Towards a Collaboration Ontology

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Abstract. Collaboration is a complex and essential process for organizations. Ontologies can provide a way to promote software tool integration, by serving as a common conceptualization among these tools. This integration may ultimately lead to lower costs and improved flexibility and revenue in business. This paper presents a collaboration ontology based on the structure defined by the 3C Model and shows how it can be used to promote integration among collaborative software tools.

1. Introduction

Organizations use collaboration as a method to exchange information inside and across their boundaries. It is believed that organizations that collaborate efficiently have greater revenue than their competitor [The Global Ceo Study 2006]. In fact, collaboration reduces transaction costs between organizations. With this in mind, organizations can create business models extremely specialized that can combine a set of services provided by collaboration among organizations.

Given the importance of the topic, it is crucial to conceptualize and formalize a common vocabulary to represent collaboration. Therefore, in this paper, we present a *collaboration ontology* based on the structure defined by the 3C Model (communication, coordination and cooperation) [Ellis et al. 1991]. This ontology is being developed to formalize knowledge about the domain in order to provide a common vocabulary, promoting integration within the *collaboration domain*. We propose this ontology as the means to integrate several collaborative software applications aiming at effectively collaboration support within organizations.

An overview of the proposed method to support collaborative software tools integration is illustrated in Figure 1. The Figure shows that the conceptual models of each tool are mapped into the collaboration ontology model, meaning that ideally, each concept in the tool can be mapped directly to one concept in the ontology, in order to promote semantic meaning integration. The figure also highlights that non-collaborative tools (e.g., the project management tool in Figure 1) may also be integrated. In other words, in this case, we can find points of integration between the collaborative tools and the project management tool, such as activities that are assigned to one user in the project management tool and participation in a forum that are performed in the same period of time.

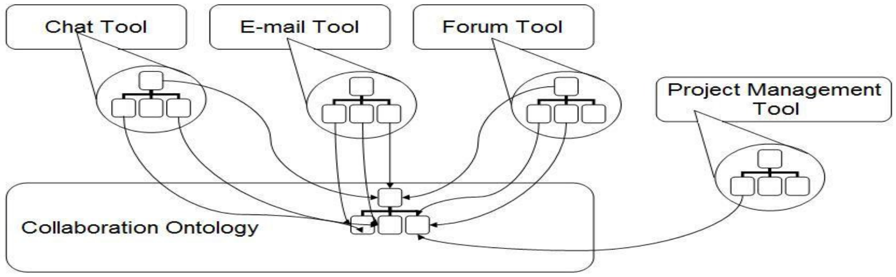

Figure 1. An Overview of the mapping between the collaborative tools' conceptual models and the collaboration ontology

In the next section, we present a brief description about the *collaboration domain*. Section 3 shows the methodology used here to build the Collaboration Ontology and the method used to give semantics for collaboration tools. Section 4 presents the ontology, including the competence questions, concepts, properties and relations between these concepts. Section 5 employs an application for this ontology, mapping the conceptual model of a tool in order to exemplify how the ontology can be mapped to it. Moreover, this section presents a mapping to a Framework called LEICA[1] that provides integration among collaborative and non-collaborative applications. This is done in order to show the behavior of the Ontology when mapped for a generic tool integration framework. Section 6 discusses some future works and presents the conclusion of this paper.

2. Collaboration Domain

In the business world, one of the most critical processes is collaboration. Be it e-mail, instant messaging, virtual workspaces, videoconferencing, collaborative text edition, shared white boards or case tools, technology dramatically shortens distances among people and frees up the flow of intellectual capital, enabling employees to work, to capture and to share knowledge more quickly. The most important gain of the information exchanged among workers is achieving greater gains in revenue growth, operating margins and productivity [IBM Global Services 2006].

A collaboration session *(CS)* is a kind of event that represents (loosely speaking) a period of time in which some agents collaborate with each other for a given purpose. There are some important concepts related to a *CS*, such as: participants, objectives, artifacts, coordination and communication.

Participants are the agents that can contribute in a meaningful way to achieve the objectives of the session. The objectives are the states of affairs the participants aim at achieving in the end of this particular *CS*. Cooperation and interaction depend on the commitments of each of the participants. In addition to that, collaboration involves sharing of specific information among members of a group that cooperate to create or consume information.

