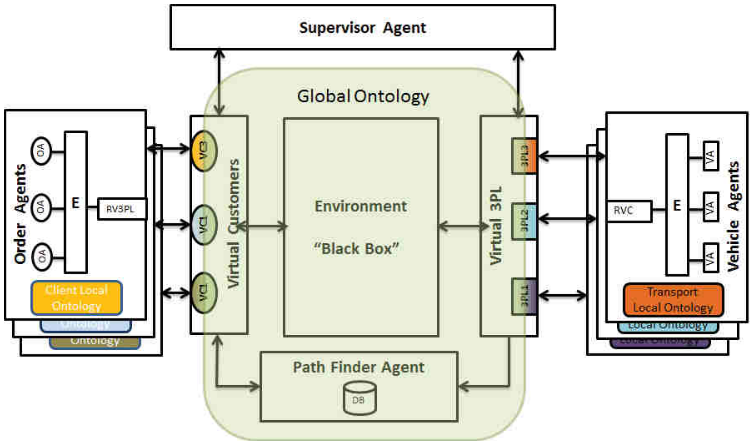

Fig. 1.2 I-POVES model

The use of local and global ontologies will provide liberty to customers and transporters to work on their own standards without bothering of everybody else. Similarly intermediary ISUs will provide interoperability between them to work together in order to provide collaborative transportation planning.

Ontologies presented in this paper are loosely inspired from the Ozone ontology developed by S.Smith and al [11,12]. Fig 1.3 presents an example of a local ontology of a transporter. Blue circles represent domain classes, red rectangles represent properties and green rectangles represent class instances and orange rectangle represents class attributes. Transporter owns fleet of vans represented by class 'Van'. These vans have facilities, which are represented by a class 'Facility' which have five instances to represent facilities type: 'Freezer', 'Freezer+Ice', 'Normal', 'Refrigerated' and 'Validated'. Association between class 'Van' and class 'Facility' is represented by a property called 'Has-Facility'. Vans with compartments are used to transport different type of products with different temperature requirements. There is another class called 'Van-Type', which has two instances called 'With-Compartment' and 'Without-Compartment'. Relation between class 'Van' and 'Van-Type' is represented by property 'Has-Type'. Each van is associated with certain nonstop trajectories assigned by transporter. Each trajectory has location of departure and location of arrival. Each location lies in certain region, where transporter provides its logistics services. Class 'Van' has a relation called 'Has A' with class 'Trajectory'. Class 'Location' is associated with class 'Region' with the property 'Lies-In'.

V1 represents one of the instances of Van which has facility of 'Freezer-Ice' and is of type 'Without-Compartment'. 'TAR-TOU' is an instance of class 'Trajectory' which has Tarbes as location of departure and Toulouse as location of arrival. Instance V1 is associated with this trajectory and is represented by the property 'Has-A'.

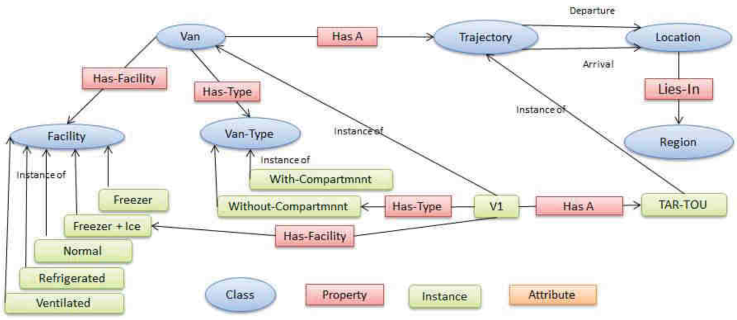

Fig. 1.3 Example of transporter local ontology

Transporters even following the same standards but residing in different countries will express locations differently as each country has its specific way of defining geographical divisions. For example in France there are regions and departments and in Pakistan there are provinces, divisions and districts. Furthermore, transporters operating even in the same region to their clients have heterogeneous way of using locations name. In our example transporter defines TAR and TOU as abbreviations of Tarbes and Toulouse, which may not be understandable by the client placing the order. This antagonism generates the need of a global ontology. It represents the concepts that are semantically similar used in local ontologies to follow a single standard during the planning process. Fig 1.5 illustrates the global ontology.

