A Trust Ontology for Business Collaborations

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Abstract. There are currently some ontologies of business collaboration that facilitate automated collaboration, such as e^3value, REA, and BMO. However, these ontologies model the situation that all business actors can be trusted. This is not true in practice. To realize automated business collaboration, trust needs to be added to the business ontology. In this paper, we extend the e^3value ontology with the concept of trust and show how this can be used to reason about trust on actors in a business network. We take a minimal approach, i.e. rather than adding all the nuances of the concept of trust, we provide the minimal extension that allows an actor to reason about trusting other actors in a useful way. We end the paper with a discussion of how this approach can be generalized to other approaches.

1 Introduction

Nowadays, the networks that enterprises operate in, become increasingly complex. There are many reasons for this. Among others we can refer to more advanced user needs, upward tendency toward specialization, changing customer demands, higher customer satisfaction criteria, advancement in information and communication technology (ICT), globalization of markets and manufacturing, increasing competitiveness, exposure to a bigger audience, etc. In fact, collaboration of different enterprises to co-produce a product or service is nothing new, however, here in this paper, we focus only on those business collaborations which are facilitated by ICT. In other words, we are concerned with the design and use of IT in IT-enabled business collaborations.

A collaborative network is a network consisting of a set of autonomous actors (e.g. enterprises, organizations and people) that collaborate to achieve common or compatible goals [1, 2]. Collaborative networks come with different names in the literature, such as business webs [3], Virtual enterprises (VE) [4, 5], extended enterprises [6, 7], strategic alliances [8, 9], value constellations [10–12], to name a few. The common theme among all these names is the alliance of some business actors - which often involves technology transfer (access to knowledge and expertise), economic specialization, shared expenses and shared risk [9] to co-produce value with each other.

In a collaborative network each enterprise contributes with its own specific products or services to satisfy the consumer need. The model which shows the

creation, distribution, and consumption of goods or services of economic value in such a network is called value model. The main goal of the value modeling is to reach agreement amongst profit-and-loss responsible actors regarding the question "Who is offering what of value to whom and expects what of value in return?" It also enables the actors to assess their potential profitability in the collaborative network and develop an insight into the economical viability and sustainability of the whole collaborative network. The value model assumes that all partners in the business web behave in accordance with the rules and promises expressed in it (they do not act opportunistically). However, the risk in any business network is that a partner will not behave according to the rules and promises and act in favor of its own goals, to the detriment of other partners' goals. This forces a business to take appropriate and sufficient measures against those who it does not trust, i.e. who may not live up to its commitments.

In fact, for doing any business in the real world, trust is crucial for the success of the business, because, after all, we need to trust at least some actors, such as a bank or other trusted third parties. This basically means trust is an inevitable concept in business collaborations. Here in this paper we propose an ontology for business collaborations by enriching the e^3value ontology with trust and risk related concepts.

The rest of the paper is organized as follows. First, in section 2, we discuss the related work and then in section 3 we briefly introduce the e^3value business ontology/methodology. After that, in section 4, we introduce a trust ontology for business collaboration settings based on the e^3value business ontology. We conclude the paper in section 5.

2 Related Work

An ontology is defined as "a specification of a conceptualization." [13]. It specifies the concepts and the relation between the concepts of a specific domain and they play an important role in knowledge sharing in the specific domain.

In [14], Akkermans and Gordijn introduce the e^3value ontology and discuss about the necessity of ontologies for scientific research. Baida et al. [15] developed a multi-actor business model for e-service bundles by ontology-based analysis of e-service bundles in networked enterprises. However, their model represent an ideal situation that lacks the trust related issues.

Andersson et al. [16] represented a reference ontology for business models based on three business ontologies - the REA, e^3value, and BMO. The core concepts in the REA [17, 18] ontology are Resource, Event, and Actor and it claims that every business transaction can be described as an event in which two actors exchange resources. The Business Model Ontology (BMO) [19] aims at providing an ontology that enables us to describe the business model of an enterprise accurately and in detail by considering a single enterprise and its environment which faces a particular customer's demand. Surprisingly non of these ontologies consider trust related concepts.

