# Practical Implementation of a Virtual Currency Based Incentive Mechanism in a Direct Connect Peer-to-Peer System

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***Abstract*—Peer-to-peer file sharing communities form dynamic vaults of information and ideas that single users are not capable of aggregating on their own. Users willingly join and willingly share their resources on peer-to-peer networks. These types of networks are very prone to free riding, unless share limit restrictions are imposed. The free riding problem on peer-to-peer networks and corresponding incentive mechanisms has been addressed in the literature in detailed mathematical models, business models, design objectives and case studies for various types of peer-to-peer networks. Direct Connect networks are very popular among relatively small file sharing communities of up to a few thousand users in size, due to their simplicity and ease of use. Direct Connect does not natively support any elaborate contribution incentive mechanisms. In this paper, we present a practical method to control free riding in Direct Connect networks by means of a virtual currency and provide feedback on the utility and effectiveness of our implementation.[1]**

***Index Terms*—P2P Optimization, Direct Connect, DC++, Incentive Mechanism, Virtual Currency**

## I. Introduction

Peer to peer file sharing networks allow a community of users to locate and exchange files among each other. Users cooperating in a large file sharing community collectively own a much larger set of information than a single user could practically store. The dynamic flow of information within communities with a large amount of actively contributing users reaches a level of synergy that individual users are not capable of achieving themselves.

The success of a file sharing community is largely dependent on each user's willingness to contribute resources to the peer-to-peer network. Normally, users need an incentive to make contributions, as the resources that can be consumed on such networks are generally shared with the entire peer-to-peer community and are thus freely available. An ideal incentive mechanism would strike a delicate balance between forcing users to contribute and allowing users to free ride the system. An ideal incentive strategy would steer the community towards success in terms of original contributions, community size, number of actively contributing users, volume of data exchanging hands and, ultimately, end user satisfaction.

[1]This work was completed at the Telkom-Grintek Centre of Excellence at the NWU.

## II. Background

### A. Online cooperation

Users connecting to peer-to-peer networks have a primary interest to consume resources. If all the users on a peer-to-peer network only intended to consume resources, however, no resources would be available for consumption if nobody contributed anything.

Kollock describes the economics of online cooperation in terms of public goods and gifts [1]. Information transferred between individuals in cyberspace has the property of a gift. The unspoken obligation of giving a gift in return is not necessarily answered by the receiver of the gift, but by anyone in the community. This way, everyone's contributions to the community eventually involve every community member in the process of giving and receiving. Reciprocation of gifts by community members to the community in general instead of individual users is known as generalized exchange. A rough balance of giving and receiving is achieved over time.

The relatively anonymous nature of peer-to-peer file sharing systems and the zero cost of obtaining an identity in most of these systems allows users to escape the consequences of not reciprocating gifts by simply free riding the system. Therefore, a mechanism designed to appeal to the selfishness of users can increase participation and levels of collaboration.

When designing a peer-to-peer system, one has the luxury to incorporate an incentive mechanism into the design to adjust the bias between individual and collective rationality. Most of the mechanisms proposed in the literature involves a credit and debit system involving histories of the actions of users [2], [3], [4], [5]. The service quality a user experiences can be adjusted according to this built-up online reputation by improving service times of sharing users compared to that of free riders [6], [7].

Cooperation incentives not only include reciprocity-based schemes, since a small subset of users gain the feeling of utility simply by sharing their resources with a peer-to-peer community. These seemingly selfless acts of generosity positively influence the self-image of these users, motivating them to make contributions.

Another method to ensure participation is with monetary payment schemes [8], where accounting infrastructure tracks micropayments for each file transfer transaction. [9]

An incentive mechanism does not necessarily need to be comprehensive in order to be effective. In [10], Antoniadis discusses economic concepts and models that are applied to peer-to-peer incentive schemes using complete and incomplete information of the individual peers. It is shown that in large peer-to-peer networks, the incomplete incentive schemes converge to a fixed proportion of the efficiency of the complete information schemes.

