Studying Viable Free Markets in Peer-to-Peer File Exchange Applications without Altruistic Agents

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Abstract. File sharing networks are among the most popular applications of Peer-to-Peer (P2P) technology to date [1] and have been widely studied in terms of performance, behavior, topology and other properties. A persistent theme throughout this research has been the evidence that many P2P file sharing systems rely on the presence of *altruistic users*, who provide files, network capacity or some other goods without obvious personal gain and are potentially damaged by the presence of too many *free-riders* (users who consume resources but do not provide to others in return). In this paper we will explore the use of simple market mechanisms for P2P file sharing which function without the need of altruistic users and consider the conditions under which such markets may be viable.

1 Introduction

Many P2P file sharing systems are known to rely heavily on the presence of *altruistic* users which act as sources for content which benefits others but not necessarily themselves [2][1]. But experiences with P2P file sharing systems confirms that large resources owners are not always altruistic [4]. Economic market based systems have been proposed widely (and in some trial systems also adopted [5]), as a regulatory mechanism to provide incentives for users to provide content/resources to a system rather than relying on the altruism to others. Systems such as Karma [6] and MojoNation[2] are well known for introducing "virtual currency" based markets in order to facilitate exchange. Systems based on reputation [7], ranking [8], or other means have also been suggested.

[1] In some P2P systems a non–negligible percentage of peers were proven to be altruistic. In Gnutella for example, 1% of peers served about 37 % of the total file shared [3].

[2] MojoNation has ceased operations, although information is still online: web.archive.org/web/*/mojonation.net/*.

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The majority of the analysis of such systems [9], however have focus on free riders – actors who take more than their fair share of the benefits or do not shoulder their fair share of the costs of their use of a resource – and how to eradicate them. The danger for a system is that the presence of too many free-riders will reduce or force to zero the number of altruists in the population – thus stopping a system from functioning. In this context, an additional question arises: *can a market-based system for P2P file exchange function at all without the presence of altruistic agents?* and if so *what are the conditions necessary for it to function?* It seems intuitive that the answer to the first question should be *yes* since digital content can arguably been seen as a good like any other. However, as is argued in this paper, there are a number of pitfalls in implementing a functioning market system. In the work described, we study the conditions under which a file exchange market mechanism based on a "virtual currency" such as those tried in Karma and MojoNation can facilitate viable file-exchange. The paper is organized as follows: Section 2 describes the environment, Section 3 characterizes different types of markets, Section 4 are analysis experimental results for different market configurations and finally Section 5 provides conclusions and outlook. A longer version of this paper is available as [10].

2 Token Based Markets for P2P File Sharing Environments

File–sharing applications provide the means for interchanges of content between users. Specifically, users typically have in their possession a certain amount of content but they would like to obtain other files they currently do not possess. Other users, in turn may wish to access the content a user may have. In an ideal world, a user would like to obtain all the content of interest to him/herself without incurring any infrastructure costs (note that in certain systems costs for content itself may apply - these are not considered here). Other members of the community however have a similar aim and given that there are inevitably some infrastructure costs incurred from providing content files to others, such as bandwidth, continual connectivity etc. the question arises as *how should these costs be shared between participants?*

Given the assumption that no agent in the world is willing to altruistically incur costs simply in support of the community, as in human economic systems, a balance therefore needs to be struck between a member of the community providing content and their ability to download access content. A powerful mechanism to achieve this is the use of a concrete means of transferable value which can be earned by providing content and spent by downloading it.

3 Types of Market Scenario

A market provides a mechanism to regulate exchange between members of a community in which each member of the community wishes to maximize its utility [11]. A natural step is to create market places which use a type of artificial currency in order to simulate transferable value between users in a system – and hence facilitate exchange. As is shown in this section however, there are pitfalls to doing this. In particular the types of markets envisaged include: Time limited markets, content limited markets, and time and content unlimited markets. The model for file interchange, described in [10], has three main elements: are content distribution, monetary system, and agent behavior. The most relevant aspects to look on as is that the model are:

- The model is composed by two markets. The inner market model used to study the application and the outer market model which models a real world currency.
- Agents select their strategies (offer/download content) depending on the quantity of tokens that they have/do not have via a set of thresholds.

3.1 Time Limited Markets

In this case, the number of interactions in a given market place is limited (time limited). Concretely, this means that in a time the system will cease functioning (for example if all files are exchanged, a certain deadline passes or after some signal is given). In a time unlimited market, members cooperate with the objective of getting a benefit in a long term future.[3] However, when the time is limited, the hope of a future benefit is not apparent because members know that in a concrete time the game will finish.

