Competencies and Profiles Management for Virtual Organizations Creation

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Abstract. Sharing information about profiles and offered competencies of individual members within an alliance of cooperating companies facilitates searching for potential members of Virtual Organizations. This paper presents a concept of structuring of the competencies as well as a prototype proving this concept. The prototype follows a naturally hybrid architecture of alliances that consists of mutually independent alliance partners, who may be supported by central institutions of the alliance. The use of the agent-based solution enables information sharing among partners in such distributed and dynamic environment.

1 Introduction

In business-to-business (B2B) e-commerce, a group of collaborating partners may act as a single company and create a more competitive whole [14] in order to exploit businesses that cannot be executed by individual companies on their own. The work of Davidow and Malone from early 90's suggest Virtual Corporations as an industrial strategy for the 21st century [4]. Though innovative, this approach introduces a logical continuation of existing collaboration strategies [17]. During the last years, the concept of Virtual Corporations has evolved into various collaboration models. In our work we focus on the original concept of Virtual Organizations (VO). The results may be applied to the other collaboration models as well (e.g. Extended Enterprise).

Gruber specifies the key features of VO also defined by most of another definitions as: *an extensive use of information technology for a coordination of the partners*, *sharing risk and knowledge with partners*, and *focus on core competencies* [9]. Defining a *competence* Neubert refers to *"the cognitive, conative and expressive abilities of humans to organise their activities in order to produce certain results"* [13]. Neubert suppose the competence to be a necessary prerequisite *"realizing a business process to create valuable results"* [13] for each VO member. Fischer describes a *core competence* of an enterprise as a set of skills, technologies, and know-how crucial for the added value provided by the enterprise [6].

This paper presents a concept of profiles and competencies management for alliances in B2B domain. The goals of our work are simplification and integration of cooperation between the partners facilitated by means of sharing information about their competencies. The concept is based on a hybrid architecture consisting of peer-to-peer cooperating units supported by centralized components. Such central components are inherited from the architecture of alliances (e.g. clusters or Virtual Organization Breeding Environments) that are formed by companies in order to facilitate formations of Virtual Organizations. The alliances may support their members also by means of tools for effective partner search, social knowledge management, negotiation support and others. The concept presented in this paper is proved on a prototype tool e-Cat, which is build upon a distributed (multi-agent) framework.

2 Theoretical Background

Adesta explains that information and communication systems are crucial for effective collaboration. Referring to an other work, Adesta calls information to be the blood of Virtual Organizations [1]. In this section we focus on distributed architectures for information sharing, mainly on multi-agent systems that the framework for presented prototype builds upon.

2.1 Distributed Architectures for Information Sharing

A common solution used for document management in teams consists in a central point maintaining the shared documents and enabling an access for all team members. Friese compares features of centralized (client-server architecture) and distributed technologies for information management. Without a central server, bottlenecks and single points of failure are avoided and individual peers keep their independence. On the other hand, network administration lacks any central control, which is required in some domains to ensure consistency and verity of data within the network [7]. Jun Yan *et Al.* also discuss weaknesses (mainly architectural limitations) of conventional workflow management systems: poor performance, lack of reliability, limited scalability, user restriction, and unsatisfactory system openness [18]. Examples of distributed architectures for information sharing during the VO creation process and further workflow management tasks are: peer-to-peer networks, grids, and multi-agent systems.

The peer-to-peer (P2P) network is a distributed technology consisting of mutually independent entities (peers) having respective physical and logical resources [7]. The only effort required for a peer to connect to a P2P network is to implement the corresponding network protocol [16]. In order to distinguish between different kinds of networks, Friese defines (beside the centralized architecture) a pure P2P network, consisting of "equal" peers, and a hybrid P2P network, which contains specialized nodes for certain functions. Friese presents a Resource Management Framework used in a P2P business resource management

framework for managing resources such as web services and business process execution engines [8]. The P2P architecture may be also utilized for decentralized workflow management system of VO (e.g. SwinDeW by Jun Yan *et Al.* [18]). The maintenance of distributed and heterogeneous knowledge bases is widely studied also in works related to the Grid technology.

Another example of a distributed architecture is the multi-agent technology (more detailed explanation of the technology is in the next section). The KRAFT architecture presented by Preece supports VO by "knowledge fusion" [14]. Referring to earlier works Preece specifies two essential common mechanisms of successful integration to VO: an exchange electronic documents, and a synchronization of workflows. The KRAFT employs the multi-agent technology to integrate all local data sources and other knowledge-processing components. Limitation of the KRAFT is its orientation only to pure cooperative environments. Another agent-based system is MAIQS by Linn, which concentrates on cooperative document indexing and querying in geographically distributed networked environments of 5–20 workers collaborating in peer-to-peer manner [12]. Agents support their users by searching for and indexing of workgroup data and documents. In the MAIQS, there is no centralized data store, register, or broker; all information is stored on workstations of the team members and its exchange is queried by the agents directly. The membership in the workgroup is resolved by means of configuring a respective agent to be aware of the other members in the workgroup as well as by means of configuring the other agents in the workgroup to be aware of the respective agent.