### *B. Peer-to-peer networks*

Peer-to-peer networks have evolved over time in distinct generations. The first generation of peer-to-peer networks consisted of clients connecting to a specified server, which coordinates searching and initiates file sharing between clients. [11] The central server of first generation networks makes searching these networks fast and efficient. Direct Connect [12] is a first generation peer-to-peer system that supports hash-based searching and multi-source downloads. Its functionality and ease of use makes it a widely deployed technology today in relatively small file sharing communities.

Addressing the single point of failure in first generation hybrid peer-to-peer networks, the second generation strives to decentralize the network by disposing of the central server and building a network of peers that rely on each other to forward searches and connect users. The FastTrack [13] and Gnutella [14] protocols are popular second generation examples.

Third generation peer-to-peer networks have anonymity features built in, by routing traffic through other users' clients based on a Friend-to-Friend topology. Encryption is used to prevent interpretation of traffic by sniffing. [15] Examples of third generation networks are GNUnet [16] and Freenet [17].

Direct Connect, being server based, is an example of a first generation network. It combines fast and efficient searching with multi source downloading. Files are located and verified using the Tiger Tree Hash (TTH) algorithm. Direct Connect also natively supports private and public messaging features.

The central hub server in a Direct Connect network relays chat messages and search and connection requests in the network. The hub also maintains a list of online users and information on their share sizes, open download slots, client versions, connection types, as well as descriptive fields users can enter arbitrary data into.

The primary weakness of a Direct Connect network is its single point of failure at the central server. The load on the central server scales quadratically with online users, placing a practical upper bound on the network's size. [18] Furthermore, Direct Connect networks are not private and censorship resistant.

From a file sharing perspective alone, Direct Connect is a suboptimal network type. Its native chat room features, however, distinguishes it as a popular choice among virtual file sharing communities.

We choose Direct Connect for its ease of use, its easy and efficient sharing and searching and the wide selection of intuitive client programs available for Linux, Windows and Mac. The server based architecture provides some control over the network and therefore simplifies the implementation of an incentive mechanism. The integrated chat facility provides a natural way to integrate the visible part of DC Dollars into the system.

## III. Design and Implementation

We focus our efforts of implementing an incentive mechanism strictly on Direct Connect (DC++) peer-to-peer networks. Practical use of this type of first generation peer-to-peer network is very relevant in the South African context. Despite the scalability limitations of the Neo Modus Direct Connect (NMDC) protocol, the technology is still very popular among private and relatively small virtual communities with a file sharing dimension in their scope of existence.

Previous work done on peer-to-peer incentive mechanisms mostly uses a game theoretic approach to achieve a global balance of giving and receiving in a peer-to-peer network. The inherent limitations of the Direct Connect protocol makes it difficult to practically implement such fine-grained tracking mechanisms in DC++ networks.

The only contribution stimulation mechanism native to Direct Connect systems is the ability to enforce a minimum share limit. This restrictive strategy excludes non-contributing newcomers with the potential to actively participate at a later stage from the community, and is therefore inappropriate for our purpose. The question however remains open to find a more natural way to motivate users to willingly contribute resources to Direct Connect peer-to-peer systems.

Accurately quantifying an individual user's contribution as a whole to a Direct Connect network is a difficult problem. The NMDC protocol does not report client bandwidth usage. Traffic volumes cannot be estimated from connection requests, as all data transfers are strictly peer-to-peer, of which varying amounts are transferred in chunks from multiple sources simultaneously.

The only feasible method to determine contributions to the peer-to-peer network is to measure individual share sizes over time. Although it is impractical to capture the essence and measure the relevance of the information shared, community perceptions directly correlate share size to contribution. We exploit this perception to base our incentive mechanism on.

We implemented a virtual currency named DC Dollars and introduced it to our Direct Connect network. The basic connectivity and communication service is provided for free. Using the value-adding search function of the Direct Connect client costs users DC Dollars, while sharing information on the peer-to-peer network earns users DC Dollars.

