Trust mechanism on facilitator for E-partnerships

Dai Kanetomo
NTT Comware
1-6 Nakase Mihama-ku Chiba-shi
Chiba 261-0023 Japan
+81-43-211-2409
kanetomo.dai@nttcom.co.jp

Chihiro Ono
Stanford University
1st line of address
2nd line of address
+1-650-724-3410
ono@kddlabs.co.jp

Keesoo Kim
Stanford University
Terman 298
Stanford, CA 94305, USA
+1-650-723-3923
kskim@stanford.edu

Charles J. Petrie, Jr.
Stanford University
Packard 232
Stanford, CA 94305, USA
+1-650-725-0162
petrie@stanford.edu

Boyd C. Paulson, Jr.
Stanford University
Terman 296
Stanford, CA 94305, USA
+1-650-723-2235
paulson@stanford.edu

Mark Cutkosky
Stanford University
Terman 523
Stanford, CA 94305, USA
+1-650-725-1588
cutkosky@cdr.stanford.edu

ABSTRACT

In this paper, we describe a trust mechanism that is implemented with an agent facilitator, which is a typical mechanism for mediating agents in multi-agent systems. Although many facilitators are based on tracking the capabilities of each agent, they do not track the dynamic relationships between participants necessary for e-commerce, most especially that of trust. We propose to add a trust model to capability-based facilitators based on word of mouth, or "gossip", in which participants evaluate each other. The facilitator collects evaluations and propagates trust between participants who may not know each other. We propose a practical algorithm to realize our mechanism, currently implemented as a JATLite agent facilitator, and plan to test it in the area of construction supply chain coordination.

1. INTRODUCTION

1.1 Background

The amount of business being conducted over the Internet has been increasing, and the characteristics of Internet business transactions are changing. Three trends are evident. First, ‘close-knit relationships’ are developing, which can be expressed as a change from E-commerce to E-partnerships. E-commerce involves simple business transactions, such as buying and selling, whereas E-partnerships are collaborations in which the participants share risks and benefits. Second, business activities in general have become more complicated. Third, business relationships are being established more rapidly in response to the equally rapid changes in the business environment. Given these trends, we think software agent technology is very useful as it can autonomously follow changes in the business environment, and it can be easily implemented in electronic markets (E-Markets).

In contrast with conventional non-electronic merchant systems, newcomers find it is easy to participate in an E-market, so at any given time an E-market will have a large number of new participants, most of whom do not know each other. Thus the task of finding partners, or more generally, forming groups, is crucial. In particular it is hard to ensure that one’s partners are trustworthy.

1.2 Facilitator Concept

Facilitators mediate between software agents. In this section, we introduce a typical facilitator and its mechanism [Sycara *et al.*, 1999].

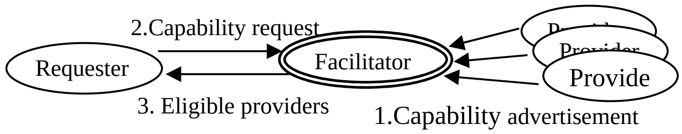


Figure 1. Typical mechanism of a facilitator

Facilitation is executed in the following order.

1.) Provider agents, which want to provide their services to other agents, send the facilitator advertisement messages which include capability information. After receiving these messages the facilitator store the capability information.

2.) A requester agent, which wants to use a particular service(s), sends the facilitator a request message, which includes information about the requested capability.

3.) The facilitator refers to the stored provider agent information to select the agents that have the requested capability. It then sends information on the eligible provider agents to the requester.

Facilitation as described by the above procedure is entirely based on the agent's capability, however we think that the facilitator should promote trust between participants in order to form more close-knit relationships. Trust is thus a new aspect with regard to facilitation, but should bring more satisfaction to participants, because it is a fundamental to social processes [Zolin *et al.*, 2000].

The facilitator concept has advantages in regard to handling trust information. One advantage is efficiency. Because a facilitator is a centralized mechanism, it is more efficient than a distributed information handling mechanism in circulation of trust information. A centralized mechanism also makes it easy to maintain the privacy of the participants. Moreover, trust is capability-oriented [Abdul-Rahman *et al.*, 1997]. For example, even if Chihiro (C) trusts Dai (D) as an engineer, C may not trust D as a nanny. Therefore, trust and capability should be handled with the same mechanism.

2. Trust

2.1 Classification

Before outlining our proposal in detail, we should define what we mean by trust. Trust has many meanings, but we will classify it according to the following five criteria.

1.) *Standardized* or *Personalized*

Commonality of gauges: Same for all participants or different from one participant to the other.

