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Analyzing the Influence of Free-Riding Behaviour and Approaches to Overcoming it in Peer-to-peer System

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Abstract

Peer-to-peer systems are alternative systems to traditional client-server systems, which is becoming popular nowadays. However, as the system is dependent on each individual user contribution, the P2P system is facing problems due to users that consume more than they contribute to the system; so called free- riders. This paper offers solutions with the free-riding behavior of users introducing various mechanisms which would force users to actively participate in contribution to the system.

Keywords: Performance, Reliability, Free Riders, Peer to Peer System

I. INTRODUCTION

A P2P system is a resource sharing network environment that does not depend on centralized authority which give users more freedom than in client-server system [1]. A typical P2P system is formed from nodes where each of them is owned and operated by an independent user, making the system self- organizing and self-maintaining [2]. Users of P2P networks are called peers.

Lack of central authority in the peer-to-peer network makes it more powerful than the traditional system, having no concern with load balancing and scalability. Enabling zero cost identity and file sharing to be free of charge, peer to peer systems are getting more popularity. However, on the other hand, provision of such broad freedom and not obligating users to benefit back to the system deteriorates the performance of the system. Users who do not contribute to the system and do not share their resources are called free-riders [1]-[11]. According to Gnutella file sharing network, in 2000, 70 percent of peers shared no resources and top 1 percent contributed 37 percent of overall shared resources. In the same network, the number of free riders in 2005 increased to 85 percent.

The problem of free-riders in P2P systems remains a big obstacle in the way of development stable peer-to-peer system with high performance and a great degree of scalability. Although, it is difficult to counteract the free-riding behavior without the use of effective mechanisms. Therefore, several approaches were developed as feasible options to solve the free- riding problem. By solving free-riding problem, one usually means identifying free rider and then apply some penalties to him, or restrict the free rider from using the service according to his behavior/history. The solutions can be categorized as monetary, reciprocity and reputation based schemes.

In this paper a simulation on the effects of free-riding behavior on the overall system performance is provided. Also, the general points on the reasons of free-riding behavior will be determined. Finally, the most effective ways for countering free-riding behavior will be reviewed and analyzed. Some improvements in overcoming free-riding behavior will be suggested.

II. PEER-TO-PEER NETWORK

To justify the hypothesis claiming that growing number of free-riders deteriorates the system's performance, a simulation illustrating the working process of an ordinary P2P system is conducted on "ns-2".

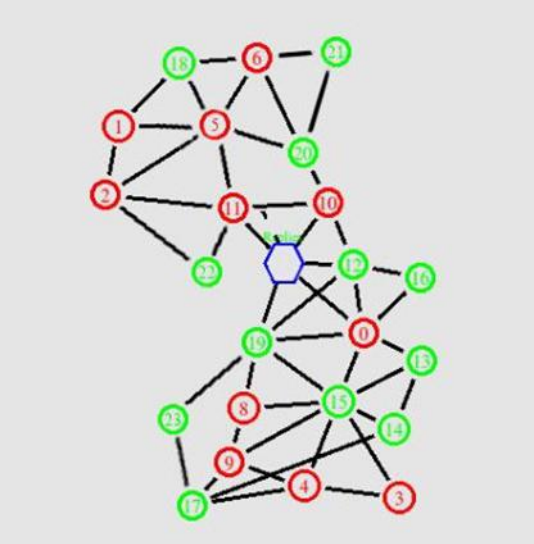

Figure 1. Topology of P2P network

As it can be seen in the figure 1, there is a blue hexagon central node which stands for the server node. Apart from the server node, there are 23 other nodes which belong to users or peers who transfer a sample file of a constant size. In a modeled topology only 12 peers which are highlighted in green on a topology map are actively sharing their resources with others. Other 11 are free-riding in the system, downloading a file, however sharing no resources with the other peers. Here the one thing which should be determined is the time needed to distribute the sample file between all 23 nodes. The time to distribute will change depending on the number of actively uploading peers.

The size of the File taken for simulation is $F = 20Mb$, the uploading rate of the server is $u_s = 10Mbps$. The uploading and downloading rates of the peers are $u_i = 1Mbps$ and $d_i = 2Mbps$ respectively. The results of the simulation on "ns-2" were plotted in Figure 2.