To understand the effect of this fact given that players know that a game has exactly n rounds. Then, no matter which round has been reached (say $n-1$) the agent is aware that the currency used in the inner market will no longer be useful after the end of the game. Hence no agent will offer content in the last round (round n). Subsequently this also means that the currency is no use not only after the end of the game but also not in the last round. Similarly no agent will offer content in round n-1 and so forth. By repeating this argument many times, rational agents would deduce that they should not offer content at all. In a simulation where an agent can chose between two strategies, the only difference between the two strategies (s_1,s_2) and (s_1',s_2) is that in the period t the first strategy chooses C (cooperate – offer content) and the second strategy chooses D (defect – not offer content). Until the end T of all iterations the benefits of choosing the strategy (s_1',s_2) will be greater than (s_1,s_2). This concept is clearly analogous in the well known game theory known as the Prisoner's Dilemma (PD) [12] result for games of known duration.[4] The conflict between the individual and collective interests is expressed in this game, which has implications in real life in areas like the policy, society, economy. Concretely the relation is with a subset of PD, named PD with finite repetitions.

[3] The shadow of the future [12].
[4] PD rules are explained in detail in [13].

3.2 Content Limited Markets

This hypothesis considers that the content is limited even if time were unlimited. In such world the number of total different content items is finite and unchanging. In an ideal world all members in the market should obtain all content items that they want. If agents are aware of this fact, this goal will not be achieved. When an agent obtains all the content that it desires (satisfied agent) it is conscious of the fact that it has all it may want so a rational agent would cease offering content. The reason is similar to that in the previous case: the agent will, in the future, not derive benefit from the inner–market tokens (IMT) obtained. This fact entails that other non-satisfied agents may not obtain all the content they desire if some of it is held by satisfied agents. The tokens have value for an agent if they can be exchanged for something desirable. Once it is known that there is no more new content to obtain, the value of tokens tends to zero. In turn, this causes the agent to become resistant to offering content before all possible useful exchange have been made. Only altruists would continue once they had obtained everything they needed.

3.3 Time and Content Unlimited Markets

In the previous section it was argued analytically that markets limited in time or/and content function sub–optimally, if at all. In this section, we move on to the case of behavior of the market without these limitations. With respect to the cost of offering a piece of content versus the satisfaction that someone can obtain from obtaining outer–market tokens (OMT), we have the following alternatives:

A. If the cost of offering is less than the benefit obtained: In this case, agents have interest in offering their contents because they can obtain benefit of it in return – a benefit that in the future the agent can re–invest.
B. If the cost of offering is equal to the benefit obtained: In this case, no net benefit is generated through offering content on average.
C. If the cost of offering is greater than the benefit obtained: In this case file exchange generates a net loss for the community over time and most likely for the individual – increasing with the number of transactions carried out.

For the three options above it is probable that A and B could function in some form (although option B only in a very limited manner), while option C appears to be unsustainable in the long run since agents in the system will all incrementally loose satisfaction.

4 Experimental Evaluation

In this section we describe a number of simulations which help to clarify the nature of the dynamics of a token–based P2P market under the scenarios listed in the previous section – Time and content unlimited markets.

Table 1. Initial experiment parameters

Symbol	Meaning	Value
A	n of agents	200
F	n of files	200
C	n of categories	5
CxA	n of categories x agents	2
$Cimt_{f_x}$	Cost per file (IMT)	500
$Bimt_{f_x}$	Benefit per file (IMT)	500
$Comt_{f_x}$	Cost per file (OMT)	Minimum $Bomt_{f_x}$
$Bomt_{f_x}$	Benefit per file (OMT)	Greater than $Comt_{f_x}$

Agents in the system[5] do not act altruistically[6] and this is concretely interpreted as a fixed rule: agents only offer content to generate IMT up to a set limit (threshold) which is *the level the agent expects to be able to usefully spend on new content*. Further, since an agent cannot buy content if it has less IMT. By means of these thresholds, the period where agents offer content is constrained by need. When an agent has more tokens than supply threshold, none of its content will be offered, although the agent wishes to purchase some content from the market. If an agent has less tokens than the demand threshold and wishes to purchase content in the market, it will automatically begin to offer content.

4.1 Experimental Results

In this section we analyze the results of experiments simulating options 2 and 4 above. Different cases considered for option 2 are:

Simulation 1: At this case agents have a quantity of 2900 IMT, near to threshold related with the supply.
Simulation 2: At this case 2000 IMT per agent.
Simulation 3: At this case 600 IMT per agent, near to the demand threshold related with the demand.

In option 4, three cases are considered:

Simulation 4: Half of the members 600 IMT and the other half 2000 IMT.
Simulation 5: Half of the members 200 IMT and the other half 2000 IMT.
Simulation 6: Half of the members 200 IMT and the other half 6000 IMT.

Figures 1 a) and 1 b) show the cumulative density function of the different scenarios proposed above, in terms of quantity of files exchanged in the system and times that agents did not have enough tokens to buy contents when they would

[5] Table 1 describes the system settings.
[6] However when the system starts to work in the initial state some agents are randomly selected and forced to offer their contents. Without this jump start, no agents would offer content initially.