2.2 Multi-agent systems

Multi-agent technology provides mechanisms for information exchange, negotiation, and team action coordination. These features are very suitable in VOs and their workflows management [14].

A multi-agent system is a technology of distributed artificial intelligence. This technology is used to link logically or geographically distributed systems together or to model negotiation in such systems. Different requirements may lead to different agents. For business environment the agent "is an agent of someone" and plays any of the following roles:

- **Assistant** – agent's task is to acquire and analyze information in order to support the human operator's (partner's) decision making.
- **Representative** – it is a tool used for collaboration with others. Negotiation with an agent within the scope of its power is equivalent to negotiation with the partner.
- **Model** – a simplified representation of an original (real) partner equipped with required attributes and abilities sufficiently consonant to attributes and abilities of the original partner. For defined domain the agent is a model of the partner and may act on behalf of the partner by means of emulating the partner's behavior.

Agents are allowed to share their knowledge and dynamically form teams to achieve their goals [5]. Such goals do not need to be necessarily related or compatible [2]. An agent also keeps knowledge about other agents as well as the level of confidence in that knowledge. In the area of multi-agent systems the concept of clustering individuals into cooperating groups is often used (e.g. Pěchouček in [15]). Pěchouček defines an *alliance* and a *coalition*. The former one (alliance) is a collection of cooperating units that share semi-private knowledge (e.g. information about resources if considered as non-private knowledge) and all agree to form possible coalitions. The alliance is regarded as a long-term collaboration agreement among the units. The latter one (coalition) is a set of units agreed to collaborate to fulfill a single, well-specified goal. A coalition, unlike an alliance, is thus usually regarded as a short-term agreement between collaborating agents.

3 Competency Terminology

Since there is no common terminology in competency management domain, the terms "competency", "competency class", "competency instance", and "profile" are used in several slightly different meanings. In some cases, the term competency is used only for a competency class (e.g. Biesalski [3] or NASAPeople[3]). On the other hand, e.g. HR-XML[4] (focussing mainly on human resources management) uses the term "competency" both for the competency class and the competency instance. Here we suggest definitions of the competency related terms. These definitions are based on our previous work in this domain [11]. As the first step we define the *competency* and the *profile*:

- **Competency** is *"an ability to perform business processes, which are supported by necessary available resources, practices and activities, allowing the organization to offer products/services."*
- **Profile of subject** contains *"two main elements: (i) general information about the partner, and (ii) a set of competencies offered by the partner as their core competencies"*

The competencies presented in the profiles are derived from commonly understood and accepted definitions in order to ensure consistency and avoid misinterpretation of the presented competencies. Then we distinguish between the *competency class* and the *competency instance*:

- **Competency class** defines *"an existence of the competency in the world; it distinguishes it from other existing competencies and defines relations to them. Competency class may be extended by defining means used for measuring the level and robustness of the competency.*

[3] http://nasapeople.nasa.gov
[4] http://ns.hr-xml.org

– **Competency instance** refers *"exactly to one competency class related to one subject*[5]*. If the competency class defines means for measuring level and robustness of the competency, the competency instance can optionally assign values to them."*

As the competencies in the real world are more-or-less related, competency classes also provide for descriptions of such relations. There is no more than one direct relation between each two competencies. The relations of one competency to others are:

– **Specialization** – A competency does not need to be specific enough in some cases. Then, a specializing competency may exist to extend some features of the original competence.
– **Generalization** – Generalization introduces an opposite to specialization. A competency specialized by one or more competencies introduces a generalization of all those competencies.
– **Affinity (also "relation to")** – A competency may be somehow related to another one, but the relation is neither generalizing nor specializing; the relation may be unspecified – either due to its complexity or due to its intuitiveness. Such relations are present only in some competency structures.
– **Closeness** – It describes similarity, relation or coherency between each two competencies. It enables search for alternative competency if desired one is not available (not instantiated anyone or competency owner is not available for whatever reason). It can be defined explicitly between every two competencies or defined as a metrics using specialization, generalization and affinity relations.