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[1] **Loosely-coupled Environment for Integrating Collaborative Applications**

According to Nguyen et al. (2005), the purpose of the concept of *collaboration artifact* is to serve as a bridge that connects agents and software. This means that a collaboration artifact provides a shared workspace for the participants. Participants can exchange data with peers as well as with agents that did not participate in the *CS*. This creates a kind of record that can help to re-construct the experiences of the *CS*, which most of times is only "recorded" in the agent's mind.

In collaborative work, cooperation is a joint effort in a shared space to achieve some goal. To avoid implicit rules and uncontrolled behaviors in a *CS*, participants should know the rules and procedures defined for the *CS*. Hence, these rules and procedures must be very explicit, defined in a way that makes each participant comfortable to use and contribute to the *CS* in a meaningful way. This motivates the need for a formal protocol, commonly known as coordination, defined by the Webster dictionary [Merriam 2007] as the harmonious functioning of parts for effective results. In other words, coordination can be described as a layer that mediates the communication and the cooperation, to enforce the success of collaboration.

Coordination services support management and enforcement of group activities [Fuks et al. 2005]. After all, how can people collaborate without coordination? Without coordination, people will usually engage in conflicts or repetitive actions. Due to that, coordination is essential to solve problems that share common objectives, resources and activities [Ellis et al. 1991]. In fact, we here generalize this by stating that one of the most important prerequisite to accomplish collaboration goals is coordination. For an organization, the main objective of coordination is to execute the project scope without exceeding limits of time and cost, while maintaining quality.

Another point worth mentioning is the relationship between collaboration and communication [Fuks et al. 2003]. Communication is the basis to any collaborative system. The objective of communication is to exchange knowledge among individuals. To transmit content, the sender expresses his intentions or goals, defined by symbols in a language that must be understood by all receivers. Moreover, information transmission needs to be accomplished by a communication media [Fuks et al. 2005].

A communication action involves interaction among individuals, (agents that can be messages' senders and receivers), a dialog event (an event characterized by the exchange information through messages), a context (a situation in which the communication occur) and a protocol (a set of rules that coordinate the communication). Moreover, a communication action generates commitments that create new objectives [Winograd and Flores 1987]. To achieve these goals, through a set of individual tasks, it is necessary to coordinate the activities necessary to carry through the commitments. It supports the group to manage their information.

3. The Ontology Development Methodology

Domain ontology captures the common sense of a particular domain in a generic and formal way to improve reuse and sharing through applications and groups [Gómez-Pérez et al. 2004]. In other words, it defines a specific vocabulary used to describe a portion of reality. A domain ontology should have a representation that captures concepts, relations and their properties in a domain, and a set of axioms that constraint their interpretation [Guarino 1998].

In this article, we have adopted the following Ontology development strategy. Firstly, the SABIO (*Systematic Approach for Building Ontologies)* methodology has been employed [Falbo 2004]. SABIO proposes a method of ontology development and coordination process whose life cycle has the following steps: **(i)** purpose and requirements specification: identifying the ontology's objective (or purpose), application area and competence (through competence questions); **(ii)** ontology capture: capturing of the concepts of the domain, along with their relations and properties; **(iii)** ontology formalization: representing the formalization of the conceptualization captured in the previous step; **(iv)** reuse and integration with existing ontologies: integrating with ontologies already available; **(v)** Evaluation: verifying if the developed ontology accomplishes its purpose; **(vi)** Ontology documentation: recording all knowledge gathered in the process of ontology development. These steps are organized in an interactive life-cycle [Falbo 2004].

For the purpose of representation, the SABIO methodology suggests the application of a graphical language named LINGO which in [Falbo 2004] has been implemented as a UML profile. However, in [Guizzardi 2005] proposes a much more expressive extension to UML. The latter represents (among other things) a number of distinctions betweens different types of classifiers (depicted in figure 2). Thus, to create the conceptual representation of our collaboration ontology, we have used the language proposed by [Guizzardi 2005].

