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New P2P Sharing Incentive Mechanism based on Social Network and Game Theory

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***Abstract*—P2P technology has been used widely in file and live media streaming sharing fields. But the architecture of P2P technology which we used is imperfect. In P2P system, most users are free-rider. They were not sharing their own resource because the architecture has no perfect incentive mechanism. Therefore, in this research, we propose a *novel incentive mechanism (NIM)* that considers useful information in social network and various important factors of the peers in P2P architecture to affect the system performance. In addition, we analyze the effectiveness of NIM by game theory. The simulation results show that deploying NIM to P2P system not only promotes the peers to spontaneous sharing their own resource but also decrease amount of free-rider.**

Keywords-P2P,Incentive mechanism, Social network, Game theory

I. Introduction

In recent years, with the emergence of P2P technology, there are many of the applications for P2P technology has emerged and how to effectively inhibit the free-riders is a hot issue. According to statistics, most of the P2P applications used Gnutella protocol and BitTorrent protocol [1][2]. BitTorrent uses the Choking algorithm to isolate free-riders, but Choking algorithm is simply giving free-riders choke. Gnutella uses the EigenTrust algorithm to combat free-riders. However according to the actuality, EigenTrust algorithm is not a consummated algorithm. Therefore, both of Choking algorithm and EigenTrust algorithm have a bed effect. A research was conducted in 2005, there are nearly 85 percent of Gnutella network users are free-riders from all users. Furthermore, there is only 1 percent of users voluntary to share new files.

Due to the resource in the P2P applications are like public goods [3] that everyone can use it for free. It makes most of the users were not sharing their own resource, to cause tragedy of the commons and inefficiency. Therefore, in this paper, we propose an incentive mechanism on the basis of game theory; it promotes the peers to spontaneous sharing their own resource. We also use social network to promote users to share their resource, to maintain a long-term cooperation between users, and also use user's relationship of social network to exclude free-riders.

To deploy the mechanism to the architecture, the system will give users counters by considering bandwidth, computing power and electricity of each user. These counters will be stored in server and managed by server. In addition, the sharing model of the system can be divided into live media streaming sharing and file sharing. In live media streaming sharing, users can participate in the auction and using their counters to bid the tickets of high-quality live media streaming. In file sharing, users have to pay counters for every unit download bandwidth. In other words, users need to use the counters to bid or buy service from server. Therefore, the mechanism can promotes the peers to spontaneous sharing their own resource if they need some resources from server.

The simulation results show that payoff from users chooses different strategies in different situations, and the amount of free-rider is decrease after deploying NIM to P2P system. The proposed mechanism not only promotes the peers to spontaneous sharing their own resource but also can enhance the transmission performance of P2P system. Finally, this paper proves this incentive mechanism could effectively inhibit the free-riders and allocation of resources to users more equitable.

The rest of this paper is organized as follows. Section II individually describes details of game theory and social network. In section III, we describe the details of the incentive mechanism and illustrate how users earn and spend their counters in the system. Section IV is simulation and analysis. We will conclude this paper in section V.

II. Background

A. Game theory

Game theory has been created by John von Neumann in 1928. Today, it has been widely application of in various fields. Game theory used to analyze the rational player's strategies. If we divide P2P architecture based on the time slots, the architecture just as an indefinitely repeated games. Therefore, assuming all the users in P2P architecture are rational players, and we already know the other player's

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strategies, then we can define a player's best response [4][5][6] [7].

B. Social network

Social network has risen rapidly in the year. Today, facebook has more than 600 million users. According to the researches, there are 68% of all the contact in each user's social network are family, colleagues and good friends. Those contact persons have higher reliability, also have similar characteristic of space and time, and the same file likely interests them. Therefore, in P2P architecture, we can easily use characteristic of social network to promote the peers to spontaneous sharing their own resource and exclude free-riders [8][9] [10].

Social network is an important factor in NIM, so users have to operate their own social network for long time by sharing. Therefore, it can effectively inhibit the free-riders. If users don't want to share their own resources, social network will cause crowding-out effect to separate the users.