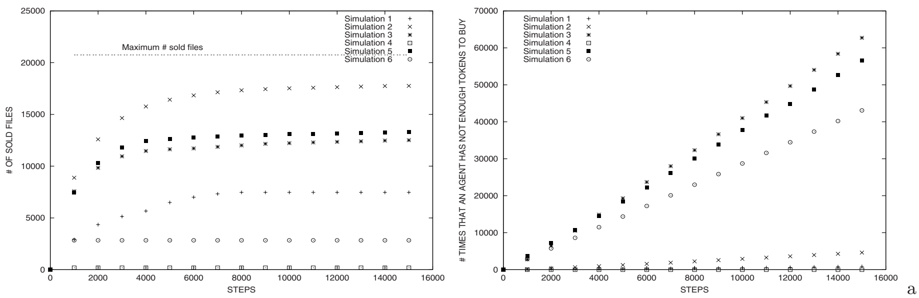

Fig. 1. a) Experiment showing the number of sold files x simulation b) Experiment showing the number of times that agents in the system did not have enough tokens

have liked to (indicating inefficiency of the market as an exchange mechanism) respectively. The first figure shows the relationship between quantity of tokens and number of files on sale. The second figure relates the threshold and quantity of times an agent in the system does not have enough IMT to buy content. Both figures show the importance of the amount of tokens that the agents in the system runs.

4.2 Evaluation Results and Discussion

The simulations show the following results:

– The first observation is that at the beginning all simulations show a significant increase of activity due to different facts: initially, agents have enough money to buy at least one file; also we may think about many agents having an interest in the content offered by the rest of members.
– Simulations 1, 2 and 3 reveal that the quantity of tokens in the system modifies the behavior of the market, in terms of global number of files exchanged (at satisfaction level). Reviewing values shown in figures 1 a) and 1 b), in a first glance it is shown that in simulations 2, 6 and specially 3, in many cases agents want to buy content but they do not have enough tokens to buy anything, showing that it is not a optimum market. Reviewing in detail different steps in the simulation 3, it can be seen that the distribution of tokens is not appropriate to the right working of the system: Some agents pass boundary of supply, so they can't offer anything; and other agents do not have enough tokens to buy content. This creates a deadlock in which potential sellers of this desired content in turn cannot obtain funds to buy the content they desire – a clear liquidity problem.
– Simulation 4 shows that selfish agents can actually prevent the system from working correctly. This occurs because; if an agent have more tokens than threshold supply they will not offer their content. And, in this case, the remaining agents have a number of tokens near to the threshold supply. Hence once a few files have been purchased, they also pass this quantity and

cease offering files. This confirms the stability of market fails in the case of token oversupply.

– In simulation 5, agents that have fewer tokens than the purchasing threshold can trade to move above the threshold. Limited trade becomes stable in token undersupply situations.
– In simulation 6, agents that have more tokens than the threshold supply can trade with agents that have fewer tokens. A transferring of tokens is generated from agents that have tokens to agents who do not have tokens.

Throughout this paper we have discussed which market conditions which are/are not viable for P2P file sharing systems. While the restrictions discussed in this paper do not apply to all P2P systems they may certainly arise in systems. Examples could include: 1) limited content a system of interchange of contents could exist specialized. In particular file categories, 2) limited time markets in special short–term corporate promotions (where tokens loose validity after a certain date) or 3) in time/content unlimited scenarios where the balance between cost and benefit is very narrow. The analysis and experiments show that:

– Markets finite in time or content are likely to fail (either because agents can reason about the eventual collapse of the token currency, or because content is withdraw from sharing to early once some agents gather all the files they are interested in).
– That even in markets with infinite time and content, where token based economies can function, barriers still exist to fluid interchange even if the cost/benefit of trading files is above zero.
– Money supply issues in infinite time and content markets play a large role in success/failure (as implicitly does new content supply). This mirrors real world inflation/deflation/money supply issues in a simple way which is unsurprising. However, in such limited environments, effects are more dramatic and further the existence of upper and lower bounds suggest that optimal values may exist which would need to change over time with the amount of users and content.

The first result suggests that artificial currencies would not be a good solution for time/content limited scenarios and in these cases, despite the added cost/complexity, real currency approaches may need to be used. The second two statements suggests that even in cases where virtual currency approaches could be applied, careful management of the currency in question needs to be carried out – most likely regulating the money supply over time to ensure efficient functioning.

5 Conclusion and Outlook

The results presented here provide a rough classification of types of token-based markets. In order to understand these phenomena in detail however, more work is needed in particular to: establish the range of conditions under which such a phenomena arise, analyze the detailed dynamics of those cases under which the system works. The overall aim of further work would be to explore money supply and market policy issues in order to manage the economy of the inner market to keep it in the identified functional zone. Each of the model changes considered above would likely change the visible market dynamics but the underlying results of a relatively narrow set of market conditions being viable seems likely to be stable.

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