2.) *Public* or *Private*

Is the report on an agent's reputation open to everyone or is it closed?

3.) *Objective* or *Subjective*

Are the evaluation criteria are explicit? Do they apply equally to all participants?

4.) *Quantitative* or *Qualitative*

Are the reports of reputation numeric or are they symbolic?

5.) *Authoritative* or *Collaborative*

Are the evaluations done by a third party or by the participants themselves?

We use the criteria to classify some existing applications and services (Table 1). As for the commonality of gauges, all are classified as "Standardized".

2.2 Our model

Gossip, as it is commonly thought of does not seem to be a source of reliable information, many consider it one of the bad aspects of life, yet it is our model of trust. That is, we use word of mouth to make decisions involving trustworthiness.

Table 1. Example of classification (Standardized)

	Public / Private	Objective / Subjective	Qualitative / Quantitative	Authoritative/ Collaborative
D&B [dnb]	Public	Objective	Quantitative	Authoritative
BBB [bbb]	Public	Subjective	Qualitative	Authoritative
Ebay [ebay]	Public	Subjective	Qualitative	Collaborative
Credit Review	Private	Objective	Quantitative	Authoritative

One important characteristic of word of mouth information is that it is 'personalized'. Most existing applications use standardized trust for all participants, however we think that personalized trustworthiness is more helpful to provide facilitation with satisfaction of the participants. It also corresponds to private, subjective, qualitative, and collaborative in our classification.

Trust based on word of mouth is evaluated by individual participants, which means that it is distributed, and that one's reputation is propagated. It is also bi-directional and independent because participants evaluate each other.

2.3 Previous approaches

Much research has been done on handling trust, and some focus on mechanisms utilizing personalized trust.

In an E-market, when two business entities (A and B) have no relationship but a common intermediary (C) has a trustworthy relationships with both entities and each trustworthy relationship is given a value for the trustworthiness, it has been shown that a relationship that is trustworthy can be established between A and B, and we can calculate new value of trustworthiness [Manchala 2000], but a concrete method of calculation has not been developed. On the other hand it has been shown that one participant can compute a reputation for an unknown participant by using a sequence of pairwise ratings when participants numerically evaluate each other in an E-market [Zacharia *et al.*, 1999]. However this calculation is very ad-hoc, so it can not apply to handling messages in the facilitator, which needs to be prompt in its handling of requests. Moreover the participants should use complicated values for the reputation: a continuous value from 0.1 to 1 is used as input and a value from 0 to 3000 is output.

Of course, we sometimes utilize word of mouth itself as means to gather information when we make some decision [Abdul-Rahman *et al.*, 2000]. For instance Epinions.com is using a reputation mechanism based on "Web of Trust" [Epinions]. On Epinions.com there are many reviews of items by its users. The users can evaluate not only an item but also a review of an item that has been written by other users. As Epinions.com seems that a review by A is helpful to C who rates the review by B highly if B rated the review by A highly, it shows each user which review is helpful to the user.

Table 2 shows the classification of the above examples and our model. As for the commonality of gauges, these are classified as “personalized”.

Table 2. Example of classification

	Public/ Private	Objective/ Subjective	Qualitative / Quantitative	Authoritative/ Collaborative
Manchara [2000] Zacharia [1999]	Private	Subjective	Quantitative	Collaborative
Epinions	Private	Subjective	Qualitative	Collaborative
Word of Mouth	Private	Subjective	Qualitative	Collaborative

3. Our approach

Word of mouth may be an effective way to make a decision concerning trustworthiness, however, the previous approaches are not suitable for the facilitator. Our approach stresses three points:

- Simple classification of trust
- Collecting and storing trust information
- Trust propagation

3.1 Simple classification of trust

The facilitator uses trust relationships between agents to choose eligible agents. We must ensure that it is easy to distinguish trustworthy agents and from untrustworthy agents according to eligibility. To do so, we define five trust values.

- Two in which a participant evaluates someone else directly.

1. “Direct positive reputation” (DP)
2. “Direct negative reputation” (DN)

- Two in which participants do not evaluate each other directly but instead use ‘trust propagation’.

3. “Indirect positive reputation” (IP)
4. “Indirect negative reputation” (IN)

- One for the case that participants can not make an evaluation directly or indirectly. This is the initial value of trust.

5. “Unknown” (UN)

Of course, basically DP and IP indicate trustworthiness, and DN and IN indicate untrustworthiness.

3.2 Collecting and storing trust information

Word of mouth information passes among distributed entities, but it can be stored in a centralized mechanism in the same manner as capability information. The evaluations are collected by the facilitator and stored as trust information. A participant can evaluate other participants at any time, so trust information is updated dynamically. The facilitator usually uses the latest trust information to select trustworthy participants.