III. P2P INCENTIVE MECHANISM

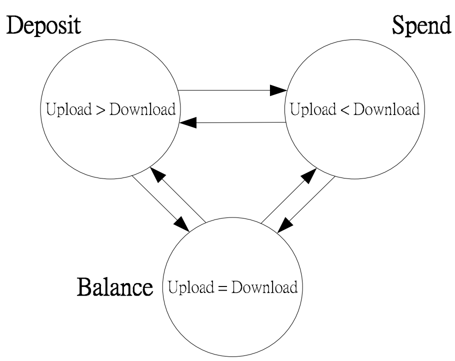

Figure 1. User's strategy state diagram

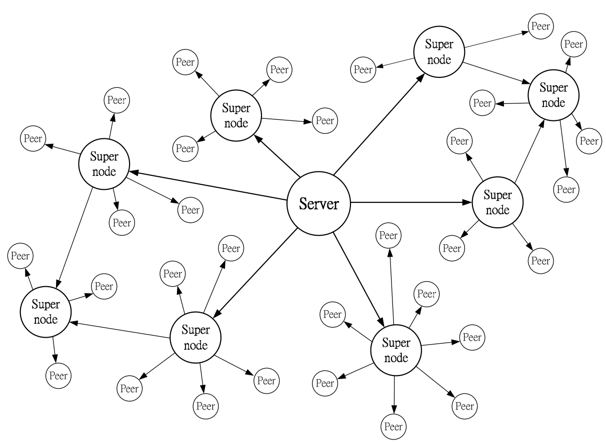

Figure 2. P2P sharing architecture

In this research, we deploying a novel incentive mechanism to P2P system. In our proposed system, server will reference several important factors of node in each time slot, and give counters to nodes by according to this factor with certain weight value by (1). N_C is the number of counters given to node. B_C is node's upload bandwidth contribution, B_{share} is node's shared upload bandwidth, B_{have} is node's had upload bandwidth. I_S is node's social networking information. P_C is node's computing power. P is node's energy. D_P is content popularity, it's about number of times all of the node's contents be downloaded in last time slot. E_S is performance of P2P sharing system. T is veridicality of node's contents; it can deter the malicious nodes. S is stability of node; this factor will increase system stability. By emphasizing the factors that mentioned before, it can raise the satiability of system. Furthermore, the counters information will recode in the server and unify management by server. In the system, users can use these counters to bid or buy service from server, and the users will have different strategic through the counters, shown in Fig. 1. There are three situations, if user shared upload bandwidth higher than download bandwidth, he can deposit his counters; if user shared upload bandwidth lower than download bandwidth, he will spend his counters;if user shared upload bandwidth equal to download bandwidth, his counters was not change. In addition, server will choose some special nodes to become super-nodes by considering bandwidth and computing power of each node [11], they can share the burden of server (Fig. 2). In return, super-nodes will get percentage increases for counters from server. Next, we will introduce how user spends their counters in live media streaming sharing system and file sharing system.

$$N_C = E_S \times B_C \times I_S \times D_P \left(aP_C + bP + cT + dS \right) \quad (1)$$

$$B_C = \frac{{B_{share}}^2}{B_{have}}$$

A. Live media streaming sharing

NIM adds the auction system into live media streaming sharing system. The mechanism will provide tickets of high-quality live media streaming to nodes for bid. When each time slot is beginning, the server will secretly decide the number of tickets, and the total value of all tickets whether the server service all nodes watch low-quality live media streaming needed number have counters in last time slot. Using Dutch auction [3] to reduce the value of each ticket gradually till sold out all the tickets. The nodes in the auction don't know the remaining number of tickets and the value of past transactions. The variance of revenue by Dutch auction might be bigger. However, in the simple shared value, the expected value of revenue by Dutch auction is higher.

Therefore, the server will have sufficient performance to services all of nodes in the system. Server will use the lowest download bandwidth to provide low-quality live media streaming to all nodes which have no ticket with super-node support. The node without enough bandwidth and hardware resource to watch and share high-quality live media streaming can use the policy described in Fig. 1 to take strategic action. For example, a user plan watches an interesting high-quality sport game streaming after few days, but the user doesn't have enough bandwidth and hardware resource to let him share the media streaming at the same time. In this case, in order to achieve his purpose, the user can save his counters strategically few days ago.

B. File sharing

In this system, user has to pay corresponded counters for every unit download bandwidth in every time slot. The value of unit download bandwidth depends on proportion of total download bandwidth and the average download bandwidth last time by (2), that is E_S in (1). Therefore, when total download bandwidth is bigger, the value of every unit download bandwidth will be higher. In the case of paying the same upload bandwidth, if the download bandwidth is bigger in the time slot, the counters user get will much higher.

$$E_S = \frac{B_{now}}{B_{past}} \qquad (2)$$

Lack of information is often the main reason leading to social dilemma occurred. The Prisoner's Dilemma [3] in the game theory is a typical example. In Table I, we can easily observe that in the case of all player can't communication and lack of information, player will choose the strategy is good for themselves. So, two players will choose surrender, and it will present the worse results. Sharing information will be more efficient to achieve the best results and help player to take strategic action. Therefore, NIM will make some information to public. For example, in NIM, the average of download bandwidth and upload bandwidth from all nodes, therefore, the compensation from system will not be underestimated, and also contribute nodes to invest their own resources.