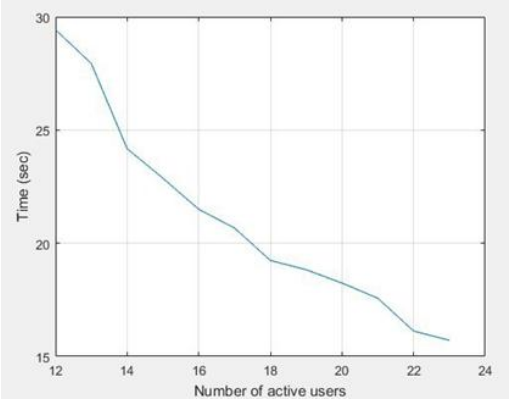

Figure 2. File distribution Time dependence on the Number of actively uploading peers

From Figure 2, it can be seen that the higher the actively uploading peers number, the lower the time needed to send the file. To check the results of the simulation for relevance, another figure was plotted using the equation 1 where N and D_{P2P} are the number of peers and the time needed to distribute the sample file respectively.

$$D_{P2P} \geq \max \left\{ \frac{F}{u_s}; \frac{F}{d_{min}}; \frac{NF}{\sum_{i=1}^{N} u_i} \right\} \qquad (1)$$

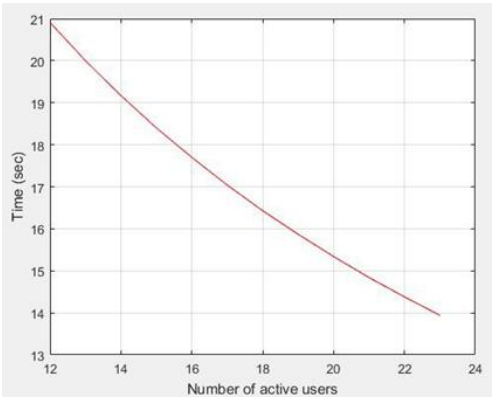

Figure 3. File distribution Time versus Number of actively uploading peers calculated using equation 1

Both Figure 2 and Figure 3 show that the time needed to distribute the file is higher for lower number of actively uploading peers. It can be concluded that the lower number of peers uploading the files deteriorate the performance of the whole server.

III. COUNTERING FREE-RIDING BEHAVIOUR

As it was already discussed, the greater the number of free- riders in a network, the worse the overall performance and an individual performance for each node are. Therefore many approaches were provided to combat the free-riding behavior. All the existed approaches can fall in one of the following categories.

A. Monetary Based Approach

Monetary-based approach proposes a micropayments-based system, in which every peer pays for the services they receive. Since the payment for this kind of electronic services is very small, the system should be able to provide infinitely small transactions in a very short amount of time. Therefore, the incorporated security system should also be lightweight and not increase the transaction time and infrastructure complexity. P2P network can have either online and offline payment methods. In the first scenario when a peer receives services, at the same time the transaction starts to proceed. On the other hand, P2P network can execute a payment sometime after the service was received; this removes the responsibilities from the central authority to be permanently online to provide the payments. However, the latter payment mothed may require users to use the permanent method of identification. P2P network developers may choose the offline payments from a practical point of view, since this payment mechanism involves lower computational and communication power and lower latency. Monetary–based approaches however, have some implementational limitation due to which it is still not a trivial task to implement this system into the real P2P systems [2].

1) ***Centralization and Communication Overhead*****:** To implement such a complex system, one should propose some centralized authority which will be able to store information about balance and monitor each peer's balance. At the same time, one central node will cause single-point-of-failure problem and decrease scalability. Moreover, managing transactions, applying additional infrastructure and disseminating virtual currency will increase the overload and communication overhead in a given network [3].

2) ***Persistence Identifiers:*** To manage the transactions and store information about balance and other personal information, the system should use persistent user identifiers. How- ever, implementing persistence identifiers in the P2P system may become a great problem, because of peers' anonymity and wide dispersion in most decentralized P2P networks.

3) ***Mental Transaction Code:*** Users might confuse while deciding whether a few cents that service provider asks for the service is an adequate price to pay. Therefore, the

monetary-based solution implemented through the micropayments system involves users' mental effort for low pricings for resources.