3.3 Trust propagation

Indirect trust is based on trust propagation. Trust propagation is like gossip that is spread with the help of centralized mechanism.

Our assumption

Trust is not always transitive, so the propagation mechanism itself must be trusted for trust to propagate [Jøsang 1996]. We assume that each participant will trust an evaluation by trustworthy participants to judge trustworthiness of unknown participants because it is hard for a participant to evaluate all of participants. Moreover, we can recognize that transitivity of trust is realized by word of mouth implicitly. To see that our assumption is reasonable, consider for example PGP [Simson 1994], which is a famous cryptographic software. It authenticates a public key with a web of trust. Note also that as social beings, we tend to trust a friend of a friend more than a total stranger [Zacharia *et al.*, 1999].

Rule

In the following, Xn represents the evaluated participant, X1 represents the evaluating participant, and evaluation(X,Y) means the evaluation of Y by X.

When the following condition applies to the participants, we can calculate an indirect reputation with trust propagation between X1 and Xn.

- $\exists$ Xn-1, evaluation (Xn-1, Xn) = {DP, DN}
- $\forall$ j, $2 \leq j \leq n-1$, evaluation(Xj-1, Xj) = DP

The reputation of Xn can be calculated by X1 using the direct reputation of Xn as evaluated by Xn-1. We illustrate this procedure with the help of Figure 2. In the figure, X1~X4 represent participants, and the arrows represent direct reputations. The direction of the arrow indicates who is doing the evaluation and who is being evaluated. For example, the arrow between X1 and X2 represent the direct reputation of X2 as evaluated by X1.

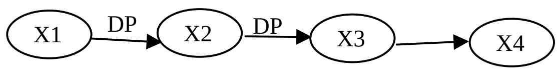


Figure 2. Example of indirect reputation

The indirect reputation of X4 as calculated by X1 depends on the reputation of X4 as evaluated by X3. If the X4 by X3 reputation is DP (DN), the X4 by X1 result is IP (IN).

When there are many participants, more than one chains of DP may exist. In this case, we apply a tie-breaking rule to determine the reputation (see next section).

4. Reputation calculation algorithm

We implement some practical algorithm in the facilitator to realize our approach. They are relevant to the following problems.

1. To search for trust chains

2. Tie-breaking rule for trust propagation
3. Maintenance of trust information

4.1 Searching algorithm for trust chains

When there are many participants who have evaluated each other's trustworthiness, there will probably be many chains of trust. In this case, to reduce search cost, the algorithm uses only the shortest chains of DP when it calculates an indirect reputation.

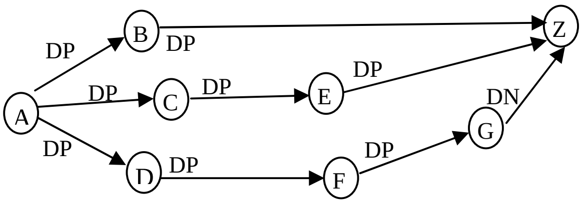


Figure 3. Example of shortest chains of DP

In Figure 3, for example, the indirect reputation of Z can be calculated by A along three paths, but the facilitator's algorithm uses only the path via B, which is shortest. The procedure is as followings.

1. The facilitator searches for participants who have been directly evaluated by A.

   B, C and D are found.

2. As Z is not one of these participants, the facilitator searches for the participants who have been directly evaluated by these participants, who are trusted by A.

   E, F and Z are found, and the facilitator finishes the search.

3. If the facilitator didn't find the goal participant by the above procedure, it repeats to search for the participants who have been directly evaluated by the participants who are found newly as trustworthy participants by A until the goal is found.

Once this procedure finds one or more shortest paths, it stops, so it is a practical pruning algorithm.

4.2 Tie-breaking rule on trust propagation

Basic rule

When there are more than one equal-length paths of direct reputation and all reputations are the same, the result indirect reputation follows immediately. However, if the reputations are mixed, we apply the following rules, which are based on diction by majority.

- When IP (IN) is calculated for the majority of paths, the reputation is IP (IN).
- When numbers of IP and IN are equal, the reputation is "UN".

In Figure 4, the facilitator calculates indirect reputation of Z as evaluated by A, resulting in three shortest paths from A to Z, and all paths are founded as the shortest path. Because

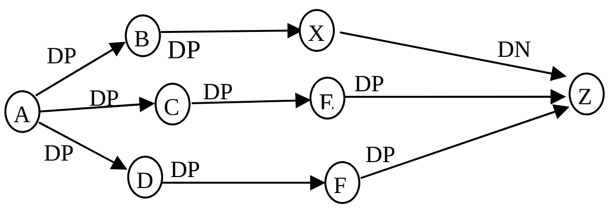


Figure 4. Example of tie-breaking rule

the number of IP is more than the number of IN, the total indirect reputation of Z as evaluated by A is IP.

