A Framework for Process Management in Service Oriented Virtual Organizations

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Abstract—**Virtual Organization (VO) is a network of autonomous organizations sharing their competitive advantage to address a specific business opportunity. Due to their autonomous and interdependent nature, management of collaboration among such organizations is a challenging task. In this paper, we present a framework for process management in service oriented virtual organizations. We propose 6 layers for the framework with multiple components within each layer. In designing the components of the framework, standard reference architecture such as Open-EDI reference model and the S3 service oriented architecture, as well as best practices such as ITIL V3 and PMBOK are used. Further, we present a distributed SOA infrastructure that facilitates peer-to-peer collaboration between organizations in a virtual organization. The infrastructure is based on creating specific service zone for each participating organization to build a virtual ESB. Compared to collaborative environment in networked organization usually supported by computer networks, the loose coupling of services, and the autonomous characteristics of service oriented architecture make it one the best approaches for implementing virtual organization.**

Keywords-Virtual Organization; Service Oriented Architecture; Collaborative Process Management; Enterprise Service Bus

I. INTRODUCTION

Participation in inter organizational collaboration is inevitable in today's business environments, especially when organizations need to achieve a differentiated competitive advantage. This is even more essential if the organization is a small or medium size enterprise (SME). Companies are increasingly restructuring their process models and software infrastructures to facilitate dynamic and flexible environments to engage in more complex value exchanges, partnership, and business ecosystems [1]. This results in appearance of Collaborative Networked Organizations (CNO) and temporary gathering of multiple organizations to address a specific business opportunity, and eventually, creation of Virtual Organizations (VO).

Computer aided data interchange and software interaction between different organizations has been around for a long time, and has evolved over time. Several frameworks and standards have been developed, especially for Business-to-Business interactions. Also, there have been studies on agile and flexible communications within networked of organizations. At their early stages, these frameworks were mostly relying on data interchange, but as they evolved, they also attempted to address business processes between networks of organizations [2]. EDI (Electronic Data Interchange), RosettaNet, ebXML (Electronic Business using eXtensible Markup Language) and SOA (Service Oriented Architecture) based solutions are examples of such interaction frameworks.

In this research, a framework to form and manage VOs in a distributed environment based on service oriented infrastructure is proposed. The proposed framework enables networks of organizations to form virtual workflows based on their software infrastructures, and share and monitor their performance metrics without the need for a central authority. An abstraction layer for services will enable organizations to share their designated services with other partners while keeping their own core competency private to themselves.

A. Virtual Organizations

While there are several definitions for Virtual Organizations, there is no definition that draws an exact line for VOs. In this paper, a Virtual Organization is considered as a dynamic, temporal consortium of autonomous legally independent organizations which corporate with each other to attend a business opportunity or cope with a specific need, where partners share risks, costs and benefits, and whose operation is achieved by a coordinating sharing of skills, resources and competencies [3][4]. VOs are classified differently based on their characteristics. A common classification is based on VO topologies. In [4], three different topologies for VOs are discussed: the supply chain topology in which partners' collaboration follows a linear pattern where each partner communicates to its upper and lower neighbors; the star topology, also called hub and spoke, which has a main contractor acting as the central partner, and the collaboration between different partners is arranged predominantly star-like between the central partner and other organizations; and finally, the peer-to-peer topology where the partners interact with each other with no hierarchy or central control. The VOs processes are divided into operational processes and management processes. The operational topology describes the physical and informational flows needed for the production of a product or service while the management topology describes the information and control flows of VO guidance process. The VO might follow one of the topologies in its operation and another one in its management [4]. As for the VOs contracting and costumer relationship, VOs have four different collaboration patterns. First, the explicit consortium in which the client selects and regulates the partners involved and follows a star topology managed by consumer itself. The second one is the internal consortium which follows a star topology but one of the VO partners regulates the

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communication and handles the contract with the costumer. The third solution would be a sub-contracting solution which follows a supply chain topology. The final pattern which follows the peer-to-peer topology is a partnership in which all partners are responsible for a legal contract, and interact with the costumer directly. In this case, sometimes a legal entity is formed using the partnership agreement [5].