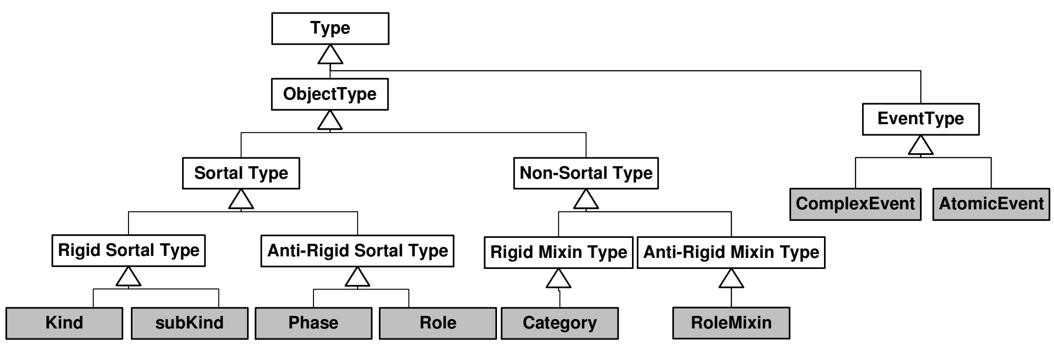

Figure 2. Part of a typology of classifiers [Guizzardi 2005]

In this model, "Type" represents the most abstract sort of classifier. An object type is a type whose instances are entities that exist in time while maintaining their identity (e.g., a car, a person). In contrast, an event type is a type whose instances happen in time by unfolding its temporal phases (e.g., a football game, a business process, a conversation). A *sortal* is an,object type which carries a proper identity criterion for its instances. An identity criterion can be defined as some property necessary and sufficient to define the identity of that individual. An object type which is not a sortal is named a *mixin*.

Sortal types are divided into *rigidSortal* and *antiRigidSortal* that are defined by the rigidity property. In simple terms, a type T is said to be rigid if every instance x of T is necessarily (in the modal sense) an instance of T. Conversely, a type T is anti-rigid if every instance x of T is possibly (in the modal sense) not an instance of T, i.e., if x can cease to instantiate T without ceasing to exist [Guizzardi 2005]. A typical example highlighting this distinction is given by the types person and employee, both instantiated by the individual Lisa in a given circumstance. While Lisa can cease to be an employee of Xerox (and there were periods of time in which Lisa was not one), she cannot cease to be a person. Thus person is a *rigidSortal* while employee is an *antiRigidSortal*. A *rigidSortal* that supplies a principal of identify for its instances is named here a *kind*. A *rigidSortal* that inherit the identity criterion supplied by a *kind* is named here *subKind*. The figure still defines *role* and *phase* as subtypes of *antiRigidSortal*. A *role* type is a type that instances of a kind instantiate in a given context (e.g. the employee type mentioned above). Another example is the role type student: student is a type contingently instantiated by people when registered in an educational institution. A *phase*, in contrast, is a type instantiated contingently by instances of a kind when these instances have specific values for a set of its intrinsic properties. Examples include alive and decease as two possible *phase* types of the kind person.

In an analogous way, a *mixin* object type is classified as *rigidMixin* and *nonRigidMixin*. A *rigidMixin* which is instantiated by individuals of different kinds that share a common essential property (i.e., a property that they must not lack) are named *category*. For example, an agent is classified as a *category*, since different kinds of individuals like person or organization are instances of the type agent. An *antiRigidMixin* describes accidental properties shared by individuals of different kinds. A *roleMixin* is an *antiRigidMixin* that describes common properties of different types of roles (instantiated by instances of different kinds). Examples of *roleMixins* include formal roles as *whole* and *part* but also examples such as Customer (which has instances persons and organizations).

Many other concepts are defined in [Guizzardi 2005], however in the scope of this paper we just use the ones presented above.

4. The Collaboration Ontology

Following the structure of the 3C Model, we divide the Collaboration Ontology in three sub-ontologies: Cooperation, Communication and Coordination Ontology. Figure 3 describes the relation among Ontologies within the Collaboration Domain, according to the discussion presented in section 2. This paper presents only the Cooperation and Communication Ontologies, while the Coordination Ontology is left as future work.