The above rules may not be best for all cases. For instance, financial markets in which safety are important, could adopt another tie-breaking rule as followings.

- When IN is in the majority for all found paths, the indirect reputation is IN.
- When IN is in the minority, its total reputation is "UN".

Applied rule

The tie-breaking rule assumes that only the shortest path is used. This condition is not necessary if the search cost is not a problem, and instead we can use the path length as a parameter of tie-breaking rule.

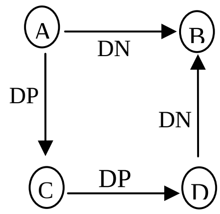
Path length means number of intermediate relationships in the path for calculation of indirect reputation. For example, there are three paths for calculating the indirect reputation of Z as evaluated by A in Figure 3. The path length via B equals 2, whereas via D, F, and G it equals 4.

In addition, if we assign a positive/negative length when the reputation is IP/IN, we can calculate the reputation more mathematically. Specifically, a mathematical central value such as median and average of reciprocal[1], could be used to calculate an overall reputation.

In Figure 3, for example, the values corresponding to each path, are 2, 3 and –4. The reciprocal average is positive, so the total reputation is IP.

4.3 Maintenance algorithm of trust information

The facilitator stores trust information as an n*n matrix (n equals number of participants). Figure 5 shows an example of correspondence between the relationships among agents and the matrix.



#0	A	B	C	D
A	＼	DN	DP	IP
B	UN	＼	UN	UN
C	UN	IN	＼	DP
D	UN	DN	UN	＼

Figure 5. Example of trust information as matrix

Whenever participants submit trust information update, the facilitator re-calculates all indirect reputation. For example, if new trust information, DP of A, is submitted by B in Figure 5, all UN and indirect reputation in the matrix are

[1] Reciprocal means to weight the shorter path.

cleared, and the facilitator re-calculates those parts. Figure 6 shows the transition of matrix in the re-calculation.

#1	A	B	C	D
A	＼	DN	DP	
B	**DP**	＼		
C			＼	DP
D		DN		＼

#2	A	B	C	D
A	＼	DN	DP	IP
B	DP	＼		
C			＼	DP
D		DN		＼

#3	A	B	C	D
A	＼	DN	DP	IP
B	DP	＼	IP	IP
C			＼	DP
D		DN		＼

#4	A	B	C	D
A	＼	DN	DP	IP
B	DP	＼	IP	IP
C	UN	IN	＼	DP
D		DN		＼

#5	A	B	C	D
A	＼	DN	DP	IP
B	DP	＼	IP	IP
C	UN	IN	＼	DP
D	UN	DN	UN	＼

Figure 6.Transition of matrix in re-calculation

The concrete procedure is as follows.

#1: The facilitator starts the re-calculation from the first row. As the first row includes DP that is the reputation for C, it uses the reputation submitted by C, so it calculates that the reputation for D is IP.

#2: As the first row is filled, then, the facilitator re-calculates the next row. The second row includes DP that is the reputation for A, so the facilitator calculates the reputation for C and D with the use of the reputation on the first row.

#3: Similarly, the facilitator re-calculates the third row. Although it uses the reputation of D, it can't calculate the reputation for A, so the reputation is UN.

#4: Finally, the facilitator re-calculates the forth row. However, the row doesn't include DP, so the facilitator calculates that unspecified reputations are UN.

When there are huge number of participants, the computational costs of the above procedure might be a problem.

5. Implementation and application

5.1 Implementation

We implemented our proposed mechanism as a JATLite [Jeon *et al.*, 2000] agent facilitator. JATLite is a Java-based agent platform, which provides the message exchanging mechanism with its original message router, and has templates for developing agents that can handle KQML language [Labrou *et al.*, 1997].

The facilitator selects the trustworthy participants along a trust category specified by the requesting participant as a condition of the facilitation. We define four kinds of trust category.

- Directly trusted only (DP only)
- Trusted (DP and IP)
- Not distrusted (DP, IP and UN)
- All (do not select with trust information)

Specification of trust categories is applied both ways (mutually). For example in Figure 1, if a requester specifies "trusted", the requester should trust the eligible provider, and, the eligible provider should trust the requester.

For facilitation protocols we adopt the standard protocols which are defined with KQML. The implemented protocols are as follows.

