Trust mechanism on facilitator for E-Partnership

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ABSTRACT
In this paper, we propose a trust mechanism which 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 don't 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.

Categories and Subject Descriptors
D.3.3 [**Programming Languages**]: Language Contructs and Features – *abstract data types, polymorphism, control structures.* This is just an example, please use the correct category and subject descriptors for your submission.

General Terms
Algorithms and Design

Keywords
multi agent, facilitator, trust, e-commerce, word of mouth

1. INTRODUCTION

1.1 Background
In recent years business activities on Internet progress with generalization of Internet, and characteristics of relationship among business partners on Internet are changing. There are three direction of change. First, more tighter relationship is needed. We can express it as the change from E-Commerce to E-Partnership. E-Commerce is simple business dealings, such as selling and buying, and E-Partnership is a basement of collaboration that its participants share risks and benefits, so E-Partnership is more close-knit than E-Commerce. Second, the relationship become more complicated, and third, it is established more rapidly because changes of business situation are very fast. In those situations, software agent technology is effective as it can follow the change of the situation autonomously, and electronic markets (E-Market) could be besetments for activity of the agents.

1.2 Problem
As a feature of E-market comparing existing merchant system, it is easy to participate in the market for newcomers, so new participants could join very often. In this case all participants don't know each other in detail. Under the situation to find partners and to form groups are crucial for participants, and In particular it is hard to find trustworthy partners and groups. This is a problem for E-Partnership which need more close-knit relationship. Now we propose the solutions for the problem, which are to use facilitator and to especially focus on trust between participants.

1.3 Trust

1.3.1 Trust on facilitator
Facilitator is a general idea in software agent technology, and we can introduce a typical facilitator and its mechanism[12]

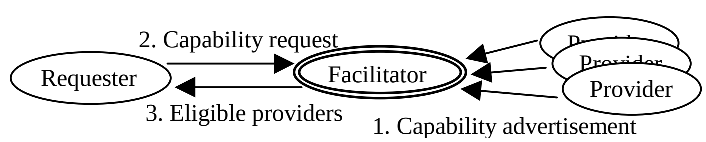


Figure1. Typical mechanism of facilitator

Facilitation is proceed by following order.

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

2.) A requester agent, which want to use services, send the facilitator its requesting message which include information about the requested capability.

3.) The facilitator refer to the stored information with the request to pick the agents which has the requested capability, then it return the picked information about eligible provider agents.

As above procedures facilitation is generally based on agent's capability, and trust is a new aspect of information for facilitation, but we think trust is effective for facilitation to bring more satisfaction to participants with trust based facilitation, because trust is a deciding factor in a social process[14].

1.3.2 Classifying trust

Before explanation of our proposal, we classify trust. Although trust has many meanings, we classify trust with following five criteria.

1.) Standardized or Personalized

Commonality of trustworthiness. Same for all participants or different from each other.

2.) Public or Private

How to access reputations. Report of reputation is open to everyone or closed.

3.) Objective or Subjective

Evaluation criteria are explicit and equally applied, or not.

4.) Quantitative or Qualitative

Formats of reputation. Reports of reputation is numeric or symbolic.

5.) Authoritative or Collaborative

Evaluator. Evaluated by third-party or participants themselves.

We try to classify some existing applications and services with the kinds of trust which is used in them along our criteria. About commonality of trustworthiness, all of them are classified into "Standardized". Other results are shown as Table 1.