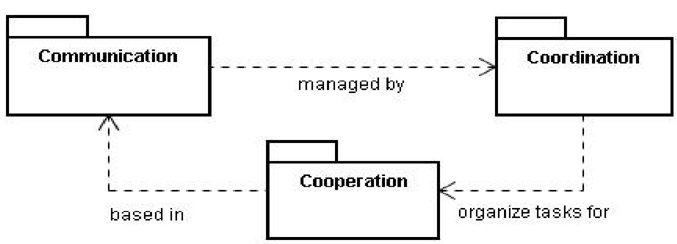

Figure 3. The Ontologies that comprise the Collaboration Ontology

To collaborate, the individuals have to exchange information (communication) and to organize themselves (coordination) to work together in a same workspace (cooperation) [Fucks et al. 2005].

As previously mentioned, the ontologies proposed are developed based on the SABIO approach. We begin with the first SABIO step, developing the competency questions, i.e. questions that the ontology should be able to answer. These competency questions identify the purpose of our Collaboration Ontology, thus summarizing the discussions proposed in section 2. Here they follow:

CQ 1 - What are the artifacts of a *CS*?

CQ 2 - Who are the participants of a *CS*?

CQ 3 - What are the objectives of a *CS*?

CQ 4 - When and where a *CS* happens?

CQ 5 - What are the rules of a *CS*?

CQ 6 - What kind of artifact a *CS* generates?

CQ 7 - What kind of participants a *CS* has?

CQ 8 - How the collaborations artifacts are generated?

CQ 9 - Who are the participants of a communication action?

CQ 10 - What is the protocol of a communication action?

CQ 11 - What is the language used to exchange messages among agents?

CQ 12 - What is the context of a communication action?

CQ 13 - What is the media used on a communication action?

Figure 4 shows the Cooperation Ontology.

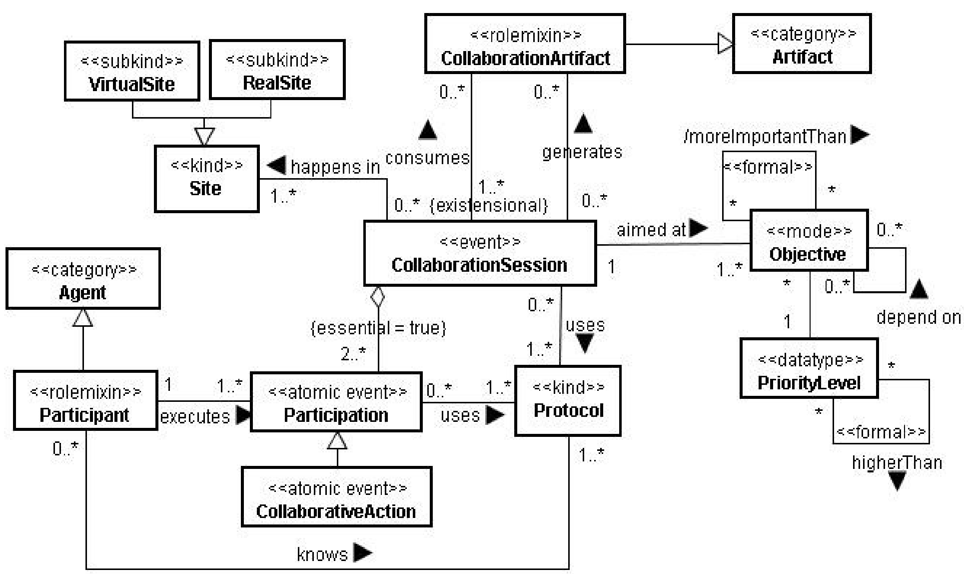

Figure 4. The Cooperation Ontology

A *collaboration session* (*CS*) is an event that is composed of the actions of its *participants*. These actions are instantaneous events (*atomic event*) and they are named here *participations* (e.g., the action of sending or receiving a message). A *participation* is performed by a *participant* and a *participant* can have one or more *participations*. A *CS* has one or more *objectives*, defining its main purpose or goal. An *objective* can depend on other *objectives* and each one have a priority level according to its importance for that *CS*. Besides, the *CS* can consume or generate artifacts, defined here as *collaboration artifact*. Finally, the *CS* happens in a place, defined in the model above as a *site*. The actions of a *CS* need some kind of coordination. In the presented model, this is represented by the concept of *protocol*. However, as aforementioned, we hope to develop, in the future, a coordination ontology to treat this matter in more detail.

