Motivating Cooperation on Peer to Peer Networks

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Abstract. This paper addresses the problem of free riding on peer-to-peer resource-sharing networks and explores methods for motivating more cooperative user behaviour via an adaptive interface. The paper argues that the free-riding problem is not so much an economic issue as a socio-psychological one due to a paradigm shift the user community is undergoing. Users do not yet understand that they, and all of their peers, are both clients and servers and must therefore be taught new behaviour. Our teaching strategy is based upon operant conditioning and employs the low-involvement processing model used in television advertising. Modeling the user's interests, attitude and relationships with other users enables the interface to adapt to the individual's cooperativeness bias and give feedback in the form of affective images.

1. Introduction

Peer-to-peer (P2P) applications have become popular over the last three years, especially with music-swapping applications like Napster, AudioGalaxy or KaZaA and the related copyright lawsuits. P2P systems consist of networked applications "servents" that act as both *serv*ers (producers) and cli*ents* (consumers) of resources. Shared resources can be files (most often music or video), computation cycles (e.g. the SETI@home project), or human time and effort (e.g. the I-Help system [8]). A servent built on the open-source Gnutella protocol is characterized by a completely decentralized architecture and by the anonymity of its users [17].

A free rider is a user who consumes far more resources than s/he offers. According to the study conducted by Adar and Huberman [1] "almost 70% of Gnutella users share no files, and nearly 50% of all responses are returned by the top 1% of sharing hosts". In the context of file sharing, free-riding is not necessarily harmful [18], provided that the users continue to share the replicated files and that they keep their servents running so that they can provide messaging and routing of queries. Therefore most file-sharing P2P applications use servents that are difficult to shut down, are set to share downloaded files by default and cleverly hide the options to turn these features off. However, free riding is pernicious in a service-sharing network, like the I-Help system [8], where there are costs associated with the resources shared (e.g. time and effort to give help). The few peers who contribute can quickly become saturated with requests, thereby consuming all of their shared resource e.g. bandwidth. In this type of network, Quality of Service (QoS) – the time to find and download a file – degrades as a result of free riding and the system is at risk of collapse.

The free rider in file-sharing P2P applications, like KaZaA, isolated by the asynchronous and anonymous nature of the P2P network, operates under the misconception that s/he is taking resources from some wealthy corporate central server. From the perspective of a single user with a single task, benefiting from a service is simply what a traditional client expects. This user is accustomed to being served and is lagging behind a paradigm shift: s/he is no longer just a client, but in the P2P realm, is a server as well. For the service to persist, everyone needs to make a contribution. The problem that needs to be addressed is creating perception in the user of the P2P network as a community of volunteers.

This paper proposes to cultivate greater user understanding of his/her role in this community. Through the user interface of a P2P file-sharing client, users are exposed to attractive and informative views of their community and are taught cooperative behaviour through affective images. Modelling the user's level of cooperativeness and relationships with other user enables the interface to adapt to individual differences.

COMTELLA (COMmunity GnuTELLA) is a Gnutella-based P2P application, that enables research or study groups of students to share resources, e.g. to exchange both services (e.g. help each other) and files (e.g. research papers, annotations, or stored previous help-sessions). Such an application is needed in an active research group, since maintaining a set of shared bookmarks or links to papers by a dedicated person is difficult and the links get quickly useless since the target-files (papers) get moved, renamed, or impose access control. The members of the group while performing Internet searches to satisfy their own interests can save interesting papers in an efficient and natural manner. The files (mostly PDF and PS) are stored locally at the machines of the members of the group and can be shared with other members using COMTELLA. To be successful, the application requires active involvement of the users. Therefore, it is important to ensure user participation and to encourage the following cooperative behaviours:

- finding, annotating and sharing files; offering services (help)
- staying connected to relay queries and to allow uploads to successfully complete.

The following uncooperative behaviours have to be discouraged:

- sharing very few or no files, not offering any services
- interrupting uploads or services by disconnecting from the network
- searching, receiving services or downloading files and promptly disconnecting.

2. Previous Work

Various approaches have attempted to control free-riding through the imposition of micro-payments [6] or through banning of uncooperative clients. Mojo Nation (www.mojonation.net) [16] attempted to introduce an electronic currency and micro-payments (i.e. payment for each download) to provide economic incentives to sharing. However, this approach failed to stimulate users to contribute, since the extra expenditure of user cognitive resources to decide whether to start a download when s/he has to pay for it acts as a disincentive [19].