Allowed relations and their cardinalities are determined by rules that are defined by structure of competencies. The structures are described by graphs, where the competencies are defined as nodes and their relations as edges. The relation of generalization/specialization correspond to oriented edge and the relation of affinity (if present) to non-oriented edges. None of competency structures allows a cycle of oriented edges – thus none competency may be its own direct or indirect generalization/specification. The common structures according to ordering of the oriented edges are:

– **Hierarchical structure (oriented tree)** – in such case there exists an only general competency that is on the top of others and introduces a common root of the all generalizing competencies. Each competency (except the top one) has defined exactly one generalizing competency while it may have defined several or none specializing competency.
– **Heterarchical structure (oriented forest)** – it is similar to the hierarchical structure, but there may exist several roots. There may exist competencies without any competency generalizing them.

[5] The relation between competency classes and their instances resembles the relation between classes and instances (objects) in object oriented programming. Each subject may instantiate several competency classes, while two instances of the same class instantiated by two different subjects differ.

– **Multiarchical structure (oriented acyclic graph)** – there is no limitation for number of any relation type for any competency. Each competency may have unlimited number of generalizing and specializing relations to other competencies.

The type of a structure that competencies are organized in has a strong impact on the competency search mechanism. For hierarchical structures there is a relatively simple and explicit way of defining closeness of the competencies (e.g. number of edges between two competencies). For heterarchical structures there may defined an explicit non-parametric evaluation of closeness for competencies belonging to two disjoint trees while for multiarchical structures even more complex metrics of closeness may be defined.

4 The e-Cat System

The e-Cat is an agent-based research prototype of a tool for the facilitation of members' profiles and competencies in alliances of SMEs. e-Cat aims at the identification of potential partners; it is used for keeping, managing and distributing profiles of alliance members. The presented technology is based on a distributed set of agents, representing individual members, which are supported by centralized elements. Such a hybrid peer-to-peer network architecture (defined by Friese [7]) enables effective cooperation in a distributed environment where agents ensure maximal independence between alliance members and private knowledge preservation.

To be found as a potential partner, an SME provides other alliance members with its profile containing identification, contact information and competencies that the SME offers as its core competencies. Each competency (instance) is instantiated from a competency class, which is known to all alliance members. Each agent stores description of core competencies on a member's local server and maintains it individually. Access to information is based on roles – only the responsible agents are authorized to edit it, the others may only read them (Only if they are authorized. This feature is required for information privacy.) If some information is expected to be out of date, the corresponding partner or information source is asked for an update of the information (agents are able to use subscribe-advertise or query protocol when negotiating the information). Identification and contact information of alliance partners as well as definitions of competency classes are maintained by alliance institutions. Centralized alliance services support alliance members by: (i) ensuring the common understanding of competencies and understanding member's profiles within the whole alliance, and (ii) maintaining identification information of alliance members (centralized part of member's profile) to limit the access to the community only to the authorized members and to prevent pretending to act as another company. Members' agents download information from central elements when needed, or they store a local copy of the centrally maintained information (or its appropriate part). The figure 1 presents use cases for e-Cat. The copy of frequently accessed information

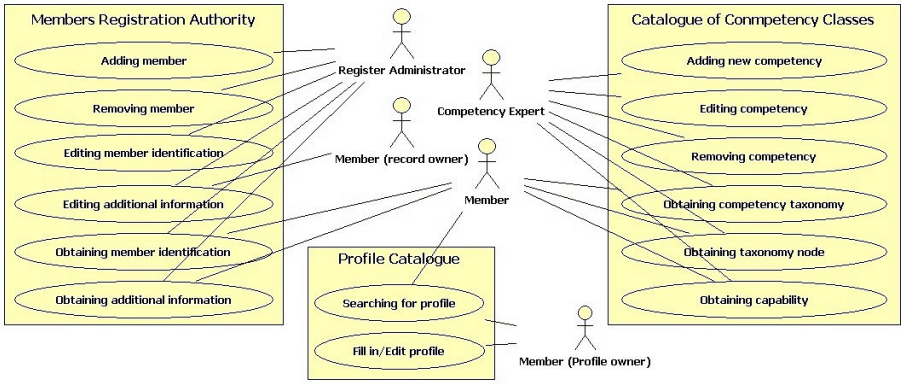

Fig. 1. Use cases of e-Cat

allows each member to use the tool, even if it is totally disconnected from the rest of the world. The e-Cat consists of following subsystems:

- **Distributed Profile Catalogue** keeps, manages and distributes members' profiles. Each member is responsible for its distributed part of the profile. A member has read-write access to its profile and read-only access to other profiles.
- **Catalogue of Competency Classes** defines the competencies that can be advertised through e-Cat, their exact descriptions, taxonomy and attributes. It ensures coherence in the common schema of competency. The Catalogue of Competency Classes is maintained by a competency expert of the alliance, who is responsible for information in the catalogue. Only this expert is allowed to edit the catalogue; the others may read it and suggest improvements.
- **Members Registration Authority** allows full control of members entering or leaving an alliance, and maintains information for member identification. This part is designed as a centralized element to allow the alliance management to control the members entering the community. The Members Registration Authority is under control of subject (e.g. VBE manager) entrusted by the alliance.