Table 1. Example of classification (Standardized)

	Public / Private	Objective / Subjective	Qualitative / Quantitative	Authoritative/ Collaborative
D&B[5]	Public	Objective	Quantitative	Authoritative
BBB[4]	Public	Subjective	Qualitative	Authoritative
eBay[6]	Public	Subjective	Qualitative	Collaborative
Credit review	Private	Objective	Quantitative	Authoritative

2. Objective

2.1 Trust mechanism on facilitator

Our objective is to develop a practical mechanism for handling trust by facilitator. Facilitator has some advantages to handle trust information. One of advantages is efficiency. Because facilitator is a centralized mechanism, it is more efficient than a distributed information handling for circulation of trust information. Centralized mechanism lead another advantage. It is easy to keep privacy of participants. Moreover trust is capability-oriented [1]. For example, even if Chihiro (C) trusts Dai (D) as Engineer, C doesn't always trust D as nanny. So trust and capability should be handled with same mechanism.

2.2 Our trust model

Gossip, which might have bad aspects in our life, is our model of trust. It can also said that we use word of mouth to make trust decision.

One important characteristic of word of mouth is to be "Personalized". Most of existing applications are using trust which is standardized for all participants, however we think that personalized trustworthiness is more helpful to provide satisfied facilitation. It also corresponds to "Private-Subjective-Qualitative-Collaborative" on our classification.

Trust which is based on word of mouth has some features else. It is evaluated by individual participants, which is distributed, and the reputation is propagated. And it is bi-directional as participants evaluate each other.

2.3 Previous approaches

Many researches have been done about handling trust, and some of them focused on mechanisms which utilized personalized trust.

When two entities (A and B) has no relationship but common intermediary (C) has trust relationships to both entities at an e-market, and each trust relationship has a value of trust, it has been shown that you can calculate new trust value of trustworthiness between A and B [10]. But concrete operation method hasn't been shown. On the other hand it has been shown that you can compute a reputation between participants who don't know each other with a sequence of pairwise ratings when participants evaluate each other with numeric value in an E-market[13]. But this calculation is very ad-hoc, so it can't apply to handling messages in the facilitator which is demanded prompt handling. Moreover each value in the reputation is complicated, which is a continuous value from 0.1 to 1 as input and from 0 to 3000 as output, so it is difficult to evaluate others for all participants.

Of course, word of mouth itself is treated as means to obtain information in society when you make a trust decision[2]. For instance Epinions.com is using the reputation mechanism which is based on "Web of Trust"[7]. At Epinions.com users can evaluate a review which is written by an other user, then the review which is evaluated highly by the reviewer of highly evaluated review is also considered useful. This mechanism is called "Web of Trust". Epinions.com can recommend its users the helpful reviews based on the mechanism.

Table 2 shows the classification of above examples which is based on personalized trust and our model, word of mouth.

Table 2. Example of classification

	Public/ Private	Objective/ Subjective	Qualitative / Quantitative	Authoritative/ Collaborative
Manchara [10] Zacharia [13]	Private	Subjective	Quantitative	Collaborative
Epinions	Private	Subjective	Qualitative	Collaborative
Word of mouth	Private	Subjective	Qualitative	Collaborative

3. Our approach

As we explained in previous chapter, while word of mouth itself is effective to make trust decision, we can't apply the previous approaches to the facilitator. In this chapter we introduce our approaches with the three important point. They are following.

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

We explain each point in following part.

3.1 Simple classification of trust

Facilitator utilize trust between agents to choose the eligible agents corresponding to the request, so it is important to distinguish trust and distrust, that are eligible and not eligible, for the facilitator, and it is advisable that the classification of trust in the facilitation is simple. Moreover, simple classification make easier to evaluate for the participants.

Along the above idea, we define five kinds of value for trust.

- The value which a participant evaluate someone else directly.

1. "Direct positive reputation" (DP)
2. "Direct negative reputation" (DN)

- The value which participants don't evaluate each other directly but they use trust propagation.

3. "Indirect positive reputation" (IP)
4. "Indirect negative reputation" (IN)

- The value in the case that participants can't evaluate either directly or indirectly. and this is also an initial value of trust.

5. "Unknown" (UN)

Of course, basically DP and IP mean trust, and DN and IN mean distrust.