"Direct Connect (http://www.neo-modus.com/) … survives because of its strong community. The community makes people feel responsibility for the network and leave the program running to help it. It also helps to keep freeloading down"[5]. The trouble with Direct Connect, however, lies in the exclusivity of its community. It forces users to share a minimum of 3 GB and bans them from the network if they do not comply. This method does not encourage cooperation because clearly banned users are not available to be influenced. Limewire (www.limewire.com) has a user-controlled free-rider policy that quietly denies access to those who do not share the required minimum number of files. While this policy allows altruists to support free-riders and is more inclusive than Direct Connect's approach, it relies on default preference settings that can be changed by the user. However, Limewire does not give any feedback to the user to effect a change in user attitudes or behaviours.

Only one P2P application, Kazaa Lite v.2, has recently attempted to model user participation and to reward it by better QoS. The servent maintains a numeric participation level and adjusts the speed of downloads based on this value. The participation level of a user seems to be a function of the difference of how much (what amount of MB) other people have uploaded from the user and how much the user has downloaded. Therefore, participation level and QoS of users offering many files can deteriorate quickly, if no one happens to download from them at a time when they need a lot of files. This leads to unexplainable for the user fluctuations in the his/her participation level, resulting in frustration and feeling of unfairness [13].

None of the above-mentioned applications employs effective methods to promote cooperative behaviour and inhibit uncooperative behaviour in the users. None have intentionally built a community structure. Successful applications such as Napster and Direct Connect can, however, attribute their success largely to the sense of community that has emerged from the common interests of their users. Napster attracted users with a shared interest in trading music, a popular goal that ensured a critical mass of user participation. Direct Connect attracts an exclusive group of like-minded people (those who enjoy visibility and abhor free-riding) together. Our approach intentionally strives to create and promote a strong sense of community.

Based on our experience with I-Help [8] we found four strategies of motivating users to participate in a community [21].

1. by trying to influence the user's feelings to stimulate altruism in the community,
2. by rewarding the user with visibility / reputation depending on his/her contribution,
3. by allowing the user to develop relationships with other users in the community (one would do a favour to a friend, but not for anonymous people),
4. by providing a tangible incentive for user contribution in terms of better QoS: priority in queues, more bandwidth for download).

It seems that to successfully apply these methods, one needs to know whether the user tends to be selfish or altruistic, whether s/he is socially motivated by status, reputation, or by maintaining a large set of friends, what share his/her areas of interest (since users behave differently in different communities of interest). COMTELLA employs user modeling to capture these features. To our best knowledge, apart from modeling user interests, there have been no approaches to modeling these user characteristics.

3. COMTELLA: an Adaptive P2P Servent

The COMTELLA servent uses an open-source Gnutella v.06 servent that has been extended to perform user modeling, advanced searches, transfers and logging of experimental data. The servent is equipped with a personalized motivational interface.

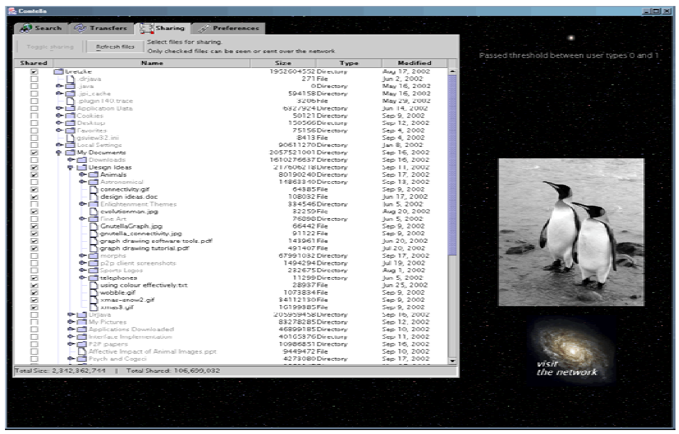

Figure 1: The COMTELLA Interface

The interface (see Figure 1) provides the user with a “Tasks” area consisting of a tabbed set of four panels. The ‘Search’ and ‘Transfers’, and ‘Options’ panels offer functionality similar to that found in the interfaces of all file-sharing servents. The ‘Sharing’ panel is hierarchical file-management tree / table with an extra left-most column containing a checkbox. Shared files are indicated with a tick mark and the file name is displayed in bold. Shared files are displayed in the context of all files and directories to provide users with a clear picture of which files and directories are visible to the network and which are private [7].