- Broker-one, Broker-all
- Recruit-one, Recruit-all
- Recommend-one, Recommend-all
- Subscribe

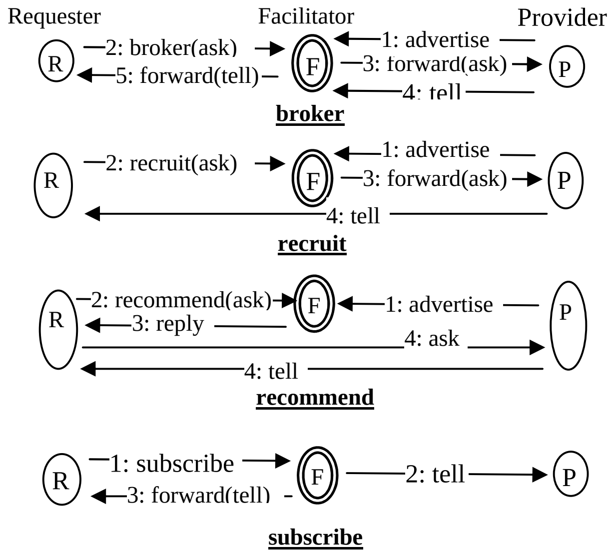


Figure7. Facilitation protocols

Messages based on the protocols are exchanged among provider agent, requester agent and our facilitator as shown in Figure 8.

Trust information is placed in the content part of KQML messages. Figure 9 shows an example of trust information in KQML message, which is displayed on the GUI of the provider agent. The underlined part is the trust information. It means "DP of client and DN of agentb"[2].

5.2 Application example

We plan to apply the facilitator to the area of supply chain coordination in construction projects.

Traditionally, construction projects were carried out by general contractors who controlled most of the resources for the projects. Subcontracting, however, became prevalent due to its cost effectiveness and risk distribution.

Subcontractors, which are usually specialty contractors,

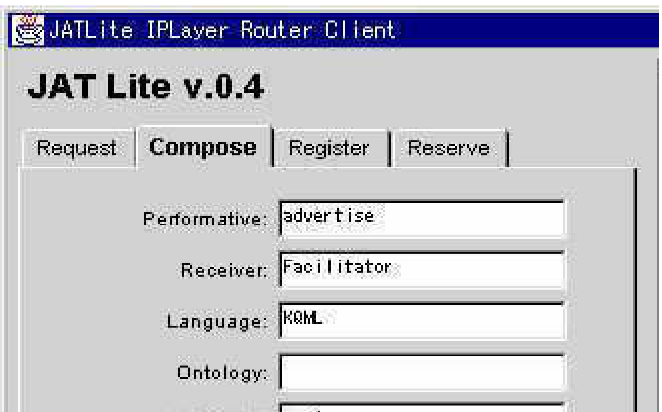


Figure8. Trust information in KQML

have special technologies and expertise general contractors do not have. Therefore, the role of general contractors has shifted from doing work with their own resources to coordinating subcontractors that actually do the work. Consequently, a project delivery network has been established where subcontractors deliver work to a general contractor which in turn delivers the completed facility to the owner. This description of the project delivery network parallels the definition of the supply chains in the manufacturing industry. Therefore, project control can be considered as a special instance of the supply chain coordination. We will refer to it as "project supply chain coordination."

The project supply chain coordination requires the collaboration of numerous suppliers and subcontractors. The community that such collaborators form for the duration of a project is more close-knit than the kinds of supply chains supported by current E-Commerce technology. In particular, the degree of collaboration, including the sharing and joint creation of extensive information as well as the sharing of risks and benefits in the face of uncertainty, requires that the collaborators have a degree of mutual trust. The facilitator will help participants to form and maintain mutual trust information through trust-based facilitation for the project supply chain coordination.

The facilitators can provide participants with opportunities to seek capable and trustworthy partners whom they want work with.

6. Future work

The algorithm in this paper might have problems regarding calculation cost, so we should simulate the calculation costs incurred by our facilitator.

Our mechanism should also be compatible with other basic technologies for EC, for example, cryptography and authentication. Therefore we should find facilitation protocols that are suitable for the combination.

Finally, although our mechanism is based on reputations of each participant, we haven't considered tampering by malicious participants. Malicious participant could for example foster distrust, however, we do not know how much effect this would have. We should clarify the potential ill effects of such tampering, and consider a self-healing mechanism against malicious participants and maligned reputations.

7. Conclusion

We described a trust mechanism that is implemented with an agent facilitator. As our mechanism is based on word of mouth information, the facilitator propagates trust between participants who may not know each other. We also describe a practical algorithm to implement our mechanism.

8. Acknowledgement

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