B. Management of Virtual Organization

VO management denotes the organization, allocation and coordination of resources and their activities, as well as their inter-organizational dependencies to achieve the objectives within the required time, cost and quality frame [4]. As VOs aggregate several autonomous partners, and operate in a highly dynamic and temporal environment, their management is complex, and also critical to the success of VOs. Efficient VO management faces challenges such as temporality in its nature, distributed operation between different business partners, need of adoption to fast changing environment which may cause restructuring in management approach or even VO configuration. In order to support dynamic and agile management within the VO climate, real-time actions, and consequently, efficient performance management with reliable real-time indicators are required [4]. Four different approaches for VO management are identified. First, managing VO as a project using Project Management Body of Knowledge (PMBOK) [6] which defines a project as "a temporary effort to create a unique product or service". A VO then fits in PMBOKs definition of a project. However, some argue that a VO management is much more complicated than a project since multiple organizations are involved, and VO creation requires initial preparation and continuous negotiation. The second approach is to define and employ decision protocols and mechanisms to manage VOs. This approach usually lacks the guidelines and supporting methodologies for management activities. The third approach is to use PMBOK and other related project management frameworks as a reference model for VO management. Finally, the fourth approach is based on collaborative discussions between different VO partners [3] [4]. VOs have a wide range of characteristics with respect to their structure, time span, lifecycle and behavior. Therefore, it is extremely difficult to define a one-size-fits-all model covering all the identified requirements of VO management. As such, the focus in VO management is mainly on governance and management services [7]. Common organizations spend only a small fraction of their lifetime in the creation and dissolution stages, whereas in many varieties of CNOs these two phases are complex and take up considerable efforts. Every CNO has four stages in its lifecycle, namely Creation, Operation, Evolution and Inheritance [8]. VO management focuses on the operation and evolution stages of the lifecycle which itself is divided to five phases including Initiation, Operation, Collaboration, Evolution and Dissolution. The ECOLEAD project has further elaborated VO management services as main components for management of virtual organization [9].

C. Service Oriented Archite ture (SOA)

SOA is more than just a flexible new technology but an IT paradigm that facilitate agility and reusability in organizations. From a manger's point of view "SOA is a journey that promises to reduce lifetime cost of the application portfolio, maximize Return on Investment (ROI) in both application and technology resources, and reduces lead times in delivering solutions to the business" [10]. From a business executive's point of view "SOA is a set of services that can be exposed to their customers, partners and different parts of the organization" [10]. From an information systems architect's point of view "SOA is a means to create dynamic, highly configurable and collaborative applications built for change which reduces IT complexity and rigidity" [10]. In today's market, enterprises have to respond faster and more efficient to shifting market requirements, regulations and customer needs. Tight competition is forcing businesses to provide more and more services to their customers to keep them satisfied. To accomplish this, enterprises need to have a palette of atomic or composite services that can be easily and dynamically assembled into business processes [11]. Due to SOAs loose coupling, policy driven, composable service architecture; it is surely one the most appropriate implementation approaches for such dynamic business processes [10]. A combination of a SOA and Business Process Management (BPM) approach, with the appropriate management focus, will facilitate a faster path to IT and business alignment. Although SOA BPM approach has known to be successful, failure stories have been reported in this area which was mostly caused by a sole web service orientation towards SOA implementation [11]. SOA principles and best practices need to be used to design services in three different layers, and to compose services on those three layers to realize dynamic BPM. The first layer is collaborative services, which include high level business processes defined between enterprises. The second layer is public services which are processes inside an enterprise composed of different business components and orchestrated properly. Finally, the private services which are internal business activities within a business component [11].

II. THE PROPOSED FRAMEWORK FOR PROCESS MANAGEMENT IN SOVO

As discussed in the previous section, VOs operate in a very dynamic environment. They also need computer networks and information systems to facilitate their collaboration while maintaining each partner's independence. VOs' operation phase is handled through their collaborative business processes, and as discussed before, one the best ways to implement and manage dynamic business processes is with a SOA approach [10]. As such, we propose a framework and an implementation infrastructure for ***Service Oriented*** Virtual Organization (SOVO) Process Management. The proposed framework is based on reference architectures and best practices to ensure an effective service oriented process design for SOVO. The layering of the framework is based on the Open-EDI reference model [12] and the S3 Service Oriented Reference Architecture [13]. Detailed descriptions of the components of the framework are derived from the best practices of ITIL V3 [14] and PMBOK [6]. Figure 1, shows the framework and its components in six layers which will be discussed further in the following sub-sections. The main boxes represent the layers and the small inner boxes indicate the components of each layer.

