

# A Trust-Based Reputation System in Peer-to-Peer Grid

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**Abstract.** Grid computing and peer-to-peer computing are both hot topics at present. The convergence of the two systems is increasingly visible, and OGSA provides a framework for integrating grid and peer to peer. However, managing trust is a key issue for peer-to-peer grid. This paper proposes a novel trust-based reputation system for peer-to-peer grid, which is based on Bayesian theory. Theoretical analysis and simulations prove that the trust-based reputation system in peer-to-peer grid can improve the performance of cooperation among Gridpeers.

## 1 Introduction

During the past several decades, the processing speed of a computer has exponentially increased over one million times. A personal computer today is more powerful than a supercomputer ten years ago. However, today's computer, even the supercomputer, still cannot satisfy the increasing need of life sciences, physics etc. Therefore, the grid computing and peer-to-peer computing obtain development gradually. At present, grid and peer-to-peer are both hot topics respectively. However, the convergence of the two systems is increasingly visible: the two research communities started to acknowledge each other by forming multiple research groups that study the potential lessons that exchanged. P2P research focuses more and more on providing infrastructure and diversifying the set of applications; Grid research is starting to pay particular attention to increasing scalability[1][2].

Up to now, many grid models have been proposed, which are based on peer-to-peer technology[3][4][5]. These peer-to-peer grid models improve the performance of the traditional grid such as scalability, autonomy and dynamic. However, new challenges in peer-to-peer grid take place. Managing trust is a key issue for peer-to-peer grid, especially among Gridpeers. To address the trust problem in the peer-to-peer grid environment, this paper proposes a trust-based reputation system.

The rest of this paper is organized as follows. In section 2, we make a brief survey on the related works. Section 3 describes a trust-based reputation system in the peer-to-peer grid. Firstly, this section presents a peer-to-peer grid model, then a trust model based on Bayesian approach is introduced in the peer-to-peer grid environment. In section 4, we present a simulation to show that the performance of the model is better than interest-based model. Section 5 concludes the paper.

## 2 Related Works

Yang, B et al. present a super-peer network in [6]. Mastroianni, Carlo et al. extend super-peer network ideas and discusses a peer-to-peer grid model in [7]. According to

[8][9], the Grid computing paradigm is aimed at providing flexible, secure, coordinated resource sharing aiming dynamic collections of individuals, institutions and resources, and enabling communities to share geographically distributed resources as they pursue common goals.

The problems of managing trust in typical grid environments are discussed by Azzedin et al.[10] who define the notion of trust as consisting of identity trust and behavior trust. Alunkal, et al. [11] propose to build an infrastructure called “Grid EigenTrust” using a hierarchical model in which entities are connected to institutions which then form a “VO”. They conclude with the realization of a “Reputation Service”, however, without providing mechanisms that can automatically update trust values.

Apart from the typical grid, there are several proposals for managing trust and reputation in peer-to-peer system. Kamvar et al.[12] present the “EigenTrust” algorithm which evaluates the trust information provided by the peers according to their trustworthiness, using trust ratings for credibility, but their system is vulnerable to malice attacks. Wang [13] use “Bayesian Networks” for enabling peers to develop trust and reputation, especially with respect to the competence and capability of peers to offer high quality files and valuable recommendations in a P2P file sharing application, but it cannot give the analysis and evaluations in detail. Mui, et al.[18] present the well-known method of Bayesian estimation as the right probabilistic tool for assessing the future trusting performance based on the past interactions. Only direct interactions were studied. The question of recommendations was not considered.

### 3 A Trust-Based Reputation Model

Based on the related paper [14], we propose a peer-to-peer grid model, and Figure 1 shows this model. In the peer-to-peer grid, grid is divided into two layers. Underlying