Chang et al. [20] presented the ontological representation of agent trust, service trust, and product trust in e-service environments. The work presented here is similar to the general service/product ontology of Chang. The main difference is that Chang et al do not look at service and product provision necessarily from a business point of view and consequently they do not include financial risks in their ontologies. They also do not discuss about the source of trust and the way in which trust develops. Schmidt et al. [21] also proposed a number of ontologies to formalize and facilitate autonomous interactions between intelligent agents in centralized and decentralized e-business environments however they also do not consider the financial perspective and consequences of trust in the business collaborations.

Haung and Fox [22] try to formalize the semantics of trust and study the transitivity of trust. From the formal semantic, they identify two types of trust - *trust in belief* and *trust in performance* and formally prove the transitivity of trust in the former and introduce some conditions under which trust relations of the second type can be propagated. Viljanen [23] surveys and classifies thirteen computational trust models by nine trust decision input factors and creates a comprehensive ontology for trust to facilitate interaction between business systems. Later in the paper we analyze our proposed business trust ontology against those nine factors.

3 E^3value Business Methodology

The e^3value methodology [12] is a tractable and lightweight methodology to explore the innovative e-business ideas - starting from understanding which enterprises and actors are actually involved, to an assessment of profitability for each enterprise.

An e^3value model consists of a graphic part and a computational part. The graphic part is a diagram and the computational part is a spreadsheet with algorithms that can perform Net Present Value (NPV) estimations for the participating actors to assess their potential profitability in the business collaboration over a specific period. In the e^3value methodology, we model a collaborative network as a graph in which the nodes represent economic actors and the edges represent economic value transfers. In addition, an e^3value model shows how a consumer need is met by a set of economic exchanges between actors in this web [12, 24, 25].

3.1 E^3value Ontology

Consider the simple e^3value model (Figure 1) in which *Buyer* gives *Money* to *Seller* and receives *Good* in return. *Seller*, in turn, gives *Money* to *Transporter* and receives *Transport*. This simple model illustrates the following modeling constructs of e^3value:

– *Contract Period.* A value model describes economic exchanges during a specific period of time, which is called contract period. The contract period

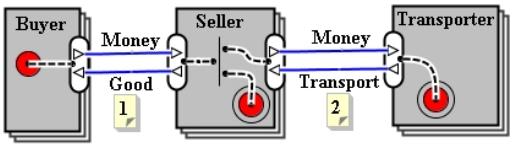

Fig. 1. A simple value model

should be specified in supporting documentation and the model will be used to analyze economic sustainability during this period only.

- *Actor.* An actor is an independent economic (and often also legal) entity with a specific interest in the collaboration (making profit, increasing utility, earning experience, ...). Actors in Figure 1 are *Buyer*, *Seller* and *Transporter*. The actor for whom the business web is made to satisfy his needs is called the *consumer*. We represent the consumer need by a bullet placed inside this actor (*Buyer* in Figure 1).
- *Value Object.* A value object is a service, good, money, or experience, that is of economic value to at least one actor and that is exchanged between actors. In our example value objects are *Money*, *Good*, *Money* and *Transport*.
- *Value Port.* An actor uses a value port to provide or request value objects to or from other actors. A value port is a conceptual construct indicating that during the contract period, an actor is capable of giving or receiving a value object. Value ports are represented by small triangles on the edge of the shapes representing actors.
- *Value Interface.* Value interfaces group value ports and indicate atomicity: if one value port in the interface is triggered in the contract period, all of them are triggered in this period (however the model makes no statement about when this will happen: this has to be specified in a corresponding coordination model). Value interfaces are represented by oval shapes surrounding the value ports.
- *Value Exchange.* A value exchange is used to connect two value ports with each other. It represents one or more potential trades of value object instances between value ports.
- *Value transaction.* The concept of value transaction is used to aggregate all value exchanges between two actors to indicate that all value exchanges should occur or none at all.
- *Market Segment.* A market segment is a set of actors that assign economic value to objects equally. They are shown as overlapping rectangles.
- *Dependency Path.* In most cases an actor has multiple value interfaces and these value interfaces can be related. A dependency path connects value interfaces of the same actor together, meaning that if one of the value interfaces is triggered the connected value interfaces also must be triggered [12]. A dependency path consists of dependency nodes and connections. A dependency node is a consumer need, an AND-fork (the sign in the actor *Seller*) or AND-join, an OR-fork or OR-join, or a boundary element (Bull's