This framework is based on a distributed service oriented infrastructure which facilitates distributed management of the VO, while keeping the actual organizations and their services and processes completely autonomous by using ***service zones*** as an abstraction layer for the organizations services. The service zone allows organizations share their collaborative services under specific rules and policies defined by the VO business processes and service choreography. The zones enable VO to manage and orchestrate its services as if it is the actual owner, while providing the business partners with complete control and autonomy to manage or change their services within the boundary of the collaborative policies and zone specifications. The VO is virtually the owner of its services and can enforce the rules, service choreography and orchestration within its domain while the zone gateway ensures organizations privacy and security restrictions. More technical details of this collaboration pattern will be discussed later.

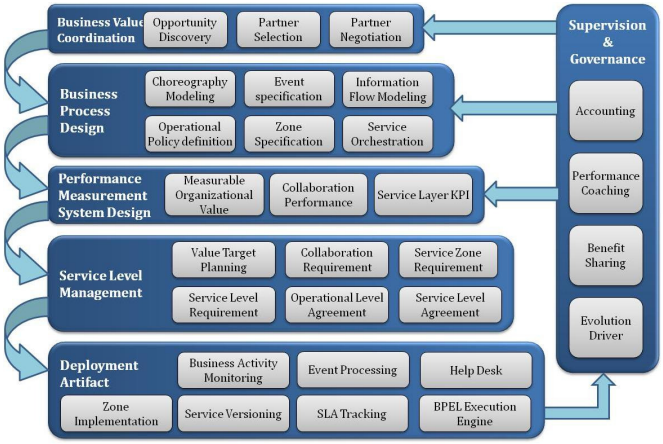

Figure 1: The SOVO Process Management Framework

A. Business Value Coordination

This layer focuses on the business values and motivations of the VO formation. It illustrates the business opportunity and the values that the VO consortium will gain. The opportunity discovery results in a set of business values that will be further discussed as Measurable Organizational Values (MOVs) and a general business model for the VO. After the business model is defined, partner discovery and selection is performed. In an ideal service oriented environment this is done by agent based semantic oriented service matching using the UDDI registry (Universal Description, Discovery and Integration). Further research on VO partner search and VO creation phase can be found in [15] and [5]. Partner negotiation and contracting − which value constellation (network of enterprises that jointly creates and distributes objects of economic value) modeled by e3-Value [16] [17] is the most important part of it− finalizes this phase. As part of the value constellation, each partners offering and competencies is identified, and their contribution in VO value creation is elaborated and modeled.

B. Business Process Design

This layer focuses on business process flow and clarifies different conditions and dependencies between processes and their related conditions. It is also responsible for design and correlation of individual services to form efficient healthy business processes. The choreography modulation focuses on partner collaboration and service interactions. It specifies each party's role and activities, and the sequences of service invocation. It serves as an agreement between the participating business partners in their collaboration [18]. This step of the business process design may even alter some of the partner negotiation. As such, some iteration between the two components might be necessary. Due to the use of Enterprise Service Buses (ESBs) and support of multiple messaging patterns in SOA infrastructure, the notion of listening and responding to events is embedded and supported which makes SOA and event driven architecture (EDA) complementary solutions [10]. Therefore, the presented SOVO infrastructure (explained in sub-section E) facilitates events specifications and their implementation. These events will be described in this module, and modeled later using Business Process Model and Notation (BPMN) [19]. The information flow is specifying data flow between different services in a process. It models what to be delivered to whom at what time. A combination of Data Flow Diagram (DFD) and BPMN will be used to model these interactions. Policy definition in VOs has two aspects, first service policy definitions which further qualify capabilities of interaction endpoints; simply put, a policy expresses anything a service wants the world to know about it other than what messages it understands. These policies will be enforced by the ESBs and their collaboration [20]. The second aspect is the process layer policies which indicate the collaborative process rules and policies. They are implemented using business rule engines (Business rule engine is further discussed in sub-section E). These policies will be modeled using WS-Policy open standard. The zone specification is focused on how each partner of the VO organizes its gateway. It indicates what services are shared, and what main policies and security restrictions it applies. These specifications are derived from the service choreography and policy definition. Finally, the service orchestration illustrates service sequences. It uses BPMN to model the final process, and derive the corresponding BPEL (Business Process Execution Language) according to the partner zone specifications.