TABLE I. PAYOFF TABLE OF THE PRISONER'S DILEMMA

		Player A	
		Silence	Surrender
Player B	Silence	↓ -1,-1	➡ -10,0 ↓
	Surrender	0,-10	➡ -5,-5

IV. SIMULATION AND ANALYSIS

In this section, we will analyze NIM by game theory, draw diagrams for game analysis, and show the relative payoff from players choose different strategies. Using Heuristic Methods can help us to find player's Nash equilibrium in NIM. Describing why the players are willing to share their own resources, and prove the player's dominant strategy in NIM is tried their hardest to share their own resources.

Today, the incentive mechanism is used by Gnutella and BitTorrent are defective and ineffective for inhibition of free-riders. We assume that all players are Representative Agent, all players have the same strategy space, and they will get same payoff when they choose the same strategy. Therefore, we can use Fig. 3 to describe this game which has many players. In this game, free-riders don't need to pay any of their own resources but also can have a minimum download bandwidth. Comparing to the normal peers, free-riders get higher payoff, when the proportion of free-riders to rise in this game, the payoff to decrease for all players. The dominant strategy shows that everyone will be a free-rider, and this result is similar to the actual situation.

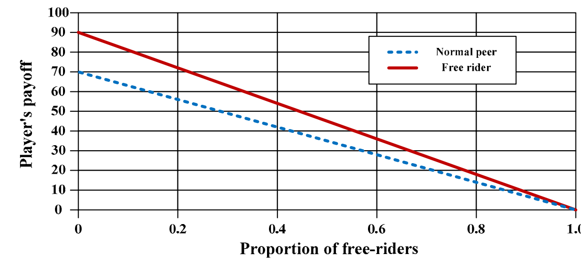

Figure 3. Pay off analysis of traditional P2P sharing game

Player A's payoff in NIM is shown in Table II. Because we propose counters system for all players to earn by share their own resources, and strategy saving or purchase of services, free-riders cannot get any resources in NIM. The dominant strategy for all players is obvious to be normal peer. The design of Nash equilibrium for all players is cooperative and shares their own resources. Therefore, free-riders do not exist in NIM.

TABLE II. PLAYER A'S PAYOFF IN NIM

		The other peer	
		Be free riders	Be normal peers
Player A	Be a free rider	↓ 0,0	➡ 0,100 ↓
	Be a normal peer	100,0	➡ 100,100

In this section, we will analyze NIM; include strategy space and payoff for each player in different situation. First, we assume all players have the same resource and focus on social network to analyze. There are player A、B、C and D, their social network relationship are shown in the Fig. 4. Player A、B and C are in the same social network, and player C and D are in the same social network. Each player can choose cooperate or betray as his strategy. Payoff matrix is shown in Table III. There is Nash equilibrium in this table. In this table, all of players choose to cooperate. Once the player chooses to betray other players, the player would be excluded by social network. And that will continue to affect social network in the future. Therefore, the player, which is betrayer, will get the lowest payoff. In which we notice that the only player C and D have social network relationship, so, when player C chooses to betray D, player D will lose social network with player A and B at the same time. Therefore, player D has to build his social network relationship with other players for better payoff as possible as he can.

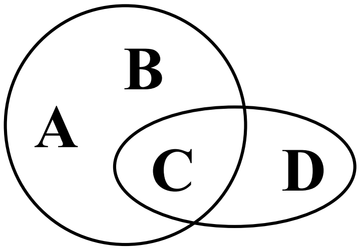

Figure 4. Social network relationship of player A、B、C and D

TABLE III. PLAYER'S PAYOFF TABLE WITH SOCIAL NETWORK

				Player C			
				Cooperate		Betray	
				Player D		Player D	
				Cooperate	Betray	Cooperate	Betray
Player A	Cooperate	Player B	Cooperate	10,10,10,10	8,8,8,1	6,6,1,2	6,6,1,1
			Betray	8,1,8,8	6,1,6,1	2,1,1,2	2,1,1,1
	Betray	Player B	Cooperate	1,8,8,8	1,6,6,1	1,2,1,2	1,2,1,1
			Betray	1,1,6,6	1,1,2,1	1,1,1,2	1,1,1,1

Next, we focus on the performance of P2P sharing system (E_S), strategy space is increase/decrease upload/download bandwidth, and player's payoff is shown in Fig. 5. We can easily find that when E_S is bigger than 1, the dominant strategy for all players is increased upload bandwidth. When E_S is smaller than 1, dominant strategy for all players is increase download bandwidth. Therefore, the system will be more balance by factors E_S, but also propose better reason to players to share their own resources in sharing live media streaming of big sport games.