In order to pursue our goal of naturally stimulating contributions, we design the DC Dollar allocation algorithm to fit the share volume profile we intend to stimulate. Small sharers should be rewarded with a functional service experience, while not excessively rewarding larger contributors in a linear proportion to the earnings of smaller contributors. This way, we provide a strong incentive for free riders to contribute, while not lowering the value of the currency by providing more resourceful users, who contribute orders of magnitude more resources to the network, with vast amounts of DC Dollars.

The cost of a search can be fixed and the allocation function be scaled accordingly, giving us the opportunity to choose the smallest monetary value bearing a positive neuro-linguistic power. Following the rules of bargain advertising, we define the cost of a search at 0.09 DC Dollars. According to our design goals stated earlier, we choose the DC Dollar allocation function to have an inverse exponential nature, approximated by chosen target points listed in Table I.

TABLE I
DC DOLLAR PROFIT PER DAY PER BYTES SHARED

| GB Shared | DC Dollar Profit per Day |
|---|---|
| 0 | 0 |
| 10GB | 3 |
| 100GB | 5 |
| 1000GB | 10 |

A statistical regression through the target points yield the DC Dollar equation, shown in Equation 1. We introduce an additional $Slots$ parameter, allocating only a fraction of the DC Dollar earnings to users with less than 20 download slots available.

$$DeltaDCD = (1.018E-7) \times (BytesShared)^{0.255} \times DeltaT \times \frac{Slots}{20},\ 0 \leq Slots \leq 20 \quad (1)$$

Graphically, the DC Dollar earnings equation is represented in Figure 1.

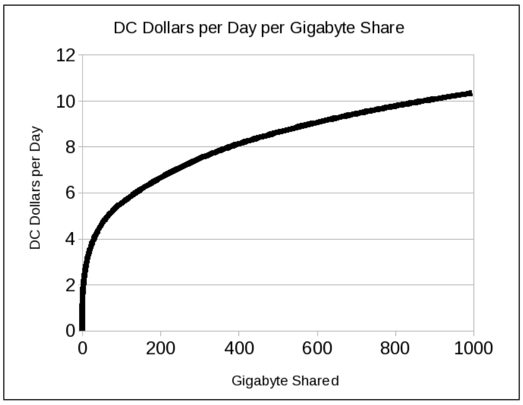


Fig. 1. DC Dollars per Day per Bytes Shared

Direct Connect clients periodically transmit `$MyINFO` messages, containing client status information on share size, open slots, client version, and the like. We calculate a user's DC Dollar earnings at the Direct Connect hub from the time lapse between status messages and the previous share size and open slots. Lapse counters are reset when a user logs in and the calculation is also done when a user logs out, for accuracy and completeness.

## IV. RESULTS

In this section, we present statistics from the Direct Connect network our incentive mechanism was implemented on. Results on searching, sharing, and online users are presented.

### A. Searching and DC Dollars

Our incentive mechanism trades off searching functionality against resource contribution. Searching for files on the Direct Connect network costs 0.09 DC Dollars per search, while DC Dollars are earned by sharing data on the network. Users with insufficient DC Dollar funds have to wait an arbitrary time between searches, which we chose to be 60 seconds.

The search statistics are presented in Figure 2. The allowed searches are searches that have been successfully completed by users with sufficient DC Dollars, or users who have waited longer than 60 seconds between searches. Unsuccessful search attempts by users with insufficient DC Dollars trying to search too frequently are represented by the blocked searches line.