The taxonomy of competencies in the e-Cat is represented by a common graph and the closeness of competencies is defined as shortest path in the graph (for the path count all edges in the graph are considered to be non-oriented with constant weight).

Members Registration Authority and Catalogue of Competency Classes are intended to be deployed on alliance management servers and maintained by responsible experts of alliance support institutions. The Profile Catalogue is naturally distributed and it may be deployed on members' servers. Members can

also share servers (the location of physical equipment is irrelevant) to install their parts of the Profile Catalogue. A specialized part of the Profile Catalogue may be instantiated on a server of the alliance management to summarize information and represent the profile of the alliance as a whole.

The e-Cat prototype is distributed system implemented in JAVA language using JADE[6] (Java Agent Development Framework) empowered by FIPA[7] interaction protocols. The agent negotiation is based on concept of enterprise-to-enterprise (E2E) agents [10] and uses Apache Jakarta Tomcat[8] powered web-based user interface. The e-Cat implementation details can be found in [11] too.

4.1 Usage Scenario

Let us assume a hypothetical, but realistic, scenario of the e-Cat usage. The company "Dirk Gently" is a SME, specialized in transport and sale services. The company is willing to join an alliance. The company contact information is added to the e-Cat and the company competencies are put into the profile to be available to other members. Thanks to e-Cat, a member looking for services offered by the "Dirk Gently" company is able to find it and contact the company.

- ***Joining the e-Cat community and creating a new profile.*** As a first step the "Dirk Gently" installs e-Cat on the server. The following configuration includes adding the addresses of Members Registration Authority and Catalogue of Competency Classes. These addresses are provided to the company during the process of joining the alliance. After that, the company can be included into the register of members and thus to be added to the community. At this moment, the expert of the Members Registration Authority creates a new record in the register and adds basic member's contact information to it. The record also contains the name and address of the new e-Cat component representing the new member.
- ***Announcing a competency.*** If Dirk Gently decides to offer some services to other alliance members, the competency class for such services is instantiated in its profile. The appropriate competency class is found in Catalogue of Competency Classes. If the proper class does not exist in the catalogue, either a generalizing competency is used or the catalogue expert adds new class to the catalogue and then the class is used.
- ***Creating a new competency.*** When a request for adding a new competency class to the catalogue appears, the competency expert reviews the request and decides whether to accept it and adapt the catalogue or not. e-Cat users are automatically notified once the catalogue is updated.
- ***Looking for a provider of a competency.*** The search engine of the e-Cat information system offers various attributes for finding potential partners among e-Cat users. The local copy of profiles of other members is searched

[6] http://jade.tilab.it/
[7] http://www.fipa.org/
[8] http://jakarta.apache.org/tomcat/

for the requested competency. If the local copy of profiles is lost or outdated, partners are asked for information dynamically. If the search result is unsatisfactory, user can decide to use the taxonomy to find a generalizing or specializing competency and search profiles for them. In fact, the first search looks for available partners with instantiated competencies of closeness to searched competency equal to zero. Next, the closeness constrain is relaxed until a suitable partner is found.

5 Conclusion

The presented system e-Cat focuses on advertising SME's competencies and searching for potential business partners to gain a competitive advantage (in order to exploit business opportunities which a single SME cannot cover on its own). The e-Cat architecture utilizes hybrid P2P networks for profile maintenance and sharing within an alliance of SMEs. The e-Cat has been verified using three different alliance datasets. The first dataset has been acquired from Virtuelle Fabrik[9] and used for a verification of the architecture on real data. The second dataset has extended the first one and has been used for a presentation of all features of the system. The third dataset has been provided by an alliance organized by IECOS[10] that had evaluated e-Cat in daily use.

The e-Cat architecture has been evaluated for independent alliances employing own supporting institutions. Possible future extensions of the presented concept are: (i) a connection to partner's ERP systems for automated negotiations on available capacities and contract details; (ii) a connection to alliance reputation management systems in order to make accessible information about the alliance members' performance in already created VOs; and (iii) tools for automated service level agreement negotiations.

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[9] http://www.virtuelle-fabrik.com/
[10] http://www.iecos.com/

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