Following the SABIO approach, a term dictionary was elaborated, with one entry for each concept. Table 1 presents a short dictionary of the Cooperation Ontology.

Table 1. Part of the terms dictionary for the Cooperation Ontology

Collaboration Artifact	Designates the object that can be either generated or consumed by the collaboration session.
Collaboration Session	Denotes in an event in which participants interact for the purpose of collaboration
Objective	Denotes the motivation of the collaboration session, in others words, a reason that motivates its occurrence.
Participant	An agent that can contribute in a meaningful way to achieve the objectives of the Collaboration Session.
Participation	Denotes an atomic event that one participant executes in a collaboration session.
Protocol	Designates a set of rules which establish coordination for the harmony of the collaboration session.
Site	Denotes a place that hosts the Collaboration Session
VirtualSite	Denotes an electronic environment which mediates the Collaboration Session.
RealSite	Denotes a place in the real world in which the Collaboration Session is held.
Collaborative Action	Denotes a participation in a collaboration session without the exchange of a message

During a *CS*, the *participants* exchanges information. This is carried out by performing *send and receive participations*, which in turn, are essential parts of *communication actions*. These concepts are defined in *Communication Ontology* depicted in Figure 5.

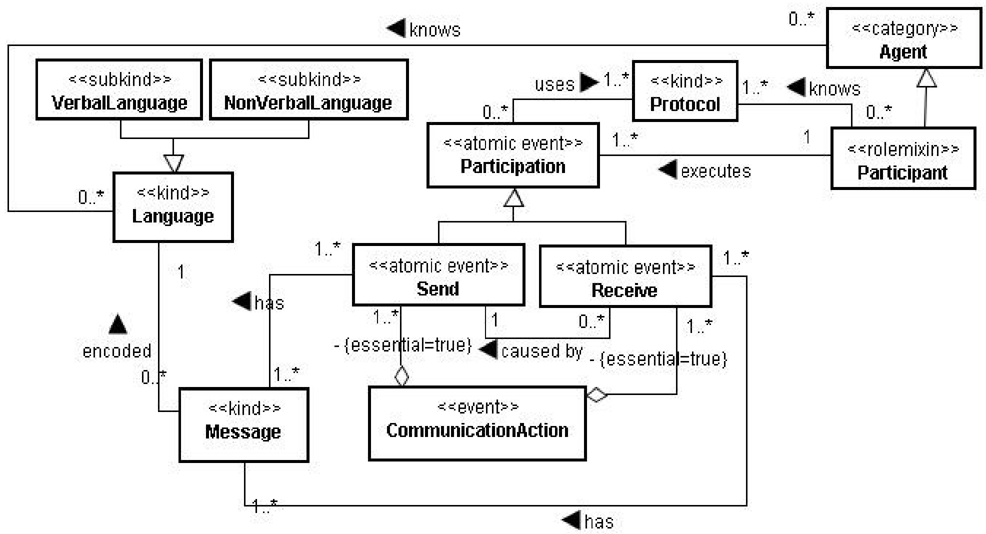

Figure 5. The Communication Ontology

A *communication action* is composed of two participations executed by *agents*. Each *participation* event has one *message* that represents the exchanged information. A m*essage* is expressed through a *language*. It also uses one communication *media* that is the instrument used to carry out communication.

Table 2 presents the dictionary of the communication ontology, describing its main concepts:

Table 2. Part of the terms dictionary for the Communication Ontology

Communication Action	Denotes an act of communication between two or more agents.
Message	Denotes the content of a participation of an agent.
Send	Denotes the event of sending a message.
Receive	Denotes the event of receiving a message.
Agent	Denotes an atomic autonomous entity that is capable of performing some (potentially) useful function [Guizzardi 2006]
Language	Designates the language in which the message is expressed

Besides the models presented in Figures 4 and 5, some axioms must be defined for these ontologies. These axioms are classified in consolidation and derivation axioms. Consolidation axioms describe the restrictions of the relations among concepts structured in the models. Derivation axioms are developed to answer to the competence questions. In this paper, for illustration purposes, we present two axioms, one of each of these types. In order to answer to the competence question (CQ2) we present the following derivation axiom:

$$\forall x,y\ collaborationSession(x) \wedge agent(y) \rightarrow (participant\_of(y,x) \leftrightarrow \exists z\ participation(z) \wedge partOf(z,x) \wedge executes(y,z))$$