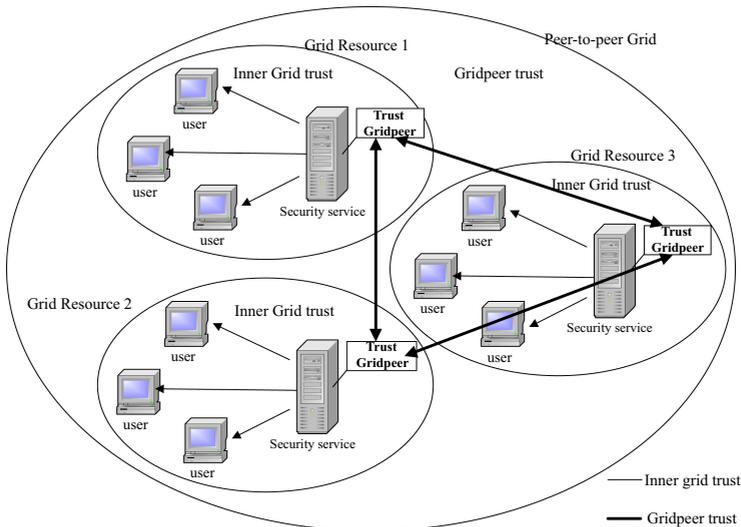


Fig. 1. Overview of peer-to-peer grid trust model

layer works by traditional grid model. On the other hand, the interaction among Gridpeers is implemented by peer to peer model. Gridpeer, according to [6], acts as Superpeer. The clients first request message from the Gridpeer by traditional grid model at local, if this Gridpeer cannot satisfy with the clients, then it forwards the request message to the other Gridpeers by peer-to-peer model. In this paper, we don't consider Inner Gridpeer trust, but only focus on the trust among Gridpeers.

### 3.1 Basic Concept

According to [15], in the information system, trust can be defined as “the firm belief in the competence of an entity to act dependably and reliably within a specified context”. Trust is usually specified in terms of a relationship between a “*trustor*”, the subject that trusts a target entity, and a “*trustee*” (i.e., the entity that is trusted). Trust forms the basis for allowing a trustee to use or manipulate resources owned by a trustor or may influence a trustor’s decision to use a service provided by a trustee.

In the peer-to-peer grid environment, when an entity makes decision, it is necessary to consider other entity’s information and options about the specified entity. As above analyzed, this paper give the definition of trust in the peer-to-peer grid environment: *Trust* is the expectation of a certain Gridpeer which acting as entity, and the expectation depends on self-behavior of the Gridpeer, including direct reputation and recommendation reputation. The *direct reputation* specifies the past behavior of the Gridpeer in some context designated, and the *recommendation reputation* illuminates the information of interaction between the Gridpeer and the other Gridpeers.

As mentioned above, trust relations are classified into two kinds: direct reputation and recommendation reputation. Using a Bayesian network[16], the trust value of Gridpeer can thus be modeled as shown in Figure 2. Fig.2(a) shows the direct trust between Gridpeer A and Gridpeer B, while recommendation trust between Gridpeer A and B is described in Fig.2(b).

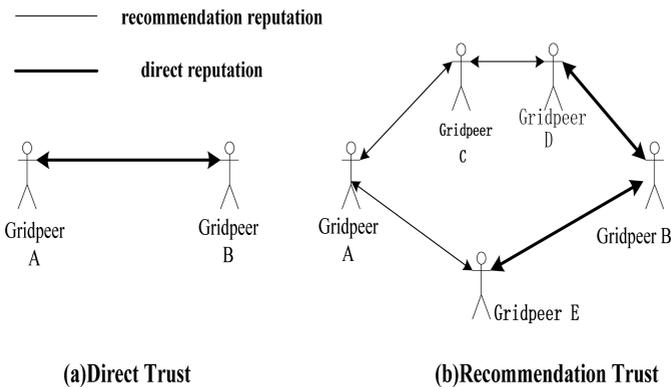


Fig. 2. Direct Trust and Recommendation Trust

In Fig.2(a), Gridpeer A directly evaluates the trust reputation of Gridpeer B through numerous collaborations with the Gridpeer B. Fig.2(b) shows the recommendation trust. Gridpeer A possesses the direct trust reputation about Gridpeer B through the recommendation of the other Gridpeer E, or possesses the trust reputation through the recommendation of the other Gridpeer C.

The Bayesian analysis is built on the basis of subjective probability, and Bayesian methods are very suitable for the trust assessment. This paper analyzes the probability of successful collaboration between two Gridpeers by Bayesian methods. And the trust model based on this method is also presented.