3.2 Collecting and storing trust information

Trust in our mechanism is based on the mutual evaluation which is made by all participants themselves. The evaluation and trust which is based on it are bi-directional and independent.

As same as capability information the result of evaluation is collected into the facilitator and stored as trust information. As all of participants can evaluate each other at anytime, trust information is also updated dynamically, then the facilitator usually utilize the latest trust information to select trustworthy participants.

Trustworthy participants are selected along a trust category which are specified by participants as a condition. We define four kinds of trust category.

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

Specification of trust categories is applied mutually. For example in Figure1, when a requester specify "Trusted" as its condition, of course, the requester should trust the eligible provider, moreover, the eligible provider should trust the requester.

3.3 Trust propagation

As we explain above section, our facilitator handle not only direct trust but indirect trust. Indirect trust is based on trust propagation. In other words, the propagation which is like gossip realize with the centralized mechanism.

3.3.1 Our assumption

Trust is not always transitive, so the propagation mechanism itself must be trusted to realize trust propagation[3]. We assume that each participant trust a reputation by trusted participants because no participant can evaluate all of participants. Our trust model is word of mouth, and a transitivity of trust usually realized in word of mouth implicitly. Furthermore you can think that our assumption is reasonable with some example. At PGP[11], which is a famous cryptographic software, we can authenticate a public key with web of trust, and we tend to trust a friend of a friend more than a total stranger as social beings[13].

3.3.2 Rule

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

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

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

The reputation of Xn by X1 is computed to indirect version of the reputation of Xn by Xn-1. We explain this rule with the example. Figure 2 shows the participants and its mutual reputation. X1~X4 represent participants, and an arrow between participants represent a direct reputation. Direction of arrow means direction of reputation, and for example, the arrow between X1 and X2 represent the direct reputation of X2 by X1.

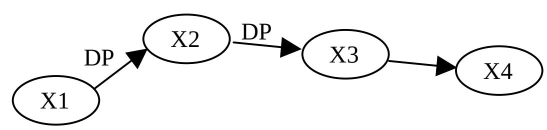


Figure 2. Example of indirect reputation

In figure2, we can calculate the indirect reputation of X4 by X1 as the above condition are met. The result depends on the reputation of X4 by X3. If the reputation is DP the result is IP, and vice versa.

When there are many participants, more than one chains of DP may exist. In this case, we apply our tie-breaking rule to the case in order to calculate the reputation. About the tie-breaking rule we explain in the following chapter.

4. Consideration of practical algorithm

In the last chapter we explained our approach to develop the mechanism for handling trust by the facilitator. However, when we realize our approach, we need some practical algorithm. So we explain the algorithm to solve the following problems.

1. To search for trust chains
2. Tie-breaking rule on trust propagation
3. Maintenance of trust information

4.1 Searching algorithm for trust chains

When there are many participants and participants evaluated each other very well, many chains of trust can exist. In this case, of course, when the facilitator calculate a indirect reputation, it can search for all of chains of trust. But we need a algorithm to reduce its search cost in practice, so we made the facilitator use the shortest chains of DP when it calculate a indirect reputation.

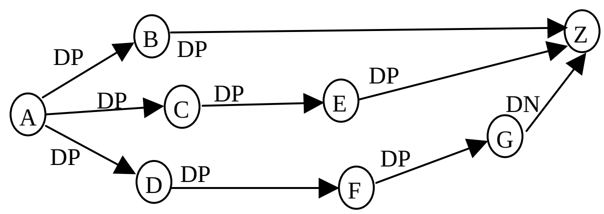


Figure 3. Example of shortest chains of DP

We explain this algorithm more concretely with the example. In the case of figure 3, if we try to calculate the indirect reputation of Z by A, we can see the three meaningful path, but the facilitator use only the path via B which is shortest. As the procedure, we can explain as followings.

1. The facilitator searches for the participants who are evaluated by A directly.
2. If Z isn't the participant who is evaluated by A directly, the facilitator search for the participants who are directly evaluated by the participants who are trusted directly by A
3. Until Z corresponds to the condition, the search is continued in the same way.