In the Communication Ontology, to execute one communication action, the receiver must receive the one message previously sent by the sender. Here is the consolidation axiom showing this constraint:

$$\forall x,y,z\ communicationAction(x) \wedge send(y) \wedge receive(z) \wedge partOf(y,x) \wedge partOf(z,x) \rightarrow (precedes(y,z) \wedge \forall m1,m2\ message\_of(m1,y) \wedge message\_of(m2,z) \rightarrow m1 = m2)$$

5. Some Applications of the Collaboration Ontology

Traditional systems have in the information source layer different understanding about the domain knowledge. Each system uses its own language or syntax to represent knowledge which forms their respective local semantic schema [Gu 2004]. In face of that, the *collaboration ontology* becomes useful to provide a common language (both in terms of syntax and semantics) in order to promote interoperability. To illustrate that, we define mappings from concrete tools to the ontology developed. First, we present a mapping the forum module of Drupal[2] to this ontology. Then, a mapping of a framework that promotes integration among collaborative and non-collaborative tools.

5.1 Mapping the Forum Module of Drupal

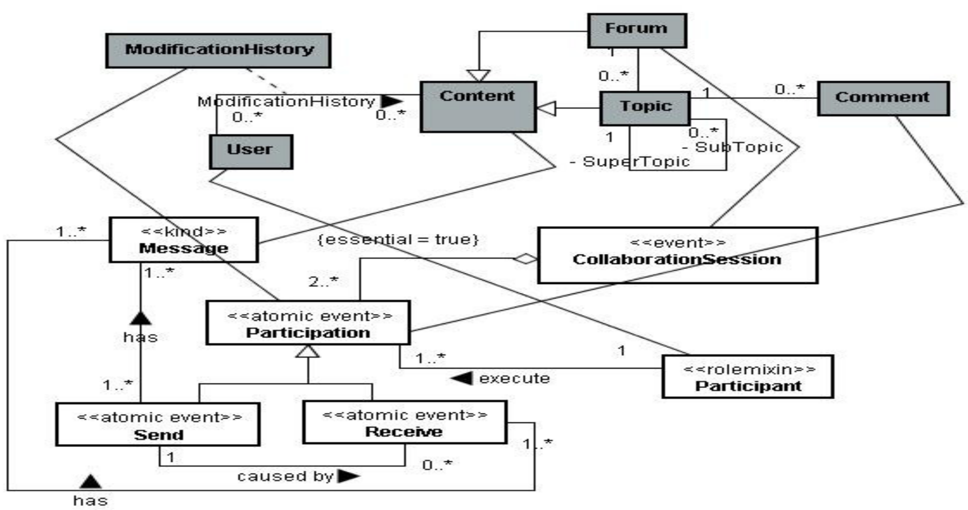

Figure 6. Mapping Drupal's Forum Module to the Collaboration Ontology

Drupal is a content management system that provides modules useful for collaboration such as: forum, blog, book and so on. Figure 6 shows a mapping from the forum module of Drupal to our Collaboration ontology. In this figure, concepts from Drupal's Forum Module are depicted in grey. This mapping defines the semantics of Drupal's concepts in terms of the notions defined in the ontology. There are, however, concepts that are

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[2] Drupal: http://drupal.org

not directly mapped to the ontology because most of tools have their own specializations, i.e., concepts which are tool specific.

5.2 Mapping the Collaboration Ontology in LEICA

LEICA is a framework that supports the integration of collaborative tools. It is based on loosely-coupled integration, which means that the integrated tools do not loose their own autonomy. Two collaborative tools are here used to explain how LEICA works. The first cooperative tool, CoLab is a co-browsing application. The second tool, Babylon is a multi-chat tool. In this example, these tools are integrated by LEICA. Figure 7 shows one *super-session* in LEICA, in which user "D" joins the same *sub-session* of user "F" inside CoLab, transforming it in only one *sub-session* inside CoLab. After this, a collaboration rule defined in LEICA is fired and moves all users that belongs to this *sub-session* of "D" in CoLab to the same *sub-session* in Babylon chat of "F" automatically [Gomes et. al. 2006].

