Trust Based Incentive in P2P Network*

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Abstract

In the world of Internet technologies, Peer-to-Peer (P2P) computing is currently receiving considerable interest. However, as experience with P2P networks such as Gnutella shows, the selfish behaviors of peers may lead to serious problems of P2P network, such as Free-riding and Tragedy of Commons. In order to solve these problems, there are increasingly considerations on incentive design in the study of P2P systems. In this paper, we give a brief survey of researches on trust based incentive in P2P network. By investigating the reputation systems in P2P networks, we outline some key issues within the design of trust based incentive in P2P networks. After that we introduce some other approaches addressing the incentive of P2P networks and conclude the paper with a summary and discussion on future research.

1. Introduction

1.1. Peer-to-Peer

Peer-to-Peer (P2P) computing is a novel Internet-based computing paradigm which is being studied widely in recent years. In P2P systems, peers are acting as service consumer and provider simultaneously. The final goal of P2P systems is to pool end-systems with all kinds of resources in Internet-scale as much as possible to construct an open, dynamic and robust cooperating and resource-sharing environments. In an ideal P2P network model, the significance of most peers is equal.

With the wide deployment of P2P networks [1], P2P solutions are currently receiving considerable interest [2], and the applications of P2P computing are now spreading from distributed computing (e.g. SETI@home, Popular Power, Centrata, United Devices, Entropia, etc.), instant message (e.g. ICQ, OICQ, Jabber, etc.), cooperative working (e.g. Groove, etc.), search engine (e.g. Infrasearch, etc.), to distributed storage (e.g. Napster, Gnutella, Freenet, iMesh, Morpheus, KazAa, Toadnode, etc.) and many critical business systems.

1.2. Game theory model of P2P network

By now, most researches on P2P networks presume that the peer's behaviors are altruistic or obedient, and the study of peers' misbehaviors often being stated as an issue of network security. But recent researches [3] indicate that, as an agent of user, the peer is a self-interesting and autonomous entity strategizing to maximize its owner's network utility. However, the rationality of the peer may leads to some irrational results for P2P network as a whole. Two most well-known observations are Free-riders and the Tragedy of Commons.

1.2.1. The Free-rider problem. According to experiments on Gnutella[4], it was found that there are two main types of "free-riders" of P2P file sharing system: 1) users that only download files for themselves without providing files for download by others and 2) users that provide files that are of low quality for download by others. There are near 66% of all Gnutella users share no file, the top 1% users account for 47% of all downloads, and the top 25% users account for 99%. The same phenomenon is observed in Napster and KazAa. The Free-rider problem indicates that individual users are often provided with no incentive for sharing their own files and thereby adding value to the network. This could be explained by analyzing the payoff of users in Game theory model as a static Game. Let the cost of sharing be v>0, the utility of downloading be u>0. For example, in a game with two players A and B:

Free-rider	*Player B*		
Player A		Share	Not share
	Share	(u-v, u-v)	(-v, u)
	Not share	(u, -v)	(0, 0)

Figure 1. Strategic form of Free-rider problem

It's easy to see that for rational players A and B, the strategy profile (Not share, Not share) is the only dominant equilibrium of this game.

1.2.2. Tragedy of Commons. In 1968, Hardin [5] proved that common resources without any exclusive ownership will be consumed without limit. He named this phenomenon "Tragedy of Commons". During the development of Internet, Tragedy of Commons is also a serious problem [6]. As a common resource that can be utilized freely, Internet bandwidth is consumed by all kinds of P2P applications without limit, for example, statistic shows that near 70% of the bandwidth of Internet backbones were occupied by P2P applications.

We can also explain the existence of Tragedy of Commons by analyzing the payoff of users in Game theory model. Let n_m>0 denotes the utility of a peer when all peers consume bandwidth with limit; n_u>0 (n_m>n_u) denotes the utility of a peer consuming bandwidth with limit when some other peers consume it without limit; n_x>0 (n_x>n_m) denotes the utility of a

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peer consuming bandwidth without limit when some other peers consume it with limit; and n_z ($n_x > n_z > n_u$) denotes the utility of a peer when all peers consume bandwidth without limit. For example, in a static game with two players *A* and *B*:

Tragedy of Common	*Player B*		
Player A		With limit	Without limit
	With limit	(n_m, n_m)	(n_u, n_x)
	Without limit	(n_x, n_u)	(n_z, n_z)

Figure 2. Strategic form of Tragedy of Common

The only equilibrium of this game is (Without limit, Without limit).

1.3. Incentives in P2P network

From the analysis above, we can say that the self-interesting of the peer is the main cause of these problems. When peers strategize to pursuing their own welfare, it may lead to lose of system goals (e.g. robustness). It shows a contradiction between the individual's rationality and the social rationality, as often be found in Games, (e.g. prisoner dilemma). In order to solve these problems, there are increasingly considerations on incentive of P2P systems, that is, to develop mechanisms to incent peers to do the "right" thing, or to give them incentives to contribute to the network or to behave well.