C. Performance Measurement System Design

Before introducing a framework for performance measurement, we need to identify the different categories of Key Performance Indicators (KPIs) for SOVO. The ECOLEAD project [21] divides performance indicators in CNOs into three different categories: 1) the performance of fulfilling the given task and the contributing performance of the partners, 2) the performance of the partners' collaboration, and 3) the performance of the management approach. In case of a service oriented virtual organization, these layers can be interpreted as 1) Service Layer KPIs, 2) Services Collaboration Performance, and 3) Measureable Organizational Values (MOVs). These performance categories can be depicted as different layers of a SOVO performance pyramid as shown in Figure 2.

The bottom-level performance indicators in a SOVO will be used to assess the performance of services provided by a specific partner in the collaborative process. These indicators are mostly domain specific and must be agreed upon by the corresponding partners. These indicators are mainly at

operational level. The mid-level performance indicator is Collaboration Performance which is used to measure the effectiveness and efficiency of the independent partners' interaction. Meeting the targets in these performance indicators enables merging of their processes to accomplish a common task in a non-hierarchic way [22]. The collaboration performance layer can be considered strategic, whereas the value creation in a SOVO can be done only by smooth interaction and collaboration among SOVO partners. The top level of performance indicators in Figure-3 is employed to measure the effectiveness of management approach and the strategic level of decision making in SOVO. Considering the time restriction and limited resources available, one approach to manage SOVOs is the IT project management [3]. Thus, using the language of IT project management, the criteria indicating the success of SOVO at this level are measureable organizational values (MOVs) [23]. MOVs are considered the most strategic level of performance indicators as they have the strongest ties with the SOVO's strategy. In fact, the temporal and dynamic nature of SOVO substitutes the long-term strategic goals and objectives with short-term organizational value creation. Balances Score Card (BSC) can be used to establish the links among these three layers. The BSC method provides a balanced approach by considering non-financial metrics (customer, internal business process and learning and growth), as well as financial ones. The change in non-financial indicators will affect the financial ones in long-term defined by mathematical relationship between the two [24].

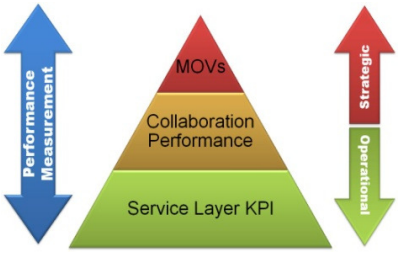

Figure 2: The SOVO Performance Indicators Pyramid

D. Service Level Management

This layer is derived from ITIL V3 service level management principles [14]. It is a set of processes that are responsible for defining and negotiating service level targets, objectives and agreements which ensure the performance of overall VO services and operations. Service level management guarantees service consistency and continual improvement which also facilitates better monitoring and quality assurance. This layer maps the previously modeled processes and performance system design to traceable services, and generates manageable service level agreements from them. The value target planning focuses on overall service level targets based on measurable organizational values defined in the previous sub-section. The service collaboration requirement specifies service interdependencies and their quantitative measurements derived from the collaboration performance as mentioned in the previous sub-section. These two components follow a top-down approach for definition of performance threshold, whereas, a bottom-up logic is followed for the definition of the performance indicators. The service zone describes the gateway requirements per each partner participated in the VO. It acts as an SLA for the overall policies and rules supporting specific partner's services. The service level requirement (SLR) is a set of specifications and requirements for a service, based on the business objectives. The main functionalities expected from a service are described in SLR and operational level agreements (OLA). OLA is an agreement on operational support between service provider and its users. The service layer KPI boundaries are set in this phase through the SLR and OLA, also projected in the Service Layer Agreement (SLA). The SLA describes the Service, documents service level targets, and specifies the responsibilities of the IT service provider and the users. The results of the negotiations and performance indicators and agreements are all projected in a single SLA document which is the main output of this process, and is used for monitoring the service in the future. Further, templates and specifications of the component in this layer will be provided in the documentation of the framework.