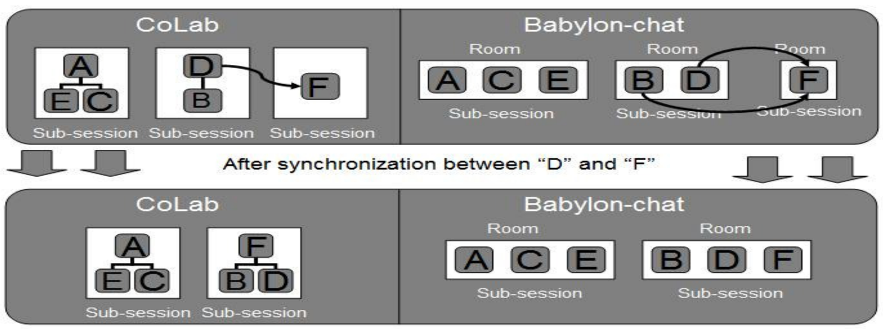

Figure 7- When user "D" joins the CoLab sub-session of "F" he is automatically moved to the same chat-room of "F" in Babylon

Figure 8 shows how we map the conceptual model of the LEICA framework into the collaboration ontology. Once more, the gray concepts correspond to concepts in LEICA.

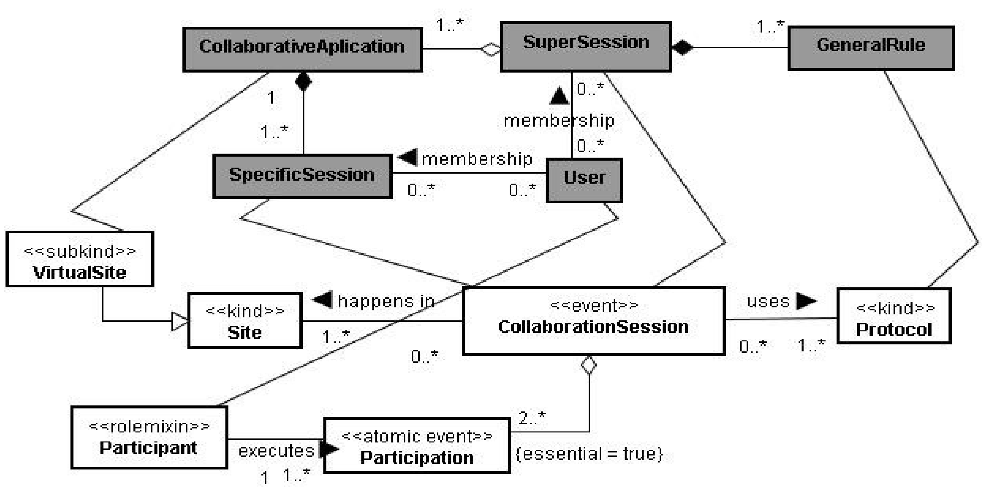

Figure 8- Mapping between the LEICA framework to the Collaboration Ontology

6. Conclusion and Future Works

Collaboration processes have a significant impact in the context of business organizations and are crucial processes to improve revenue and competition. Due to that a Collaboration Ontology is presented here using the method SABIO. The modeling language proposed by [Guizzardi 2005] is used to represent the Ontology.

In order to exemplify the usefulness of the collaboration ontology proposed here, a mapping has been demonstrated describing how a conceptual model of a collaboration tool can be integrated with the Ontology proposed. In the same way, other conceptual models could be integrated by the Collaboration Ontology. The LEICA conceptual model was mapped in the Ontology, in order to demonstrate how the Ontology covers a generic collaborative framework.

The ontology proposed here should be seem as an initial attempt to define a model in this domain. In particular, it still lacks concepts related to coordination sub-domain, which is deemed here as a fundamental part of a Cooperation Ontology. Concepts like group, protocol and roles will be provided by this ontology, which is the next step in our research agenda. Another point to focus is the integration with upper level Ontologies in other to improve both its expressiveness and generality.

In many practical situations, a collaboration artifact is controlled by access control mechanisms since some organizations have strict restrictions imposed to the use of particular some artifacts (e.g., confidential documents and information). As future work, we intend to integrate this collaboration ontology with a Software Configuration Management Ontology. This will provide means for among other things constraining the access of each participant to a given collaboration artifact.

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