eye sign). A consumer need is the trigger for the transfer of value objects. A boundary element models that no more value transfers can be triggered. A dependency is represented by a dashed line.
- *Transaction.* A transaction starts when the consumer need triggers and completes when all the value exchanges connected to that consumer need are triggered.

Figure 2, which is taken from [14], depicts the e^3value ontology for networked business models. Obviously, there is no notion of trust in the e^3value ontology. Consequently, the profitability analysis of the e^3value ontology is based on an ideal situation in which all actors are assumed to act trustworthy.

In e^3value methodology, after modeling a business case, the value model is attributed with quantitative estimations (for example, the number of consumer needs per contract period and the monetary values of exchanged objects) and a contract period. Then, the revenue of each actor in the specified contract period, is estimated by subtracting the amount of money which the actor loses from the amount of money which he earns during that period. Strictly speaking, the amount of money that a business actor loses in a specific period, is the amount of the monetary value of all value objects which he provides for other actors during that period and likewise, the amount of money that a business actor earns in a specific period, is the amount of the monetary value of all value objects which he receives from other actors during that period.

The result of this simple calculation is the first indication whether the model at hand can be economically profitable for each actor or not. However, even if the results show a profitable collaboration for all actors, it does not necessarily mean that the collaboration would be profitable in the real world. Because, this calculations are based on the assumption that all business actors are trusted and they all respect the agreements. Hence, to refine the profitability analysis and to make the calculations more precise, we need to drop the trust assumptions and then refine the profitability analysis by taking trust into account.

4 Trust Ontology for Business Collaboration Settings

Trust is a ubiquitous phenomenon in everyone's life. For example when we cross a street we trust the drivers to a certain extent that they follow the traffic rules. Trust exists inherently and latently in all our actions that we might even not be fully aware of that. This is the reason why it is overlooked in many cases and most of the time, people take it for granted. Nevertheless trust has a major impact on our decisions.

In business settings, trust plays even a more important role because in contrast to the social settings in business settings a misplaced trust might result in financial loss and after all, financial profit is the main thing that matters in business settings. Hence, we need to identify the trust factor and evaluate the financial risks that it might create and be fully aware of them before making a decision in the business collaborations. Nevertheless, trust is inevitable and in

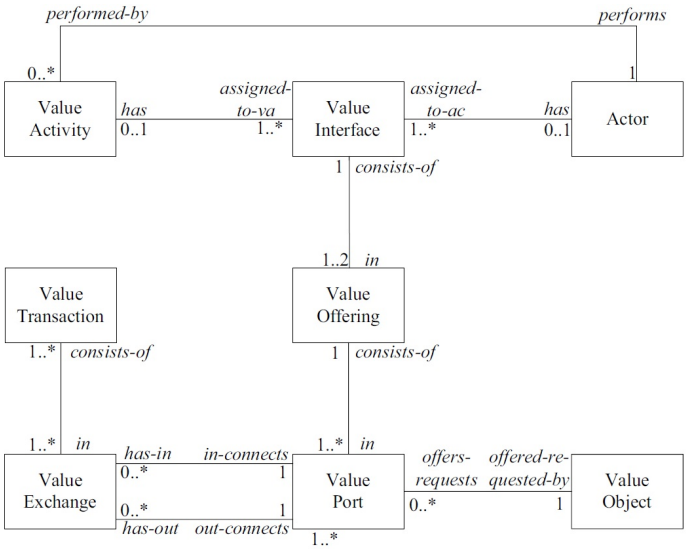

Fig. 2. The e^3value ontology for networked business models

doing any business activity, actors need to trust some other actors and as Kenneth J. Arrow [26, page 24] pointed out without trust no market could function and there is an element of trust in every transaction. In addition, as Luhmann [27] indicated trust reduces the complexity of interactions.