Trust is always connected with some specified context. For the sake of simplicity, we only consider a peer-to-peer grid system within the same context during a period of time. For two Gridpeers  $x$  and  $y$ , the successful cooperation probability between them is denoted by  $\theta$ . There may have direct interactions between them, there may also have other intermediate Gridpeers and each of them has direct experiences with  $x$  and  $y$ . On the one hand, if there are direct interactions between  $x$  and  $y$ , we can obtain direct probability of successful cooperation, which is called direct reputation value, and denoted by  $\theta_{dr}$ . On the other hand, if there is an intermediate Gridpeer  $z$  between  $x$  and  $y$ , and there are interactions between  $x$  and  $z$ ,  $z$  and  $y$ , then we can also obtain an indirect probability of successful cooperation between  $x$  and  $y$ , which is called recommendation reputation value, and denoted by  $\theta_{rr}$ . So, there are two kinds of probabilities of successful cooperation. We will combine these two kinds of probabilities to be the estimator of successful cooperation probability. That is,

$$\hat{\theta} = a\hat{\theta}_{dr} + b\hat{\theta}_{rr} \tag{1}$$

In which,  $a$  and  $b$  satisfy  $a, b \in [0, 1]$ , and  $a+b=1$ . They are weights for represent the importance of these two probabilities respectively and are decided by the personal characteristics of the Gridpeer  $x$ .

### 3.2 Direct Reputation Value and Recommendation Reputation Value

In order to estimate the direct reputation value, we use Bayesian theory to compute its estimator. So, we use the following formula to be its estimator:

$$\hat{\theta}_{dr} = E(\text{Beta}(\theta | \alpha + 1, \beta + 1)) = \frac{\alpha + 1}{\alpha + \beta + 2} \tag{2}$$

Where  $0 < \theta < 1$  and  $\alpha, \beta > 0$ .

In which,  $\alpha$  is the number of successful cooperation between Gridpeer  $x$  and Gridpeer  $y$  after  $n$  times interactions.  $\beta$  is the number of failure cooperation in the same context.

With respect to recommendation reputation value, using Bayesian theory, we obtain the estimator, which is,

$$\hat{\theta}_{rr} = E(\text{Beta}(\theta | \alpha_1 + \alpha_2 + 1, \beta_1 + \beta_2 + 1)) = \frac{\alpha_1 + \alpha_2 + 1}{n_1 + n_2 + 2}. \tag{3}$$

Where  $n_1(n_2)$  is the number of interaction between Gridpeer x and Gridpeer z (Gridpeer z and Gridpeer y),  $\alpha_1(\alpha_2)$  is the number of successful cooperation between Gridpeer x and Gridpeer z (Gridpeer z and Gridpeer y) after n times interactions; On the other hand,  $\beta_1(\beta_2)$  is the number of failing cooperation between Gridpeer x and Gridpeer z (Gridpeer z and Gridpeer y) after n times interactions.

When the recommendation Gridpeer is more than one, it is easy to be inferred from Bayesian theory that the recommendation reputation value:

$$\hat{\theta}_{rr} = \frac{\sum \alpha + 1}{\sum (\alpha + \beta) + 2}. \tag{4}$$

### 3.3 The Analysis of Relationships Between Two Gridpeers

In the peer-to-peer grid system, the relationships between Gridpeer x and Gridpeer y can be sorted into 4 kinds with reference to what if there are recommendations and/or direct interactions between them. In the following, let's discuss how to get the final estimator Gridpeer x through analyzing the parameters of Beta distribution.

**Table 1.** The estimator of the 4 kinds of relationships

(Dr,Rr)	$\hat{\theta}_{dr}$	$\hat{\theta}_{rr}$	$\hat{\theta}$
(1,0)	$\frac{\alpha + 1}{\alpha + \beta + 2}$	0	$\hat{\theta}_{dr}$
(1,1)	$\frac{\alpha + 1}{\alpha + \beta + 2}$	$\frac{\sum \alpha + 1}{\sum (\alpha + \beta) + 2}$	$a\hat{\theta}_{dr} + b\hat{\theta}_{rr}$
(0,0)	1/2	0	1/2
(0,1)	1/2	$\frac{\sum \alpha + 1}{\sum (\alpha + \beta) + 2}$	$a\hat{\theta}_{dr} + b\hat{\theta}_{rr}$

Assume Dr=1(or 0) to represent there are (not) interactions between Gridpeer x and Gridpeer y. While let Rr=1(or 0) denote there is (not) an intermediate Gridpeer z between Gridpeer x and Gridpeer y. Then, the 4 kinds of relationships can be described as Table 1.

