Planning in gas transmission: an agent-based approach

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Abstract

Due to liberalization of the gas market, a separation between the pipeline's management and the gas supply and trading activities must take place to ensure non-discriminatory third party access. In addition to the already complex process of gas transmission, new roles appear linked to the management of different clients and a larger spectrum of contracts types. Multi-agent modelling techniques allow to model distributed systems that are loosely interconnected. We propose a multi-agent model for gas transmission, where different entities (agents) are not completely transparent to each other. Our model can be executed as a simulation of their complex interactions in the context of planning. This model uses the TALMOD language, specifically designed to identify and (re)design planning activities in distributed systems.

Благодаря либерализации газового рынка управление газопроводами, поставка газа и торговая деятельность должны быть разделены для обеспечения равноправного доступа третьих сторон. В добавление к уже достаточно сложному процессу транспортировки газа возникают новые роли, связанные с управлением различными клиентами и с более широким спектром типов контрактов. Методы моделирования, основанные на использовании систем программных агентов, позволяют моделировать слабо связанные распределенные системы. Используя такую систему агентов, мы предлагаем модель для задачи транспортировки газа, в которой участники (агенты) не полностью прозрачны друг для друга. Эта модель может использоваться для представления сложных взаимодействий между участниками в контексте планирования. Модель использует язык моделирования TALMOD, разработанный специально для задач определения и перестройки процессов планирования в распределенных системах.
1 Introduction

Gas transport has been the central point of the liberalization reforms. The main goal of the liberalization is to open fairly the access to transport services. This has led to the separation between the trade of gas, seen as a commodity trade, and the gas transport. The split, that occurs within the previously existing monopolies, have led to the emergence of a gas pipeline transport market, where pipeline transport services are traded. Subsequently, the decision-making process decentralized, resulting into the application of localized policies adapted to a changing competitive environment.

Liberalization of the gas market has been the cause of drastic changes in the structure of the gas transport business and particularly in the organization of the gas pipeline transport market. The trading of transport services has become more complex in terms of number of actors involved, and type of relationships between them. Planning in this new changing environment needs new models and tools supporting the understanding of the market, bringing information over its evolution over time in terms of production and consumption structure. Considering the whole co-operation network of the actors involved in a market, it allows to support better the process change [Sherer(2005)].

Managing the relationships between the different parties within a complex network of economical actors is supported by different computer systems [Sherer(2005)], [Nissen(2001)]. Intelligent agent technology has been proven to be a suitable tool to deal with the complex, dynamic, and distributed nature of these relations [Wagner et al. (2002)], [Wooldridge (2002)]. Moreover, through the capability to formalize and embed domain-specific knowledge and market-specific expertise in multi-agent systems, this technology offers potential to substitute knowledgeable and experienced human intermediaries within cross business processes [Nissen(2001)].

In this paper, we propose a multi-agent model for gas pipeline transport market. This preliminary model can be executed as a simulation of the complex interactions existing between different stakeholder in the context of planning, more specifically in booking transport capacity.

This paper is organized as follows. First, we provide an introduction to the multi-agent approach, and to TALMOD language [Snou (2005)], specifically designed to identify and (re)design planning activities in distributed systems. Second, we identify the novel structure and dynamics of the gas transport market after liberalization, and propose a general model of the gas pipeline transport market. This model aims to support the development of the simulation of the transport network behavior. Third, as an illustration of our approach, we propose a model describing the behavior of two types of actors involved in the booking capacity process, in the context of the Dutch transport market.

2 Agent-based approach and the TALMOD language

The multi-agent approach supports naturally the modelling and the simulation of organization’s network dynamics [Nissen(2001)]. The main concepts of an agent-based representation of organizations are agents, interactions, organizational relationships [Jennings (2000)], and roles [Steimann (2000)]. In this
paper, as proposed in [Wagner(2003)], we extend the Wooldridge's notion of software agent [Wooldridge (2002)], by including the concepts of human and organizational agents. An agent is an 'encapsulated computer system that is situated in some environment and that is capable of flexible, autonomous action in that environment in order to meet its design objectives' [Wooldridge (2002)].

An agent is acting in its environment in function of its allocated roles. It can play more than one role (even in the same time) and the binding between roles and agents should allow a role to be played by multiple agents. A role corresponds to a collection of duties, authorization and interaction patterns [Jiao (2005)], where an interaction is a conceptual unit that captures the nature of a relationship between two or more roles. By separating the agent from the role and focusing on the modelling of interactions between roles, the resulting models are far more flexible and general. Indeed, very often, only the distribution of the roles among agents change with the environment. It is particularly the case in the context of national gas markets. Organizational relationships corresponds to the relationships existing between agents, representing parts of the same organization, or the whole organization.

To develop efficiently agent-based systems from business process models, it is necessary to define an appropriate modelling language. A first step in this direction has been the development of the TALMOD language [Snoo (2005)]. This language consists of 36 modelling constructs. These constructs, the TALMOD modelling elements, are represented in figure 1.

![TALMOD modelling elements](image)

Figure 1: TALMOD modelling elements

In this language, four types of diagrams are used: the role-interaction diagram, the agent-role diagram, the static structure diagram, and the local behavior diagram. In the role-interaction diagram (figure 2), the different roles involved in the process, and their interactions are identified. In this diagram, a fundamental construct, the local behavior (LB), is used. It is associated to an agent playing a role, and represents its local knowledge about the overall process. In the agent-role diagram (figure 3) is displayed which actors and entities play which roles in the modelled scenario. The static structure diagram is basically the UML static structure diagram, where the concepts of role and information ownership are added. The local behavior diagram describes in detail the activities from the perspective of an agent performing a specific role. It is modelled as a
sequence of activities adopting the agent's internal perspective about the whole process. This sequence of activities can spread over multiple roles represented as swimlanes, like in UML activity diagrams. The local behaviors of agents, playing connected roles, are modelled as "expected behaviors" and are represented as a cloud, figure 1. These are not always known in detail by the local role.