Here, we aim at designing a meta-model for trust ontology in business collaborations. To do that, we use the practical recommendation of a noble sociologist, Howard Becker [28] for designing middle-range theories and hypotheses in scientific research, which is describing case-study conclusions in an abstract way without referring to a specific case. This enables us to capture and articulate the core of the business case in more generally valid formulations.

Our goal is to extend e^3value ontology with the minimal ontology of trust to be able to usefully reason about trust in a business network. So, we do not want to express all possible meanings of trust, nor do we want to add to the literature on the meanings of "trust" one more bit of insight. We simply want to extend the e^3value ontology to make it more realistic in the intended settings, that of business networks.

By analyzing different business interactions in different case studies and also by studying the existing trust ontologies we identified the major trust related concepts in business collaborations. Then, by delineating the relations between those concepts, we developed a lightweight ontology which contains the minimal set of trust related concepts in business settings. The ontology is shown in Figure 3. The shaded concepts are those of the e^3value ontology and the rest are the new added concepts. For brevity, we exclude those concepts of the e^3value ontology

which are not directly related to new added concepts. According to this ontology, a trust relation between two business partners is as follows:

A business actor (Trustor) trusts another business actor (Trustee) with a specific confidence (Confidence value). The confidence value is in the range $[0, 1]$ *and it is calculated based on (1) the reputation (business profile) of Trustee or (2) direct trust (past experiences / collaborations between the two actors) or 3) indirect trust (the value of the trust of other business actors in the collaboration with Trustee i.e. collaborative trust). A combination of all these three factors is also imaginable.*

In fact, Trustor expects Trustee to accomplish a certain action during a specific period of time (Time Slot) with agreed upon quality/conditions. In a business collaboration context, this action is transferring a specific value object (Value Transfer) with explicit quality specifications in a specified time slot. There is a risk associated with every trust relation which means in case Trustee does not fulfill the agreement (transferring the value object with agreed upon quality), it will result in a financial loss for Trustor. The setting of the relation is described in the value model of the business collaboration.

The financial losses associated with the trust relations originate from the value objects and their monetary values. But, how can we calculate the financial loss associated with each business actor? One way to do it is to investigate each value exchange and evaluate the financial loss associated with that value exchange. Each value exchange indicates two business actors that are exchanging value objects with each other.

The financial loss which a business actor might incur, is the case in which that business actor receives a value object with less value than what he was expecting according to the agreements and the worst case is the one in which a business actor provides his partner with a value object according to the agreements, but his partner does not give him anything back. This happens because a business actor trusts another business actor but the trustee acts opportunistically.

The crucial question here is, how often does this happen and consequently how much loss should a business actor expect during the collaboration? According to the trustor's expectation, the probability of the trustee to act opportunistically is $(1 - T)$, where T is the value of trust (confidence value) of the trustor in the trustee. Strictly speaking, the potential financial loss of a trust relation is $(1 - T) * V$, where T is the value of trust (confidence value) and V is the monetary value of the agreed upon value object. Here we assume the total loss of value object V in case the trustor acts opportunistically, which is obviously the worst case.

In fact, this is not the worst case, because in some cases a business actor invests a considerable amount of money in the collaboration with another business actor in the hopes of many value exchanges. However, the other actor misuses the trust early at the collaboration or even at the very beginning and in this special case the financial loss of the trustor actor would be much more than the monetary value of the single lost value object.