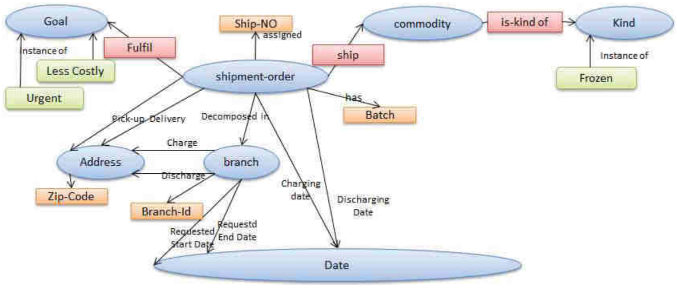

Fig. 1.4 Example of client local ontology

Similarly Fig 1.4 represents an example of client local ontology. Client generates set of TOs represented by a class 'Transport-Order' which is created to deliver a product P1 of type 'Has-Type' Live animal of quantity 'Quantity'. TOs have city of pickup and delivery in global, which are then decomposed into elementary nonstop travels called 'Tasks' by Path Finder agent. Client attaches objective to each TO in order to define its priority which needs to be fulfilled. Here 'Objective' class have three instances; 'Less Costly','Urgent','Less Distance'. Client proposes requested start date and requested end date for these tasks and in return receives potential dates and effective dates from transporter.

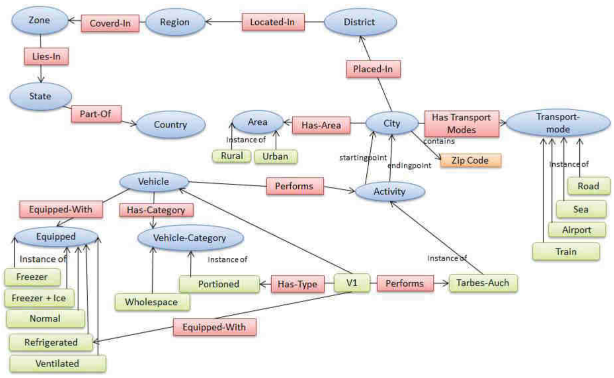

Fig. 1.5 **I-**POVES global ontology for transport

Global ontology has the concept Vehicle that corresponds to concept 'Van' and 'Truck' for local ontologies. Vehicle performs 'Activity' similar to 'Trajectory' and 'Travels' in local ontologies. Vehicle has 'category' partitioned and 'whole space' similar to 'Without-Compartment' and 'With-Compartment' in ontology for transporter.

Table. 1.1 Concepts alignment between Global and Client ontology

Global	Client
Transport Order	Shipment Order
Order-No	Ship-No
Objective	Goal
Product	Commodity
Type	Kind
Origin	Charge
Destination	Discharge
Pickup date	Charging date
Delivery Date	Discharging Date
Quantity	Batch
Task	Branch
Task-No	Branch-ID
City	Address

There have to be matching criteria between local ontologies and global ontologies embedded in ISU of both the sides; clients and transporters. Table 1.1 shows the concepts of alignment between local client ontology and global ontology, while table 1.2 shows the alignment of transporter local and global ontology. The alignment mechanism used here is constructed manually but can be automatized using approach proposed by Song Fugi in [15]. He developed an ontology alignment technique to contribute federated enterprise data interoperability approach at semantic level. ISU will use this matching mechanism to make the transformation possible from local ontologies concepts to global concepts and vice versa. Local ontologies are subjected to evolve when new vehicles and new travels are added or clients progress from local to global. This evolution will cause the enrichment of these local ontologies, also forcing the enrichment of global ontology at the same time in order to continue keeping the compliance. This evolution is independent of the planning mechanism making this framework of distributed nature. Additionally transporters and clients joining or leaving the model do not affect its interoperable nature. It will require only the enrichment of the global ontology and updating the matching and transformation mechanisms in ISUs of POVES model.

Table. 1.2 Concepts alignment between Global and Transporter ontology

Global	Transporter
Vehicle	Van
Activity	Trajectory
Equipped	Facility
Category	Van-Type
Origin	Departure(Location)
Destination	Arrival(location)
Department	Region

1.4 Conclusion and future work

In this paper we presented ontology based a collaborative and interoperable framework called "I-POVES" for transportation planning problem In I-POVES, each order agents has its own local ontology and describes its transport orders using the concepts from local ontology. Similarly vehicle agents also have their own local ontologies to describe their vehicles and activities. We used a federated approach based on global ontology that maps all shared concepts used by local ontologies on both the sides. There are two ISUs, one on the order agents' side and one the vehicle agent side, to perform transformation between local and global ontologies. In I-POVES, firstly Path Finder Agent elaborates, when solicited for each order the traveling routes between pickup and delivery locations. Secondly Order agents offer transport jobs through sequential auctions and vehicle agents compete with each other to serve those jobs. Vehicle agents propose grouping these jobs together to execute them simultaneously. Multiple 3PL enterprises collaborate through this framework to propose the delivery of transport orders together. One of the future directions is, in case when 3PLs have their own planning mechanism and they just want to use I-POVES for collaboration with other 3PLS. How much transport ISU will be capable to handle not only ontology transformations but also the transformation from I-POVES planning mechanism and 3PL's local planning mechanism and vice versa.

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