The so called "incentive" can be seen as remuneration for peers' transactional behaviors. The type of remuneration is called "incentive pattern", which can be confined to reputation and checks within the existing approaches [7]. The incentive scheme in which apply reputation as incentive pattern is called a trusted based incentive scheme.

In this paper, we give a brief survey of studies on trust based incentive in P2P networks (section 2). By investigating the distributed reputation system in P2P networks, we outline some key issues within the design of trust based incentive in P2P networks (Section 3). After that we introduce some other approaches addressing the incentive of P2P network (Section 4) and conclude the paper with a summary and discussion on future research (Section 5).

2. Trust based incentive

Trust based incentive is enabled by evaluating the transaction history of the peer and changing the peer's significance or capacity within the P2P network based on this evaluation. The evaluation of a peer's transaction history is called its reputation value, which is a form of expectation on the peer's future behavior. We call the P2P network with trust based incentive schemes trust-aware P2P network. A trust-aware P2P network is likely to be constructed based on the trustworthiness heterogeneity [9] of peers or do self-optimizing in accordance with the evolution of the reputation values of peers.

Based on the reputation value of the peer, there are three main incentive schemes have been applied in existing approaches in order to overcome the Free-rider and Tragedy of Commons Problems:

2.1. Trust-aware topology construction

The reputation value of a peer reflects both the capacity(e.g. CPU, storage, bandwidth, etc.) and participating strategies (it reflects the extent for which the peer contribute to the P2P network with its capacity) of the peer, and the difference in this value also defines the heterogeneity of the P2P network. When constructing a structured P2P network (topology), this information should be taken into consideration. The design of a trust-aware topology always follows such a simple principle: the peer with higher reputation value should take more important position in the topology, such as a high layer in a layered topology. In [8], D. Wen etc. proposed a trust-aware topology named *Terrace*. *Terrace* is an expansion of d-tree, in which the more reputable peers will always be located on a higher layer than the less reputable peers. Such a design makes the topology stable with respect to dynamic of the peer. In *Terrace*, "the stability of top layers will assure the stability of such a topology". Also, because the peer on higher layers will get a better network performance, in conjunction with approach (3) below, it incents the less reputable peers to do more contribution to the network in order to promote their topological position. However, this approach can't be applied to pure P2P networks.

2.2. Trust-based broadcast searching

In P2P networks, broadcast search is frequently used to locate resources, especially in pure P2P systems, such as Gnutella. But the usage of broadcast without limit will exhaust the network bandwidth, and such an approach will definitely results in the Tragedy of Commons. In order to reduce the influence of this phenomenon, there need some efficient ways to restrain the unlimited employment of broadcasting. In [9], D. Wen proposed a trust-based broadcast searching protocol *TBS*, in which the spreading scale of a peer's broadcast query is decided by its reputation value and its neighbors' reputation values. *TBS* enables the more reputable peers to have a farther broadcast scale than less reputable peers so that these more reputable peers will always have a better searching result than the less one. So it produces an incentive for the less reputable peers to improve their reputation. As a result, the Tragedy of Commons and Free-riding of the P2P networks will both be restrained. This approach can also be applied to pure P2P systems, such as Gnutella, with EigenRep[10] as the reputation management system.

2.3. Trust-based dynamic topology optimization

Trust-based dynamic topology optimization was first proposed by A.Garcia in Gnushare [15]. In their design, the

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system may reward peers with high reputation values and reputable peers may be rewarded with increased connectivity to other reputable peers, or greater bandwidth. At the same time, the less reputable peer, especially those misbehaved peers would be isolated to the edge of the topology (e.g. only have few connections to other peers); it makes them hardly to achieve satisfactory service within the P2P network. It gives the peer an incentive to share files, since a good trust rating may only be achieved by sharing files and do more contributions to the network and thus reduces the number of free-riders in P2P networks.

A combination of all these incentive schemes have been adopted by D. Wen [9].

Incentive schemes above explore approaches to solve Free-rider and Tragedy of Commons problems in P2P networks. It's easy to see that the efficiency of all these schemes is based on the trustable reputation value of the peer, so how to build a trustworthy and practicable reputation system (or rating system) is a key issue to make incentive schemes work.

3. Reputation system of P2P network

3.1. Reputation and peer's behaviors

The reputation value of the peer is a combination of its capacity and participating strategies. As we already seen, peers should be considered as autonomous entities whose unique goal is to maximize its utility of the system, and they have no incentive to reveal their private information, such as its true capacities. So the only way to evaluate its reputation should be based on the history of its behaviors (e.g. sharing or downloading files in distributed storage system) [11]. In P2P systems, peers may rate each other after each transaction. In a reputation system of P2P networks, the reputation value is computed with the ratings of peer's transaction history, a satisfactory rating will raise the reputation value of the peer, and an unsatisfactory rating may lower its reputation value.