## 4 Simulation and Evaluation

We can use (1) to get the final estimator of successful cooperation probability under the same context, and it is a summary about past experience. On the other hand, it can be taken as an instructor of Gridpeer x's trusting in Gridpeer y to decide if Gridpeer x

select Gridpeer  $y$  to be its partner in the future. What's more, it will form a relatively steady cooperation system with respect to Gridpeer. We use the algorithm, which is provided in [17], to aggregate the trust Cooperation.

We simulate our approach in a simulation of a file content sharing system in a peer-to-peer grid from original phex-like network in [5]. Every Gridpeer only knows other Gridpeers directly connected with it and a few file providers at the beginning. Our experiments involve 10 different file providers and 400 Gridpeers. Parameter  $a$  in formula (1) is set to 0.8. Each Gridpeer will gossip with other Gridpeers periodically to exchange their Bayesian networks. The total number of interactions is 1200 times.

The goal of the first experiment is to see if a Bayesian trust-based reputation mechanism helps Gridpeers to select file providers that match better their preferences. Therefore we compare the performance (in terms of percentage of successful recommendations) of a system consisting of Gridpeers with Bayesian trust model and a system consisting of Gridpeers that represent interest-based trust model[19]. Successful

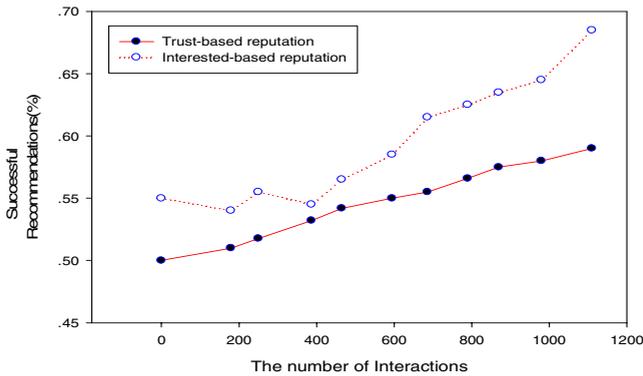


Fig. 3. Trust-based Reputation vs. Interest-based reputation

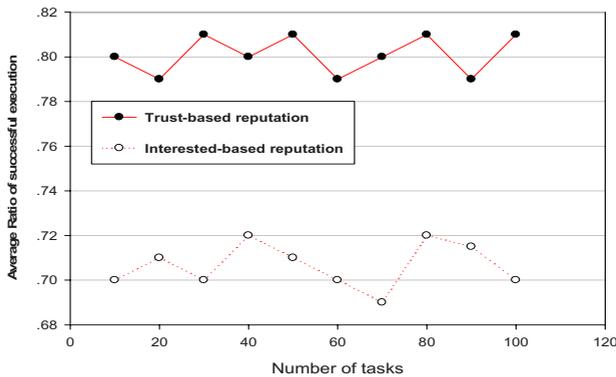


Fig. 4. Average ratio of successful execution with different Gridpeers

recommendations are those positive recommendations when Gridpeers are satisfied with interactions with file providers with good reputation value. If a Gridpeer gets a negative recommendation of a file provider, it will not interact with the file provider.

Figure 3 shows that the system using trust-based reputation performs better than the system with interest-based in terms of the percentage of successful recommendations, especially when the number of interactions is very large.

The goal of the second experiment is to see the successful execution ratio in the peer-to-peer grid in the condition of different number of downloaded files, which is called tasks. Figure 4 shows that the trust-based mechanism is helpful when executing tasks than the interest-based mechanism.

## 5 Conclusions and Future Work

In this paper, we propose a trust-based reputation in peer-to-peer grid to solve the security problems between two Gridpeers. We evaluated our approach in a simulation of a file sharing system in a peer-to-peer grid. Our approach outperforms the interest-based reputation system; however, we cannot consider malicious attacks and fraud behaviors. The future work includes adding more parameters to evaluate the performance of the approach, and applies the approach to the real peer-to-peer grid.

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