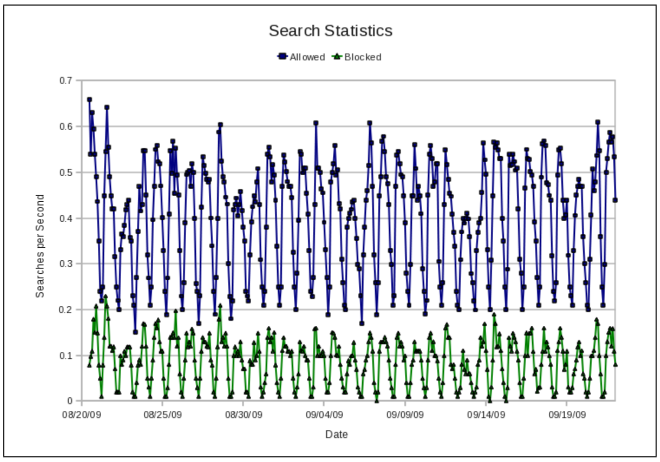


Fig. 2. Search Statistics

The graph plots search statistics for a month, in which the day-night effect as well as the weekend effect is clearly visible.

Although statistically only one in every four searches were blocked, the initial social impact of the incentive system was of notable magnitude. The majority of the free riders on the network expressed dissatisfaction having to wait between searches. After about a week, users started to accept the system and understand its purpose. The measurable effect of the system is discussed in the next section.

### B. Online Users and Sharing

In this section, data is presented on peer-to-peer network usage. Figure 3 plots the peak total cumulative share size per day, as well as the average share per user that adds up to the grand total. Figure 4 plots the peak online users per day, which correlates with the peak share size in Figure 3.

The geographical reach of the peer-to-peer network covers a university campus and a surrounding wireless community network. The discrepancy in the middle of the graphs shows the effect of the university recess at the end of a semester. It is interesting to note the increase in the average amount of data shared per user during the recess, indicating that the majority of information is stored off-campus on the community network.

Averages of the values plotted in Figures 3 and 4 for one month before and one month after the 20th of August 2009 are shown in Table II.

TABLE II
AVERAGE SHARE AND ONLINE USERS

| | Average Total Share | Average Online Users | Average Share per User |
|---|---|---|---|
| Before | 73.76 TB | 895.03 | 86.44 GB |
| After | 86.00 TB | 854.09 | 103.63 GB |

After the introduction of DC Dollars, the average peak share increased with 16% and the average share per user increased with 20%, while the amount of simultaneously online users decreased with 4.6%.