4) Payment Delivery: In order to successfully implement the monetary-scheme, one should propose a stable and self- scalable architecture for micropayments. In [10], the authors suggested using tokens which are uploaded into the data packets and later redeemed by the forwarding nodes, according to the previous nodes' reports in the system. However, this scheme, in the same manner, deals with central authority node which should make a payment to the nodes based on the value of redeemed tokens. The problems which the centralized node may bring to the P2P system are discussed in the first paragraph.

B. Reciprocity Based Schemes

Another problem among large user population is due to a rare interaction between two agents, since it takes sufficient time to build informative interaction histories among users. Therefore, it may require too long to identify and being served by an agent. In order to overcome this problem, many researchers recommend using reputation mechanism. This mechanism helps to recognize obedients, meaning there is no need in direct multiple interactions with users. In addition, it can also be used to identify free-riders according to information possessed by other users who benefit them.

In this framework, when one user m is seeking for help another user o, m asks other users C who were cooperated with the user o. By demand, C users transmit the report to the user m on their history of interaction with the user o. According to this report, user m will estimate the probability of help-offering behavior. The probability can be computed as follows [2]:

$$P_{ro}^{T}(x) = (1-\alpha)P_{r_{m,o}}^{T}(x) + \alpha\frac{\sum_{a\in A-\{m,o\}}P_{r_{a,o}}^{T}(x)}{|A|-2} \qquad (2)$$

Where $P_{ro}^{T}(x)$ is the opinion of a about the behavior of o. All these opinions averaged, but the ones which are interacting will not be involved. Also, is the weight on other's information which can be calculated [2] in terms of the demand of m for o to assistance:

$$\alpha = \frac{1}{1+no.\,of\ times\ m\ asked\ help\ from\ o} \qquad (3)$$

Thus, this strategy is useful for sharing own interaction history with other agents. In this scheme, equation 2 holds the change between using local data and other's view. On the other hand, equation 3 indicates that a user will rely more on its past interaction behavior.

According to reciprocity based schemes, clients and servers keep information about the prior behavior of other agents to decide whether to serve or being served by those agents. Many studies were done on this type of mechanism and have divided this into two categories: direct reciprocity and indirect reciprocity [2]. Direct reciprocity scheme is suitable for the agents in which their interaction lasts long, while indirect reciprocity scheme is based on the reputation scores. However, there still problems with an existence of free-riders which look like legitimate users. This happens due to the assumption of these reciprocity-based schemes which trust in reputation reports of users. Free-riders destroy this mechanism by the formation of groups which have an agreement with each other to report good information for each colluding user for third parties. Thus, they can benefit from other agents.

Possible solutions: In order to solve the free-riding problems, [2] recommends using a trust-aware adaptive P2P over- lay topology. This topology is based on the super peer- partition, which restricts peers from picking the peer as its neighbor randomly. It means that the peer will choose the neighbor according to its trust value and position.

C. Reputation Based Approach

The reputation-based approach uses reputation information of each peer in order to create and maintain high-quality p2p connections. The main goal of the approach is to provide the users with a relatively high reputation with a better downstream rate. The main information about the reputation of certain peers can be extracted from the feedback of p2p connection users, who interacted with the peer during connection. The main difference between reputation based and reciprocity based approach is the peer's reputation that constructed based on the long-term behavior, so that there is a storage that contains the long-term downstream/upstream history of each peer. Therefore, it is important to construct good upstream history from the beginning because of the difficulty of restoring from low-quality upstream history [8].

Two types of the reputation-based approach can be implemented: Autonomous reputation and global reputation based approach. First, autonomous reputation approach uses the feedback about the peer from the users, who interacted with. The extracted information is not transferred to global database. Therefore the absence of centralized storage, that maintains the integrity of the global reputation, makes the approach easy to implement.

On the other hand, global-reputation approach accumulates the feedback obtained from all peers. The collected data about the peer's reputation can be stored on global servers of the P2P hostages or on a set of peers' network. There are different types of the determination and

accessing the reputation of peers from the global servers. The one method of the accessing the peer history is the combining the reputation into P2P protocol messages – gossip mechanism. So, on receiving the protocol, the user can use the given gossip to create certain combined reputation about the given user. On the other hand, the explicit mechanism allows the users to get the reputations of the certain peer from the storage via P2P protocol [8].