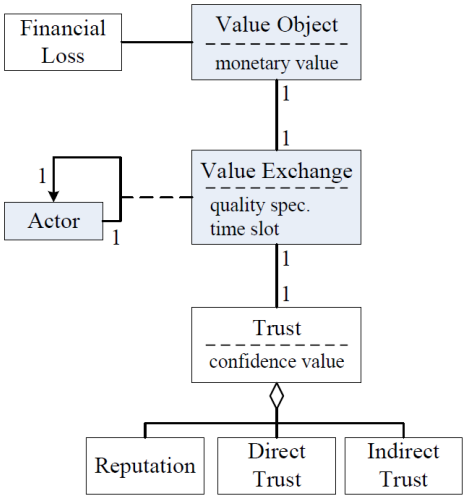

Fig. 3. Trust ontology in business collaborations settings

4.1 *E*^{3}*value* Ontology Enriched with Trust

After introducing the trust concept, we would like to explain the way in which it can be used with the e^3value methodology. To do that, we summarize our three previous papers which deal with the issue of trust in business collaborations.

The first step is to develop a method to assess/calculate and quantify the trust relations between actors in a business collaboration. To do that, in [29], we first modeled a collaboration with e^3value methodology and then analyzed the trust relations between the involved actors. After that, we explained the implications of trust relations on the coordination patterns and finally we introduced a method for measuring and managing trust relations between business actors in a collaborative network.

To measure the value of the trust of the trustor in the trustee, trustor uses (1) its own opinion based on reputation or past experiences and (2) the opinions of other direct partners of the trustee in the collaboration, because in case the trustee has a trust problem with any of its partners, it might break their relation and consequently the whole collaboration will collapse since the collaboration works only as a whole. Therefore, it is necessary for the trustor to take the trust of the direct partners of the trustee into account. For more details regarding the way in which we identify and measure the trust relations in a business collaboration interested readers are referred to [29].

After measuring and quantifying the trust relations, the next step is to refine the profitability analysis by taking trust into account. To do that, in [30], we analyzed the collaborative networks from endurability and profitability points of view based on the trust relations between the collaboration partners. The goal was to provide the partners with value models supplemented by extra informa-

tion regarding the endurability and profitability of the collaboration so that the business actors would be able to decide on those collaborations which are more durable and profitable.

In [31], we discussed about the financial impact of trust in special value exchanges that the collaboration is purely based on trust. In those situations, the trustor trusts the trustee to act according to the agreements and the only way for the trustor to know about the trustworthiness of the trustee is to run inspections which cost money. To find a balance between the frequency of the inspections and the profit of the collaboration for each actor, we used game theory technique and therefore proposed a new method for adjusting the profitability analysis of the e^3value methodology in those special situations.

4.2 Discussion

In this subsection we briefly analyze the presented trust ontology (Figure 3) with those nine trust decision input factors enumerated by Viljanen [23]. Trust in our ontology is:

- **Identity based**: Identity of actors is known to each other.
- **Action aware**: The trustor trusts the trustee with a specific action (reciprocity in value exchange).
- **Business value aware**: The financial implications of trust in terms of potential loss or benefit are the major themes in our ontology.
- **Not competence aware**: We have no specific representation of competence of an actor to perform the value transfer as promised. Nevertheless we use a competence in a higher level. We claim that one of the reasons that makes a business actor trust another business actor in a collaborative network is the somehow related to competence because if the trustee does not act trustworthy, the collaboration would fail and it will lose the opportunity to another business actor.
- **Not capability aware**: In Viljanen's paper capability is defined as a form of an access granting token. This is not relevant in our ontology.
- **Confidence aware**: We explicitly define the strength of the belief that the trustee transfers the promised value object as *confidence value*.
- **Not context aware**: Viljanen defines context as the internal or external status at a particular point of time. In this sense our ontology is not fully context aware however we emphasise that the trust relation is valid for a specific period of time regarding a particular action and in a special business collaboration setting which is modeled in the e^3value methodology.
- **History aware**: In our ontology *past experiences* is considered as one of the factors in trust calculation.
- **Third-party aware**: In out ontology the trustor uses the opinion of the trustee's direct partners in trust calculation.

5 Conclusion

In this paper we discussed about the trust relation between business actors in a business collaboration and we proposed a lightweight ontology with the minimal set of concepts for trust in business collaborations. Here we presented the trust ontology in conjunction with e^3value business ontology however despite their differences the three main business ontologies (REA, e^3value, and BMO) share the core concept of value exchange between two business actors and therefore the trust concept can be added to the other two ontologies analogously.

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