



A Comparative Analysis of Prominent VO Modelling Approaches

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Abstract: This paper is the culmination of analysing Virtual Organization Modelling Language (VOML) from the lens of prominent research contributions made in the field of virtual organizations and their breeding environments.

Keywords: Virtual Organizations, Virtual Breeding Environments, Modelling languages

1. **INTRODUCTION**

Virtual organization (VO) is a new and emerging discipline which manifests itself in a large variety of forms, including collaborative networks, virtual enterprises, dynamic supply chains, professional virtual communities, collaborative virtual laboratories, extended enterprises etc. The main reason for these different manifestations is that so far there is no consolidated definition for this paradigm. Scores of different terms are used in the literature that either refer to the same concepts or its different perspectives (Camarinha-Matos *et al.*, 1998). Rapid development of information and communication technologies have opened new ways of doing business and socializing never possible before. The facilities offered by this technological development have raised new challenges for business, societal and scientific worlds as well. These challenges are forcing entities (organizations or otherwise) to seek complementaries and join efforts that allow them to better participate in challenging and competitive environments, expand businesses and enter new markets, compete against business giants by collective size and capacity of the partners. The concept of rapidly finding a set of complementary partners and quickly configuring them into a virtual organization that best addresses the business opportunity and challenges faced in the turbulent markets has raised considerable expectations in both business and other non-business contexts ((Cummings *et al.*, 2008) ,(Hale. *et al.*, 2014), Camarinha-Matos *et al.*, 2005), (Afsarmanesh *et al.*, (2000)). The emergence of VOs in the business sector can be found in (Witczyski *et al.*, 2005). (Camarinha-Matos *et al.*, 2002) is one example in the domain of professional communities (Afsarmanesh *et al.*, (2000)) , (Nguyen *et al.*, (2006))) are example of VOs offering services. Other examples include (Rabelo *et al.*, 2000). The Grid-based technologies have also gained

momentum due to their incorporation of the VO concept as a basic service provision mechanism ((Foster *et al.*, 2001, 2002). Virtual Organization Modelling Language (VOML) framework is a novel approach towards specifying a VOs and Virtual Breeding Environments (VBEs) (Rajper, 2012). A VBE is a base long-term organization that facilitates creation and operation of VOs. It lays down basic interoperable infrastructure for communication between participants of VBEs and VOs and setting out rules for different aspects of the VBEs environment ranging from joining and leaving a VBE to forming a new VO or dissolving its existence.

2. **MATERIALS AND METHODS**

The specific comparative analysis methodology adopted in this paper is to evaluate the VOML framework is to first bring to lime light main contributions identified in the previous research work as well as identify the gaps in those contributions. Finally evaluate the strengths and shortcoming of the VOML framework. The main contributions of this article are as follows:

- It gathers different prominent contributions of the nascent domain of virtual organizations at one place.
- It brings to forefront the main contributions that individually are different pieces of the puzzle (VOs and VBEs in this case) and help look at the yet blurred picture of VOs and VBEs with new clarity.
- It helps put the VOML framework puzzle piece into its right slot in the puzzle. This in turn is hoped to help clear even further the blurred image of nascent VO and VBE domain.

2.1 VIRTUAL BREEDING ENVIRONMENT

Although VOs offer many potential and tempting advantages such as their capability to be created quickly and on time to capture the business opportunity or to

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change swiftly to react to environmental changes, VOs alone are not able to offer such advantages. Finding the right partners and establishing necessary conditions for starting the collaboration process are costly and time consuming activities and inhibit the desired agility. Besides, companies are reluctant to open up their resources to possibly unknown partners of VOs due to a lack of trust. Besides being reluctant to trust strangers there is a very good chance that even when different entities do decide to trust and collaborate, interoperability and integration of different organizations is difficult (Camarinha-Matos *et al.*, 2005). This issue is addressed by the ECOLEAD project in the form of VBEs (Camarinha-Matos *et al.*, 2005), 2006). All organizations or individuals interested in forming a virtual alliance create a permanent alliance called a VBE. The VBE serves the purpose of taking all the measures necessary for timely creation of temporary collaboration, such as resolving different infrastructure integration issues of the member organizations, standardizing data interoperability mechanisms, setting trust and security policies for member organizations, etc.