3 Structure of the local/national gas pipeline transport market

The pipeline transport market emerged from the liberalization of the gas market. In the gas pipeline transport market, the transport of high pressure gas from its production site to its destination is organized via the trade of transport services. In order to be able to understand the way this market is working and can evolve, it is necessary to identify the structure of the pipeline transport market. In this paper we are considering the market limited to the high pressure gas transport through a national/local pipeline network (GRID), adopting the perspective of the responsible of the transport. The structure of the market is dependant of two main features: the type of roles existing on the market and the organization of the business around these different roles. As a convention, in the remaining of the text, the names of roles are in italic.

In the pipeline transport market, trading occurs between shippers and transport managers. The shippers are contracting transport capacity on the GRID the transport manager manages. The maintenance, the development of the GRID, and the definition of its constraints of use are the responsibilities of the GRID operator. The metering agent is responsible of providing to the transport manager punctual measures concerning the gas flow. Very often, a transport manager operates as a monopoly on a local geographical area, defined by a GRID. Hence, one speaks of local/national transport manager. In order to prevent the local/national transport manager to take advantage of its position, it is under the stewardship of a local/national regulator, that controls mainly the tariff practices through limiting the authorized profit.

As shown in figure 2, the structure of the market has the star form, with the transport manager occupying the central position. At the periphery of the star are the roles of shipper, metering agent, regulator and GRID operator.

Figure 2: Role-Interaction TALMOD diagram describing the structure of the gas pipeline transport market
Due to the natural status of monopoly of the transport manager, the structure of the market is stable over time and has the star type everywhere in Europe. Nevertheless, the distribution of the roles among the different agents (actors) involved in different national/local gas pipeline transport markets differs. In figure 3, we show the distribution of roles among agents in the Dutch case.

In the Netherlands, the national company Gastransport Services (GTS) is responsible to manage transport, to operate the GRID and to perform the metering. This company, owned in majority by the state, is regulated by the Directie Toezicht Energie (DTe). Currently, there are 42 shippers. In the diagram (figure 3), only four shippers have been represented. In the following section, we are modeling the local behavior of the shipper and GTS, in the context of booking capacity process.

4 Modelling the capacity booking process in the Dutch national context

Capacity booking is anterior to any other interaction between a shipper and GTS. The description of this process is based on the information displayed on the GTS web page [GTS (2005)]. Briefly, booking capacity corresponds to the phase (process) where a shipper and the GTS company are interacting in order to reach an agreement for a contract. The interaction begin with a request from the shipper A to GTS for a capacity offer, for a fixed period of time. If the request is considered as admissible, GTS is sending an offer to shipper A. This offer corresponds to a list containing information about available capacity at each entry/exit point of the GRID, and available services like gas blending, possibility to trade access to points with other authorized shippers, etc. The tariff attached to each service is also indicated. Within the two following days, shipper A has to formulate and send its booking request on the base of the received offer. This booking request is then assessed by GTS regarding the availabilities of services at reception of the request. Depending of the options chosen by shipper A (e.g. accepting or not to get less capacity if the requested one is not available), the contract is drawn up. The contract corresponds to the services listed in the booking
request that have been possible to book, and for which the shipper is considered to be creditworthy by GTS.
In figure 4 and figure 5, the local behaviors associated to shipper A and GTS are shown, presenting the sequence of activities during the capacity booking process.

5 Conclusion and further work

Using an agent-based approach, we provided a preliminary general model of the gas pipeline transport market. We applied this model in the Dutch context. In this context, we shown the organization of the market in terms of distribution of the roles among the different actors, and a model of the capacity booking.
In the changing situation of the gas transport market, we need a flexible network representation. This is the reason why we are modelling the interactions between roles, instead of modelling the interactions between agents. We assume that in this way, by separating the agent from the role and focusing on the modelling of interactions, the resulting models are far more flexible and can be developed in an iterative, bottom-up and local manner. To realize this separation, we developed two models, using the TALMOD language: the role-interaction diagram.
Figure 5: Description of the transport manager local behavior concerning the booking process

and the agent-role diagram. The role-interaction diagram identifies the roles and the interactions associated with these roles in the process. The agent-role diagram displays which actors play which roles. Whenever a company - an agent - is entering/leaving the gas transmission market, the corresponding agent-role model need to be updated, the diagram describing the interactions between the staying partners remain unchanged. Also, when roles or interactions need to be added/removed/modified in the role-interaction model, these changes apply only to those agents connected with the roles or interactions in charge. For instance, in the situation where the Dutch regulator decide that metering operations has to be outsourced by the transport company and carried out by independent agencies, a new type of agent has to be introduced into the system and the transmission company agent competencies have to be modified. In the same time, the relationship between the agents performing metering operations and the transmission company has to be re-defined. This modelling approach also allows a generic representation of the gas transportation market, independently of a specific local context. We use this model in the Dutch case, but it is also applicable in other European contexts. Another advantage of our modelling is that it does not require the description of the interaction pattern beforehand. In our approach, only the local interactions between different agents (the local behaviors) need to be described, and the global
behavior of the system will evolve as an adaptation to the events.
In future works, we want to extend the model to a regional gas pipeline transport market. Another objective is to model the nomination/allocation process. In this case, the challenge will be to model the gas flow, in order to support optimally the agent playing the role of transport manager.

References