3.2. Peer's misbehaviors

From the discussion above, it is obvious to see that the trustworthiness of peer's reputation value relies mostly on the trustiness of the transaction history of peers. In P2P networks, there always exist some misbehaved peers who are likely to manipulate reputation values by forging the transaction history. There are three main types of such misbehaviors:

(1) Collude inflating: A set of peers rate one another with satisfactory of some fake (or not existing) transactions in order to increase their reputation values. For example, two colluding peers may rating each other with satisfactory for some not existed downloads or downloads of fake files.

(2) Deflating: A set of peers all rate one peer with unsatisfactory of some fake (or not existing) transaction in order to decrease its reputation value.

(3) Faker: A peer of low reputation fakes as a peer with high reputation in order to get more profit from the network.

In order to insure the trustworthiness of reputation values, the design of reputation system should contain the design of mechanisms to distinguish or disincentive the peer's misbehavior.

3.3. Centralized reputation system

P2P reputation systems can be confined to centralized reputation systems and distributed reputation systems with respect to architecture. In centralized reputation system, there are some central reputation management facilities to store and manage the reputation values and transactional history of peers. This type of reputation system suits to P2P systems with some central servers, such as Napster, eBay [12], etc. Because of the existence of these central server, it will be easy to build a PKI based trust model [13] (e.g. BitTorrent's tracker) or a CA to authenticate the information being shared, which enables monitoring of transactions. In centralized reputation system with CA, fakers can be distinguished instantly. By adding some transaction cost (e.g. charge the seller for a trade in eBay), deflating and collusion inflating can also be restrained. The main shortcoming of the centralized architecture is that the central facilities may become the bottleneck of system performance and the scalability of network will be limited.

3.4. Distributed reputation system

In contrast with centralized reputation system, there isn't any central reputation management facility in a distributed reputation system, so the transaction history and reputation values of peers should be stored distributively. By using a DHT (Distributed Hashing Table) [14], such information of a peer *A* can be stored onto another peer *B*, with *A* and *B* not to know each other. Because of the absence of CA and PKI, it's impossible to fully monitor the transaction of peers, and it will be more difficult to distinguish the misbehavior of peers. According to the study of D. Wen[8] , faker can be distinguished by a certificating method named $Cent_{IP\text{-}ID}$, which contains a challenge with respect to peer's Id and IP address; and also, by making the coefficient of the ratings from same peer drops very fast, deflating and collusion inflating can be restrain to some extent. But it is important to note that, making a distributed reputation system resistible (or proof) to these misbehaviors is much more difficult than that for a centralized system. Besides this, the iterated algorithm to compute the reputation value of peers often raise heavy communicating traffics, which is another challenge to the feasibility of distributed reputation systems.

4. Other incentive approach

Besides the trust based incentive approach discussed above, there are several other approaches addressing the incentive of P2P networks. Two important approaches are trade based incentive and AMD (Algorithmic Mechanism Design)

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/DAMD (Distributed Algorithmic Mechanism Design).

4.1. Trade based incentive

In a trade based incentive scheme, the incentive pattern often is money or other resource with the same value. Unlike trust based incentive schemes in which a successful transaction will raise the reputation value of both sides, there must have some value (e.g. money) transfer among peers of the transaction. This property makes it easier to resist the collusion of peers because these collusions may not increase the utility of both sides. In a P2P system with trade based incentive, peers should contribute to the network in order to achieve money or something else for their future utilizing of the network. In terms of the type of remunerates, trade based incentive can be classified into bond based pattern [15][16]and barter trade pattern[17][18].

4.2. AMD and DAMD

In recent years, investigating an agent under strategic model has getting increasing consideration in study of autonomous entities across autonomous domains. With the combination of incentive compatible requirements of Mechanism Design (MD) [19] and computational complexity requirements of TCS (Theoretic Computation Science), AMD [20] /DAMD [21] was proposed to solve the incentive issues in study of distributed computing. With its previous results on the multicast cost sharing and inter-domain routing problem[22], AMD/DAMD was supposed to be a new approach to design incentive mechanisms in P2P networks.

5. Conclusions

In P2P networks, peers can be seen as strategic entities with the goal of maximizing its network utility. By analyzing Free-rider and Tragedy of Common problem using a game theory model, we showed that there are contradictions between the individual's rationality and the social rationality. In order to solve these problems, the study on incentive has achieved increasingly consideration. In this paper, we investigate trust based incentive in P2P system and some issues of reputation system design for P2P networks.

As we can see, although there are many researches on distributed reputation systems for P2P networks, there still no such reputation system being deployed. The resistance to peers' collusion has not been fully explored and it may attract many researchers attention for future research.

Beside the trust based incentive, trade based incentive is an alternative approach to make incentive, which has get many achievements in recent year. We believe both these two approaches should be fully researched in future.

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