2.1.1 THE LIFE CYCLE MODEL

The life cycle (Camarinha-Matos *et al.*, (2008)) of the VBEs consists of three main stages: *creation*, *operation* and *dissolution*. The meaning of these stages is obvious from their names. In the creation phase a VBE is formed, its members are selected, the basic infrastructure and other facilities are laid down for the support and management VBE itself. VBE members, competency profile and other working principles are set up. The operation phase of VBE predominantly consists of creation and dissolution of VOs as per business opportunities and environmental changes. The VBE also keeps evolving itself by joining and leaving of its members and updating its competency profile, hence some research considers another stage called *Metamorphism* stage. The dissolution phase rarely occur in the VBE where a VBE terminates its existence. Usually instead of dissolution a VBE goes through *Metamorphism* stage where its general form and or purpose can evolve. This stage may involve the transfer of collected knowledge/information, as well as the members to a third party.

A VO exists and dismantles during the *operation* phase of the VBE. Most of the literature also suggest similar life cycle stages for the VO i.e. VO *creation*, *operation*, *metamorphism* and *dissolution* stages with similar meaning as for VBEs. However, since a VO exists to capture a particular business opportunity and dismantles when the opportunity is served a VO hardly under goes *metamorphism* phase. Rather, a different VO is created to capture new business opportunity. Hence, a

VO usually does not undergo the *metamorphism* phase. During the evolution phase a VO undergoes some changes that slightly modify the goal or the approach to achieve the goal is changed in some way; be this change in membership, structure or the competencies of the VO. These changes could be triggered as a result of changes in the market dynamics. However, the initial goal which prompted the creation of VO still remains the same.

2.1.2 VO CLASSIFICATION

A VO can be classified in many different ways according to the its different characteristics. There is no universally accepted terminology and classification of base concepts for the field of VOs and VBEs. However, the most common classification characteristics are ((Rabelo *et al.*, (2000)), (Foster *et al.*, (2001))):

_ Duration

VOs can be short term (if made for a single business opportunity and dissolve at the end of such process), or long term (lasting for an indefinite number of business processes or for a specific time span).

_ Coordination

VOs can have many different coordination structures, such as flat/democratic alliance (all cooperating nodes work on equal basis maintaining their autonomy, but joining in their core competencies), star-like (there is a dominant company surrounded by relatively fixed networks of suppliers) or Tree/Federation (having formed some kind of common coordination structure by realizing common management of resources and skills).

_ Configuration flexibility

VOs can be characterized by the flexibility of partners ability to dynamically join/leave the VO. Those VOs that do not offer such flexibility are called fixed or static VOs and those that do are termed dynamic VOs.

Beside these general classification, we can find a through classification of VOs and VBEs and their different manifestations in ((Camarinha-Matos *et al.*, (2008), (2009)). This classification captures subtle differences and similarities between them. The main similarity between them is that they all are created to offer a product/service through collaboration of their members. Hence all these forms are put under the umbrella of collaborative networks.

2.2 PROMINENT CONTRIBUTIONS

Although VOs is a very active research field and there have been major leaps and bounds in the progression of this field. This section superficially discusses the contributions that in authors' opinion are worth mentioning.

2.2.1 ARCON REFERENCE MODEL

ARCON (A Reference model for Collaborative Networks) is a generic abstract model for understanding the basic concepts and main elements of any

organization(s) showing some features of VOs or VBEs collectively referred to as Collaborative Network Organizations (CNOs) (Camarinha-Matos *et al.*, 2008), (Rabelo *et al.*, 2006). It is developed in the ECOLEAD project (Camarinha-Matos *et al.*, (2005)). It is intended as a guide to facilitate the derivation of focused model for various manifestations of VOs or VBEs pertaining to specific execution environment (Camarinha-Matos *et al.*, 2009). The ARCON reference model has attempted to consolidate different concepts developed for VBEs and VOs in different domains, in particular business-oriented view, technology-oriented view and to some extent style-oriented view which focuses on the social concepts such as culture, values, norms, principals, trust, etc. The ARCON framework is divided into three perspectives: Life cycle stages perspective addresses diversity and evolution of different VOs and VBEs during their life cycle which is same as given in Section III. Environmental characteristics perspective is divided into two parts: (a) the environment internal to the VOs and VBEs (Endogenous characteristics) and (b) the environment external to the VBEs and VOs (Exogenous interactions). Internal environment refers to elements such as VBE participants, VOs, resources used by VBE and VO, processes and operations such as member registration, competency management, governance rules, roles in VBE and VOs, etc. Endogenous elements are divided into four dimensions as follows:

- _ *Structural dimension*: This dimension refers to those entities which constitute the VBEs and VOs such as participants, relationships among the participants, the role and tasks performed by the participants, topological organization of VBEs and VOs, etcetera.
- _ *Componential dimension*: Consists of elements that are used and managed by the other elements of the VBEs and VOs such as different types of resources such as human, software, hardware, knowledge, etc.
- _ *Functional dimension*: Functional dimension refers to different processes and operations performed in CNOs to manage different aspects of CNOs.
- _ *Behavioural dimension*: Addresses different principles, policies, norms, culture, etc that drive or constrain the behaviour of VBEs and VOs members. External characteristics refers to the concepts such as how VBE is viewed by elements external to it and how those elements interact (operations) with the VBE. It consists of (a) market dimension which relates to interaction with both the customers and competitors of CNOs, (b) support dimension refers to services provided by third parties which help different aspects and elements of CNOs, (c) societal dimension refers to the impact that CNOs has on the society such as the impact on the environment, etc.

Third perspective called Modelling intent explores different intents for modelling VBEs and VOs ranging from general representation models (called general representation layer) to specific models which are more detailed than general models (called specific modelling layer) and the models which are developed for specific execution environments called implementation modelling layer.

2.3 MODELLING APPROACHES

Number of ad-hoc attempts for modelling VOs and VBEs exists in the literature. Some are limited to preliminary modelling of VO concepts, while some have put dedicated amount of effort in this direction (Camarinha-Matos *et al.*, 2008,2009), (Sari *et al.*, 2007).

2.3.1 DYNAMIC COALITIONS:

This work has been motivated by work within the GOLD project, which seeks to build an architecture to facilitate the creation and maintenance of Virtual Organisations within the Chemical Engineering sector. In this work a VO is modeled as dynamic coalition using the Vienna Development Method (VDM) specification language (Jones, C. B. (1986)). It defines a VO consisting of choices made in five orthogonal dimensions including membership, information representation, provenance, time and trust (Bryans, J. W. (2006)). This work is mainly interested in the flow of information around models of coalitions (VOs) ((Sari *et al.*, (2007))). For example, identifying states of formal models in which information has reached the wrong actor (one who is not supposed to get the concerned information), or where information has not reached the right actor (one who is supposed to get the concerned information). These models are analyzed to identify these states. In each dimension, information is distinguish between the one which is related to the material traded between agents in a coalition (which we refer to as business functionality) and the one about the agents, coalitions or information itself so called meta-information, such as the age of a piece of information, or the identity of a coalition. Each dimension corresponds to a form of meta-information and the models make that meta-information explicit. In each model, consideration of the invariants, preconditions etc. leads to alternative models representing design choices. The result of this analysis is a suite of models that deal with individual dimensions and present the coalition architect with a range of design alternatives, allowing a particular architecture to be placed within the space of coalitions. Being a formal model different kinds of analysis and verification are possible.

2.3.2 CONOISE-G:

The CONOISE-G (Constraint Oriented Negotiation in an Open Information Services Environment for the

Grid) project focuses on providing a technology-oriented solution for formation of reliable and scalable virtual organizations in a dynamic, open and competitive environment (Camarinha-Matos *et al.*, 1998). It provides agent-based infrastructure to support robust and resilient VO creation, operation, evolution and dissolution (Patel *et al.*, 2005), (Nguyen *et al.*, 2006), (Norman *et al.*, 2004), (Shoa *et al.*, 2004). In the Conoise-G architecture a VO consists of set of autonomous agents, each with some capabilities and resources, who have come together for obtaining potential benefits. When the business context changes, the VO either disbands or rearrange itself to better fit the new circumstances.

For example a service which demands 50 minutes per month of Entertainment (video clips) than this service demands can be provided by two service providers if a single provider cannot satisfy the number of minutes of video clips (Patel *et al.*, 2005), (Nguyen *et al.*, 2006, Norman *et al.*, (2004), (Shoa *et al.*, 2004).