The global reputation approach provides high speed and accuracy in free riders identification, especially in the case of large size P2P network with many active peers in the system. There is a low possibility of direct connection with the same peer with bad reputation because of fast learning rate obtained by global reputation approach. Additionally, the given approach provides the long-term and more reliable reputation information related to peers.

However, the reputation-based approach has several limitations. First, the reliability of the reputation depends on other peer honesty and objectivity. Cheating can lead other peers to misreport and not fair high/low downstream. Second, the networks, that use global reputation approach, should use the centralized authority that stores the monitors the peers' reputations. The fact that the complexity of implementing it in pure P2P networks can lead to the system's low performance. Finally, the complexity of reputation-based approach used in anonymous systems [8].

IV. Further Improvements and Suggestions

Despite developed solutions by researchers, there are still problems that decrease the P2P network's performance. The most common issue for P2P hosts is the collaborative attacks and cheating. The group of peers that promotes free rider peers or affects users with a good contribution. Additionally, peers try to modify the transaction reputation by hacking P2P protocols. For the case of cheating and attack, the vouting schemes can be used. These schemes collect protocol messages from peers and show groups that potentially cheat or uses distributed cryptographic infrastructure [8].

Another issue that usually P2P networks face is relevant fake content. Sometimes, the free riders can upload fake content with popular at that time titles in order to make other peers download it. It leads to the free rider's upstream history. The solution for this case is the P2P clients that use the interaction between the peers to check the quality of the content delivered by the upstreamers.

The most important part of the solving the free riding problem is the security of the solutions. The fact that, the P2P network is decentralized and self-organized, the security implementation is a difficult task. Therefore, different methods are involved to create a safe infrastructure of the network, such as authentication keys, integrity checking. Such methods are used in following suggested approach.

Balanced Based Approach

Here one wants to suggest a new approach to combat the free-riders in P2P systems. In an ideal case, a peer always maintains the balance between downstream and upstream rates. Hence, shares the equal amount resources he uses. This model might be achieved artificially using the number of rules to keep shared and used resources balanced.

For instance, the one can download a file and the system gives to one a time to fulfill the gap in shared/used resources i.e. distributing files within the network. Otherwise, he will be disconnected from the network. Some questions appear while figuring this approach.

1) *Presence of the Central Authority*: The system should watch and keep every peer's information about the current balance of shared/used resources. However, in this case, the Single Point of Failure appears, since the system will not be able to work properly if the node which contains balance information will fail.

Therefore, the balance information can be distributed in the peer's host machines. When a peer wants to download the file it asks other peers about the current balance information. And when the peer wants to contribute to the system the new value of a balance is saved on every peer's host machine. However, a new problem then arises when using distributed balance data.

Balance of Information Security: To keep the information about the balances secure it can be encrypted using the secure data exchange protocols such as MTProto and others, where encryption keys are only present on the destination host [9]. Finally, the balance based approach might be a good alternative to the existing free-riding overcoming approaches. However, implementation of this method might cost a vast amount of human and hardware resources.

V. CONCLUSIONS

To conclude, free-riders in P2P systems appear as a vast problem. When user does not cooperate, the overall performance decreases dramatically and the system concept becomes inefficient. Simulation on calculating of distribution time was conducted and the results have

proved the hypothesis. In addition, the presented possible solutions to decrease the number of free-riders by analyzing the articles on this topic. One of the solutions was monetary payment schemes. It allows the system to get deserved benefit for the provided resources independently from the users' altruism or free-riding behavior. However, the implementation of monetary payments may not be a trivial task in reality of the P2P system. Since it implies reorganization of whole the infrastructure and network and making the centralized node to provide and control the payments flow. Another solution was to build the networking system based on reciprocity schemes. By this way, a peer chooses to cooperate with another user according to his past serves provided to him or to other peers, which could be seen from his reputation scores.

Nevertheless, in addition to all cases discussed earlier in this paper, there is a possibility for the existence of the dynamic agent behavior in which obedient user may become a free-rider after some time or conversely. This is for future to evaluate such behaviors, since it is also important to predict actions of users. Such problems are the figure for further improvements which were discussed in this paper. Also, a new approach for overcoming the free-riding was introduced and analyzed for the perspectives of its implementation.

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