E. Deployment Artifact and Implementation Infrastructure

This layer proposes an implementation approach to virtual organizations. It consists of a set of components and implementation principles for SOVO process deployment and monitoring. It also embeds some guidelines for continual improvement derived from ITIL, which also provides input to the final supervision and governance layer. The following components will fulfill their duty more effectively if they run on a distributed infrastructure. Thus, we propose a model for a distributed service oriented infrastructure which facilitates the business process operation, monitoring and management in a peer-to-peer VO topology. Depending on the configuration of the infrastructure, it can support other topologies such as star and supply chain as well. We believe that this approach provides faster VO deployment, and enhances peer-to-peer VO management and collaboration. The distributed infrastructure is based on multiple ESBs collaborating with each other, while creating zone gateways to guarantee specific organizational rules and policies.

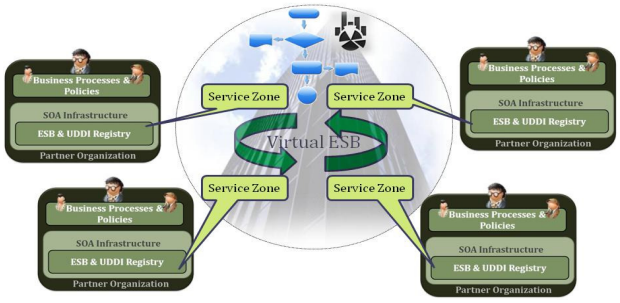

Figure 3: Virtual ESB Facilitating a Distributed SOA Infrastrcuture

With this zone approach, organizations have total control over what services to share securely and conveniently. It is easier to control competitive advantage through zones without worrying about complex integration process. Generally, ESBs are the enablers of service interaction, and facilitate large scale implementation of the SOA principles manageable in a heterogeneous world [20] [25]. In addition to providing the basic infrastructure for service interactions, the ESB provides a set of common patterns for construction of on demand applications, and provides specific capabilities to support realization of distinct service categories that play particular

roles in those patterns [25]. We use these different collaboration patterns to create a specific service zone for the partner participating in the VO to build an ESB federation [26] [27] (Virtual ESB) to support VO collaborations. The components in the deployment artifact layer shown in Figure 1 facilitate VO process management above the virtual ESB as shown in Figure **3**

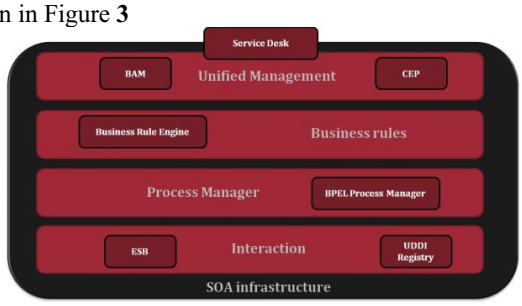

Figure 4: A Proposed Architecture for the SOA infrastructure

Except the ESBs that facilitate the virtual ESB in every organization, we assume that a service oriented infrastructure is in place which helps organizations to implement their own services. The VO processes will then run on their service oriented infrastructures. As such, no additional infrastructure will be required for the VO. In an ideal service oriented world, deployment of a VO would only require zone specific configurations. Figure 4 illustrates the architecture of such an SOA infrastructure. This architecture is based on the S3 reference architecture [13], IBMs web sphere SOA foundation and Oracles SOA suite 11g architecture. The first layer includes ESB and UDDI registry. The second layer is a business process engine which mainly supports BPEL executions and service compositions. At the third layer, a business rule engine facilitates the enforcement of business rules throughout the service execution lifetime. This layer would be responsible to guarantee policies defined in the higher level of the framework. And finally, at the top layer, a Complex Event Processing Engine (CEP) triggers various events, and facilitates an event-driven architecture in the service execution environment. The Business Activity Monitoring (BAM) module monitors the infrastructure, and the performance of the services to facilitate the SLA management. The service desk module– which is at the edge of the infrastructure and can be considered as a part of a bigger help desk solution of the owner organization– is a necessary component of ITIL. Most of the features and benefits of the proposed framework is realized by employing a suitable ESB.