2.4 THE VOML FRAMEWORK:

The Virtual Organization Modelling Language (VOML) is framework geared towards developing VO models in the context of a VBE. The framework (Bocchi *et al.*, 2009), Rajper, 2012) (Reiff-Marganec *et al.*, 2011) supports the definition of structural and behavioural models of VBEs and VOs based on three different levels of representation: (1) the definition of the persistent functionalities of the VBE; (2) the definition of the transient functionalities of the VOs that are offered by the VBE at a specific moment in time and (3) the ensemble of components (instances) and connectors that, at that time, deliver the services offered by the VOs present in the business configuration. VOML provides three sub languages, each addressing a specific level of a VO. VO-S (the structural VO modelling language) is concerned with the description of structural level a VO, VO-O (the operational VO modelling language) is concerned with a description that refines the structural model by providing operational details. Briefly, the basic elements of VOML are: (1) Members, (2) Process, (3) Tasks, (4) VBEResource and (5) Data-Flow. These elements are directly supported by VO-S sub language. Members can be Partners (permanent members of the VBE), Associates (transient members who have temporarily joined VBE to fulfil demand for a VO) and ExtEntity (transient members of a VO (not VBE) who are discovered for each VO instance). The workflow that lists those tasks that directly contribute towards achieving the goals of the VO are specified by the Process element. The Data-Flow expresses which data items are expected from the members and customer of a VO and their flow between tasks. VBEResources

are resources provided by the VBE and are available to all VOs. Finally, Task descriptions specify the competencies required by the VO from its members. Tasks are complex and a more detailed description is available in (Reiff-Marganec *et al.*, 2011). VO-S provides three types of tasks: (1) AtomicTask: tasks performed by one member only, (2) ReplicableTask: tasks that can be shared between more than one member to gain extra capacity and (3) ComposableTask: tasks that can be shared between more than one member to address capability issues.

The VO-O sub language describes the operational model of a VO-S model; which is derived from VO-S model and possibly further refined. Main elements of the VO-O sub language are components and wires. The VO-R sub language helps adopt the VO-S model (and in turn VO-O model) with the changing internal as well as external environmental factors such as change in business opportunity, ceasing of a VO member, etc. VO-R does this adaptation and modification by using policies that reconfigure the VOs.

3. RESULTS AND DISCUSSION

3.1 COMPARATIVE ANALYSIS

This paper has attempted to extract the main contributions from different research and industrial projects for virtual organizations, put the pieces together in a synergy such that this article at one hand could serve as an introduction to the field of VOs and VBEs and on the other hands analyses the VOML framework with respect to already done research. Following is the synopsis of the those observations:

The Life cycle model discussed above in detail is the basis on which the concepts of VOML framework are laid. VOML framework specifically targets the operation phase of VBE in which the creation, operation and dissolution of VOs take place.

The framework is capable of offering all sorts of VOs described in the VO Classification section. The VO classification is usually done on the parameters duration, coordination and configuration flexibility that give rise to VOs with distinct characteristics. VOML framework can support long term as well as short term VOs, VOs with different coordination structures. The framework also offers the dynamic configuration flexibility such as adding and removing of partners.

Looking through the lens of ARCON reference model, it can be easily noticed that the framework can also abstractly mapped to the dimensions offered by the ARCON. The top level of VOML framework can be abstractly mapped to the structural and component dimensions of ARCON, whereas functional and

behavioural dimensions can be abstractly mapped to different VOs and VBE tasks active any particular moment in time and policies that govern creation, and managements of such VOs and other tasks respectively. With respect to modelling and specifying the concepts of VBEs and VOs, the VOML framework offers the novel set of three languages that specify different aspects of VBEs and VOs.

With regards to CONOISE-G work, it is the rearrangement and letting more than one member to collectively satisfy the demand that grabs the attention in VOML framework. This corresponds to replication of task based on capacity (minutes with respect to the example mentioned in the Section 2.3.2) in VOML. However, unlike CONOISE-G the framework aims at developing a reconfigurable modelling language rather than providing a platform and technology specific solution. Another difference is that their reconfiguration is limited to dynamically replacing one member with another having similar behaviour and capabilities whereas VOML allows for sharing a task between members with each contributing either part of the capacity required or different capabilities required for the task.

Contributions of the research carried out in “Dynamic coalition” is closer to VOML framework in the sense both attempt to specify formal models of VOs. However, the intent is slightly different. The main intent of dynamic coalition is to able to verify different properties of VOs using general purpose rigorous and formal specification language i.e VDM. Understanding such specification might be a bit of struggle for the stakeholders of the VO and VBE domain who are familiar with the domain terminology but mostly naïve at understanding a rigorous specification. VOML framework offers a modelling languages that utilizes the terminology widely used by the users of the VOs and VBEs as the language constructs of the VOML language. Hence, the VOML framework complements the work done in dynamic coalitions.

4. CONCLUSION

This paper has attempted to serve two purposes (1) it has tried to culminate scattered research contributions at one place allowing researchers entering into domain of VOs and VBEs to have through understanding of the concepts developed so far, identify the gaps in the research and continue to contribute from there and finally (2) comparatively analyse the novel framework with respect to the prior contributions.

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