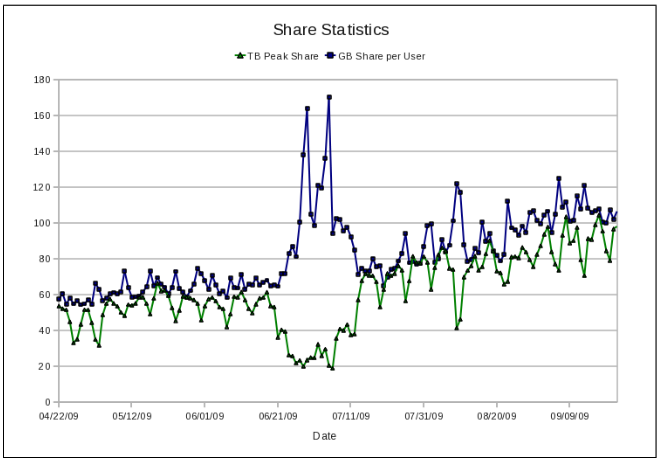


Fig. 3. Peak Share Statistics

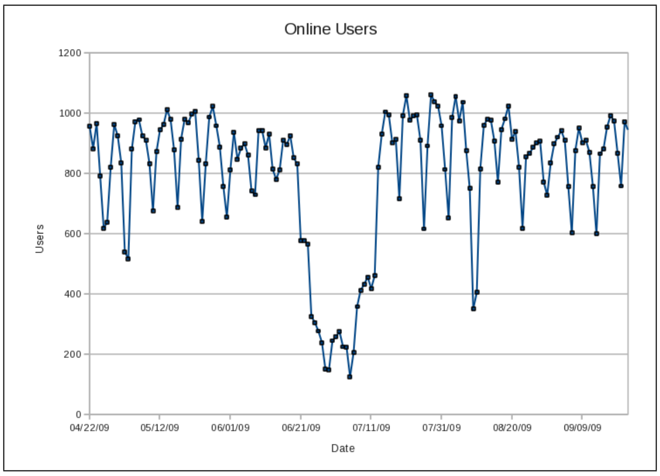


Fig. 4. Peak Users Online

## V. DISCUSSION

Virtual currency based incentive mechanisms deployed with the intent to stimulate participation is not a new concept. Mainly applied to social network like systems with a human involvement factor, its name ranges from *karma points* to *diggs*. Most of the studies on virtual currencies follow a game theoretic approach to mathematically model the behaviour of the humans using the system and simulate its working. In practice, when applied to more advanced peer-to-peer systems than Direct Connect, transferred or stored data is mainly used as a metric to measure the level of participation. Linear relations or threshold triggered mechanisms are the most popular techniques to express participation or allow a user access to resources.

In the particular Direct Connect network we used to evaluate our incentive strategy on, the majority of users are free riding the system. This network does not impose a minimum share limit, as its purpose is to enhance collaboration and pool resources over geographical barriers that would otherwise inhibit the levels of cooperation achieved. The user base chiefly exists of individuals wishing to collaborate, with no particular interest in or knowledge of the underlying technology. The way in which people interact within this private community by means of the Direct Connect infrastructure differentiates its application and use from open Direct Connect hubs on the internet.

The trends observed after the implementation of DC Dollars on our peer-to-peer network confirm that the per capita contribution increased more than that could be attributed to natural factors such as Moore's law. The slight decrease in concurrently online users might be attributed to reduced time spent online by dissatisfied non-contributing users, but is too small to be of significance given the size of the community.

Our design decision to introduce a nonlinear rewarding algorithm proves to be effective by emphasizing DC Dollar allocation to small contributors. The purpose of the incentive mechanism is to motivate zero-contributors to start contributing, therefore identifying and rewarding small contributions is critical. The exponential nature of our algorithm de-emphasizes contributions logarithmically increasing in size, enabling us to linearly relate between a gigabyte-level contributor and, for example, a potential petabyte-level contributor. The key concept is not the absolute numbers, but rather emphasis, relation and balance.

From a security perspective, the system is as secure as the underlying Direct Connect technology. Although the design of the reward system in itself is relatively secure, nothing prevents a free rider with proper knowledge and skills to misreport their share size and gain DC Dollars in the process. This same technique is used to overcome the more simplistic step functions native to Direct Connect systems. Although it is difficult to automate the share fake detection entirely, an automated diagnostic system performing periodic random file downloads can be used to verify that a user contributes real resources to the network, by one-way hashing the file with the Tiger Tree Hash (TTH) algorithm native to Direct Connect and cross-comparing it with other users. The primary goal with the implementation of the DC Dollar is, however, to stimulate participation. It provides a sound opportunity for users who are free riding because they are not familiar with the concepts of contributing to learn and enrich themselves in the process.

Currently, due to technical limitations inherent in Direct Connect networks, the DC Dollar leverages only the roughly-grained perception that share size relates to valuable contribution. Opportunities exist to increase the accuracy of reward allocations by individually incorporating factors such as randomly verified share integrity and network capacity and conditions measured over time. Such information would enable us to automatically penalize users who contribute false resources and reward users who sacrifice their own network experience by contributing over slow and unreliable networks. Methods to accurately determine network conditions without having access to network management data are open to investigation.

The DC Dollar system was designed on top of Direct Connect infrastructure and is therefore closely integrated with it. It does not have any value of its own in any other incompatible type of peer-to-peer system. This specific implementation of the concept of nonlinear reward allocation in peer-to-peer networks, however, demonstrates its effectiveness. It opens possibilities to engineer new rewarding mechanisms into next generation networks.

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