After Z corresponds to the condition, even if there may be more meaningful path, the facilitator doesn't continue to search them, so we can explain that this is a practical pruning algorithm.

4.2 Tie-breaking rule on trust propagation

4.2.1 Basic rule

Although we apply the algorithm which is explained in last section, some meaningful path of equal length of direct reputation can be founded. In this case, if all reputation are same, of course, the reputation is adopted, but if two kind of reputation is mixed, we apply following rules which are based on diction by majority.

- When IP is majority in the reputations based on the found paths , the total reputation is also IP, and vice versa.
- When numbers of IP and IN are same, the total reputation is "UN" .

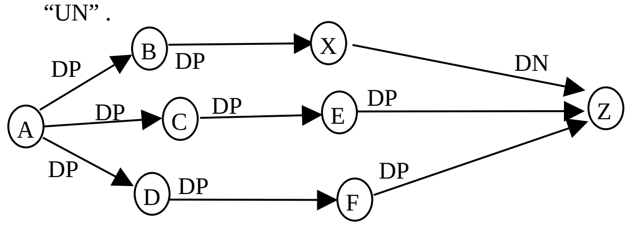


Figure 4. Example of Tie-breaking rule

We explain with figure 4 concretely. In figure 4, when we calculate indirect reputation of Z by A, there are three paths from A to Z, and all paths are founded as the shortest path. In this case we take notice of the indirect reputation based on each path. Because number of IP is more than number of IN, the total indirect reputation of Z by A is IP.

The above rules is understandable easily, but maybe they are not most suitable for all of cases. For instance, when our proposed mechanism is used at a financial market in which safety is important, we can adopt another rules as tie-breaking rule for participant's safety. They are following.

- When IN is majority in the reputations base on the found paths, its total indirect reputation is IN.
- When IN is exist as minority, its total reputation is "UN" .

To adopt suitable tie-breaking rules is important, however what tie-breaking rule is suitable depends on the kind of application.

4.2.2 Applied rule

We explained the tie-breaking rule under the condition that only the shortest path is handled. If this condition isn't applied as the search cost is not a important problem, we consider path length as a parameter of tie-breaking rule.

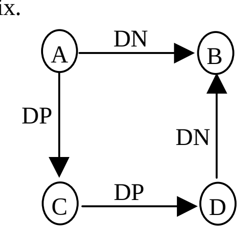
At this point, path length means number of intermediate relationships in the path to calculate the indirect reputation. For example, we can find out three paths to calculate the indirect reputation of Z by A in figure 3. In this case the path length via B equal 2, and via D, F, and G equals 4.

In addition, as we seem the value of length is positive when the reputation is IP, and vice versa, we can calculate the total reputation more mathematically. Specifically we calculate a mathematical central value such as median and average of reciprocal[1], then when the central value is positive, the total reputation is IP and vice versa.

In the example of figure 3, we can lead the three value corresponding to each path, which are 2, 3 and –4, then, the average of reciprocal is positive, and the total reputation is IP.

4.3 Maintenance algorithm of trust info.

In the facilitator, it store the trust information as 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 new trust information to update, the facilitator re-calculate all of indirect reputation. For example, if new trust information, DP of A, is submitted by B in the case of figure 5, all UN and indirect reputation in the matrix are cleared, and the facilitator re-calculate those parts. Figure 6 shows the transition of matrix in the re-calculation.

[1] To use reciprocal means to weight shorter path.

#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	＼	IP	IP
C	UN	IN	＼	DP
D	UN	DN	UN	＼

Figure 7.Transition of matrix in re-calculation

With our algorithm, the facilitator can utilize the latest trust information to make the facilitation, but when there are huge number of participants, the computational costs might be a problem.