F. Supervision And Governance

This layer of the framework focuses on driving VO towards the right direction based on performance monitoring and the feedback it receives. It facilitates forecasting, planning and design of future trends of the VO which result in continual improvement and change management in the virtual organization. Performance coaching includes the efforts taken for performance appraisal, and providing appropriate feedbacks to partners in order to improve their performance based on the specified objectives and performance targets. In other words, performance coaching is the systematic effort to link the performance reviews and evaluations to the continuous training and development [28]. The benefit sharing component aligns VO partner benefits based on the value constellation and value creation in accordance to their performance. It uses performance as the criteria for assessing rewards or sharing benefits [28], as well as services offered through the infrastructure. These two components are both drivers for moving the performance of partner organizations to desired level of performance. Accounting is related to the financial shared activities of the VO which is affected by the benefit sharing component of this layer. This component requires further specification that is not addressed in this framework, and is left to the VO financial planners. Finally, the evolution driver is a set of processes designed to drive appropriate changes in the VO based on performance monitoring aspects [3]. These changes are classified in three categories: the first one is usually within a partner's services, and only triggers performance indicators; the second category is the one that affects VO service choreographies, and is results in a higher level change in VO; and finally, the third category which involves changes in VO value creation and might even result in renegotiation between partners.

III. THE SCOPE OF THE PROPOSED SOVO PROCESS MANAGEMENT FRAMEWORK

As discussed in section I.B, there are different approaches to manage a virtual organization. Our approach is based on the PMBOK reference model and its nine knowledge areas in combination with a peer-to-peer collaboration that uses guidelines and decision protocols derived from performance management.. ARCON (A Reference model for COllaborative Networks) [8] which is a comprehensive modeling framework for CNOs is referenced to illustrate our modeling approach in the framework. ARCON reference framework divides CNO modeling into endogenous elements and exogenous interactions. Our proposed framework focuses on modeling the endogenous structural, componential, functional and behavioral elements of VOs in various PMBOK knowledge areas except the risk management. The framework does not intend to model or provide any guidelines on exogenous interactions of VOs. Since we are using a service oriented infrastructure for implementing VO , ITIL foundation V3 is considered as a third reference for the framework in order to define VO service design and management principals, and to highlight VOs governance and continual improvement [14].

IV. BENEFITS OF THE FRAMEWORK

The collaboration model and the infrastructure proposed in this paper facilitate a peer-to-peer inter-organization collaboration through existing SOA infrastructures in the organizations. The proposed framework specifies the design and management of VO business processes in a service oriented environment. This offers several benefits including 1) facilitating creation of global virtual organizations faster and easier through web services. With this framework, organizations in various geographical positions can form a secure infrastructure for their B2B interactions with less cost and easy configuration; 2) B2B interactions and VO formation is done more efficiently and the total cost and effort of VO formation and maintenance are reduced; 3) The framework provides agile inter-organization process automation, and brings dynamicity as a competitive advantage to the VO. The VO will adapt and integrate with partner's information systems much easier with less cost; 4) VOs dependency to its partner

organization is reduced because of a loosely coupled service oriented infrastructure; 5) This infrastructure facilitates collaboration among any network of organizations using any common topologies; and 6) Since the proposed infrastructure is based on current partners SOA infrastructure, and due to the SOAs scalable and reusable nature, the risk of VO creation will be reduced significantly because of low initial investment.

V. COLCLUSIONS

Inter-organizational collaboration and interactions are becoming essential to businesses in today's fierce competitive environment. Thus, heterogeneous networks of organizations come together to form virtual organization with peer to peer topology. Managing such collaborative environments is challenging and requires dynamic IT infrastructures to support the variety of topologies. In this paper, (a) a framework for designing and modeling SOVO processes was proposed. The framework consists of six main layers, and embeds a continual improvement cycle. Further, the various components in each layer is described using standard reference models and best practices.; and (b) we provided a distributed SOA infrastructure to facilitate implementation of different VO collaborations. We proposed specific service zone for each participating organization in the VO to build an ESB federation (Virtual ESB). We also described the details of the proposed architecture for the SOA infrastructure. This is an ongoing research in our center. The proposed infrastructure is currently being implemented using IBM WebSphere V7. The implementation is done at University of Ottawa in collaboration with IBM on a prototype and the results will be published in future publications. Some of the PMBOK knowledge areas such as risk management and human resource management are not fully addressed in this framework, and are left as future works. The design of agent based partner discovery and negotiation for VO creation will also be considered in our future works.

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