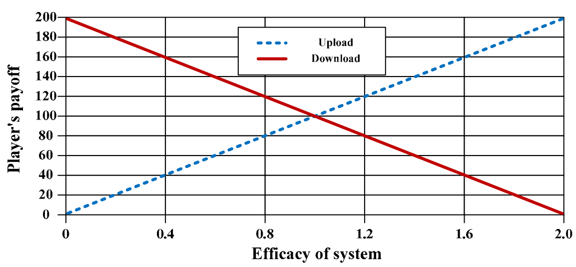

Figure 5. Payoff analysis based on the performance of P2P sharing system (E_S)

Payoff of the different players which have different upload bandwidth resources and choosing different strategies are shown in Fig. 6. We can find out no matter how many upload bandwidth resources players got, the upload bandwidth players shared the similar upload bandwidth resources from all. This will lead the payoff become well. Therefore, dominant strategy for all players is trying hard to share all of their own upload bandwidth resources. In this way, if someone is in developing countries, will not be limited the low bandwidth resources, also can obtain a fair payoff.

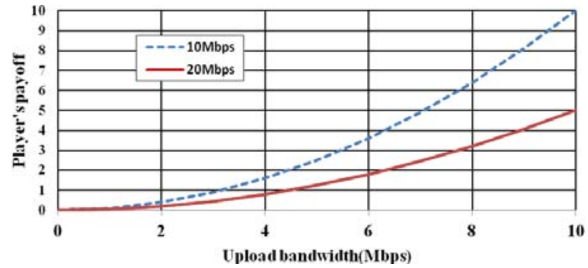

Figure 6. Payoff analysis based on bandwidth contribution (B_C)

Finally, we simulate counters change the value of six players A、B、C、D、E and F to choose different strategies in NIM in twenty time slots. It is shown in Fig. 7. Table IV shows the parameter setting of six players. Player A is a new node which just joins this incentive mechanism, he have limited data to share. Player B shares all of his own upload bandwidth resources. Player C's income is equal to expenditure. Player D is super-node with the additional bonus. Player E chooses to strategically save his counters. Player F is free-rider. Due to player A is a new node which just joins NIM, system will give him some preferential treatment, so beginning of player A join NIM, he have 100 counters and he will spend it to download the data with high popularity, and then earn counters after fifth time slot. Player E strategically saves his counters to buy the tickets of high-quality live media streaming in the fifteenth time slot; therefore, his expenditure will increase to 150 and stop to share his own upload bandwidth resources after fifteenth time slot.

In NIM, player A can spend preferential counters from system to download the data with high popularity and earn counters by sharing it. Player B has better payoff by sharing all of his own upload bandwidth resources. Player C chooses to share upload bandwidth resources equal to download bandwidth which he needs. Player D chooses to be a super-node and help server to manage system by share his upload bandwidth and computing resources, so system also gives additional bonus counters to him. Player E strategically saves his counters for download high-quality live media streaming, therefore, when he downloads high-quality live media streaming, he also can stop sharing to keep his own resources. Player F doesn't share any upload bandwidth resources, so he will run out all of counters which he has within a short time and excluded by system.

TABLE IV. SIMULATION PARAMETERS

	A	B	C	D	E	F
N_C	100	10	10	10	10	100
E_S	1	1	1	1	1	1
B_C	1	2	1	2	2	0
I_S	1	1	1	1	1	1
D_P	0→2	1	1	1	1	1
P_C	2.5	2.5	2.5	2.5	2.5	2.5

P	2.5	2.5	2.5	2.5	2.5	2.5
T	2.5	2.5	2.5	2.5	2.5	2.5
S	2.5	2.5	2.5	2.5	2.5	2.5
Bonus	0%	0%	0%	50%	0%	0%
Spend/Round	15	10	10	15	0→150	10

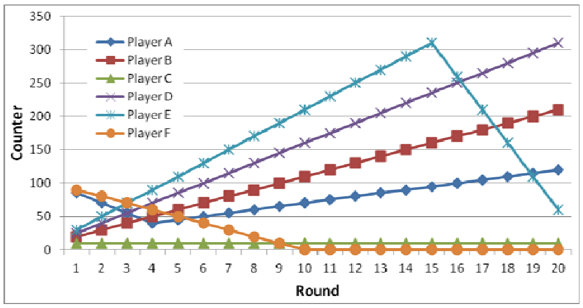

Figure 7. Simulation result

V. CONCLUSIONS

This research proposes a new incentive mechanism, to solve the free-rider problem in traditional P2P file sharing applications. We use the counter system to convert important contribution of each node into counters, and trade counters for service. This mechanism also uses the properties of social network to natural exclude free-riders and promotes the spontaneous cooperation between users. Therefore, this mechanism can comprehensive solve the free-rider problem, at the same time fair share resources to all users.

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