5. Implementation and application

5.1 Implementation

We have implemented our proposed mechanism as a JATLite[8] agent facilitator. JATLite is a Java-based agent platform which provide the message exchanging mechanism with its original message router, and the templates which help for developing agents which handle KQML[9] language.

For facilitation protocols we adopt the standard protocols which is defined with KQML. The implemented protocols are followings.

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

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

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

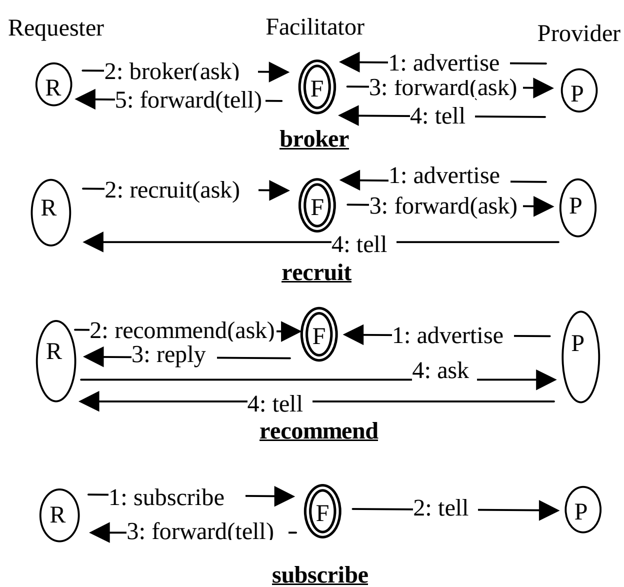


Figure 8. Facilitation protocols

[2] Both “client” and “agentb” are names of agents.

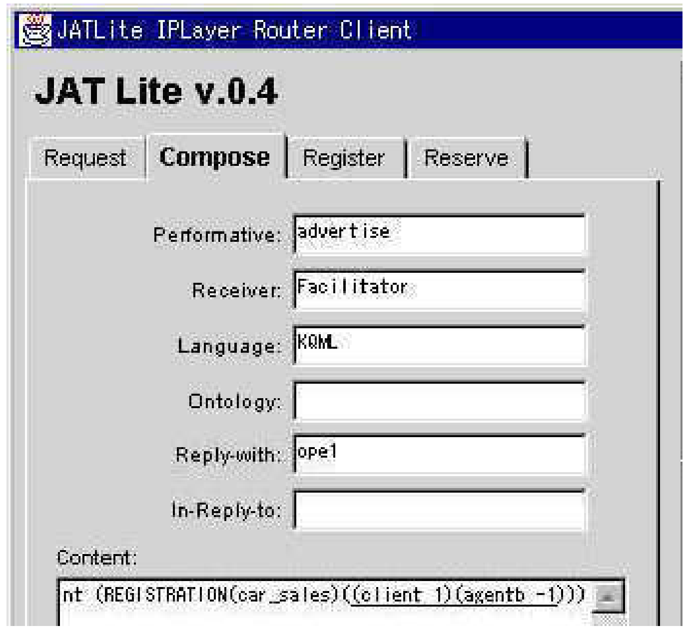


Figure9. Trust information in KQML

5.2 Application example

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

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, 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. Further works

As further works, we’ll consider the following issues.

First, although we have proposed some practical algorithm in this paper, they aren't impeccable. We think that they might have problems for calculation costs, so we should simulate the calculation costs with our facilitator.

Second, we expect that our proposed mechanism should coexistence with other basic technologies for EC, for example cryptograph and authentication. So we should consider their combination, and find better facilitation protocols which are suitable the combination.

Third, although our proposed mechanism is based on reputations of each participant, we don't mention about malicious participants. Of course, malicious participant could deselect along reputations as distrust, however we don't know how mach have effects with each malicious reputation. We should clarify the effects, and consider a self-healing mechanism against the malicious participants and reputations.

7. Conclusion

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

8. Acknowledgement

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