To the right of the tasks area is a rectangular frame reserved for displaying motivational images and text. In the lower right of this frame a spiral galaxy icon invites the user to visit the community. The galaxy button toggles between the tasks window and the community view. It is intended to arouse user curiosity and when clicked, reveal views of the system that exceed user expectations [14]. These two views, the community view and the motivational images/text, comprise the persuasive aspects [4] of the interface and adapt to changes in user behaviour. The graphs shown in the community view, the motivational images and text are generated based on the user model. The COMTELLA servent models three types of user characteristics: the user interests, relationships and level of cooperativeness. The next three sections discuss these models in more detail.

3.1. Modeling user interests

The servent models the user's interests through reinforcement learning with evidence coming from the user's queries. To form an ontological model of user interest groups, a 2-level hierarchy of search categories and subcategories was created for the domain of computer science extending the ACM Computing classification system. The user's strength of interest *S* in an area *a* is calculated based on how frequently and how recently the user has searched in this area.

$$S^a(e_t, t) = i * S^a(e_{t-1}, t-1) + (1 - i) * e_t \qquad (1)$$

where the new (at time *t*) evidence of interest $e_t \in [0, 1]$ is calculated as $e_t = 1/d$, and $d = 1 + \textit{the distance}$ between the level of the sub-area of the query and the level of the area *a* in the ontology hierarchy.

The parameter $i \in [0.5, 1]$ is an inflation rate used to model the fact that older experiences become less important over time. It can be fixed at a given value, say 0.5, giving equal weights to old and new evidence or be computed as a function of the time elapsed since the last evidence of interest in this area, which better captures the current tendency in user interests.

3. 2 Modeling user relationships

The agent also models the servent's relationships with each peer with whom it has a history of file sharing or service usage in areas of shared interests. The agent uses reinforcement learning to update the strength of each relationship within a certain context (area of interest) and computes the balance (reciprocity) of relationships over all contexts.

The success of each download or service is used to update the *strength of the relationship* between the users using a reinforcement learning formula similar to (1). Servents searching for files / services offered by the user, who choose to download files or use the services offered by the user, are also added to the list of "relationships" of the user for the particular area of interest. The area of interest is dependent on the query used for the search. Thus relationships are indexed with respect to areas of interest.

Also a *general ranked list of relationships* is maintained. The same two users *X* and *Y* can be involved in different relationships R_{a1}^{XY}, R_{a2}^{XY}, R_{a3}^{XY} in different areas of interest *a1*, *a2*, *a3*. A high *general strength of relationship* $R^{XY} = \Sigma_i (R_{ai}^{XY})$ between *X* and *Y* means an overlap of interests between the users, so they are considered as "friends". The general ranked list contains the relationships in which the user is involved, sorted with respect to "general strength".

In addition to the relationship's strength and context, the servent keeps track of the general *balance (reciprocity)* of each relationship. The servent of user X calculates the balance of its relationship with the servent of user Y as:

$$B^{XY} = (N^{X \leftarrow Y} - N^{Y \leftarrow X}) / (N^{X \leftarrow Y} + N^{Y \leftarrow X}) \qquad (2)$$

i.e. the difference between the number of times when the user X has downloaded files from Y ($N^{X \leftarrow Y}$) and the number of times when user Y has downloaded files from X ($N^{Y \leftarrow X}$). If the balance is negative, the user X "owes" user Y.

The sum of the balances of all relationships of a user defines how much s/he has contributed to the community and how much s/he has consumed. This measure seems similar to the participation level computed by KaZaA Lite v.2. However, keeping a balance of each relationship allows us to maintain a model of the user's contribution to individual users, to every interest group in which s/he participates and to the network as a whole. The servent uses the model of user relationships to create a visualization of the community, as will be explained in the section 4.

3.3. Modeling user cooperativeness level

The user cooperativeness model is based on a three-way classification of user type: *altruistic*, *receptive-giver* and *selfish* [22, 23]. Altruists give because they are good by nature. Receptive-givers will contribute, if they are compensated. Selfish users take but do not give. The user type is initialized as receptive-giver, since it can be assumed that most users are rational and will contribute if the incentive is sufficient.

When the user performs an action that gives evidence of her cooperativeness, the model is updated accordingly. These actions include selecting files for sharing, selecting files for revoking sharing privileges, stopping and/or cancelling uploads, setting the program shutdown options, i.e. whether to terminate all transfers and exit immediately, whether to allow all transfers to complete before exiting, whether to complete downloads only, whether to complete all uploads or only uploads to friends. Cooperativeness is a real number in between –1 and 1 and is updated by a 2-argument function of bias and weight. Bias is a character that can be either '**+**' (altruistic act), '**-**' (selfish act) or '**$**' (evidence that user is a receptive-giver, i.e. this user can be motivated by rewards). The weight parameter is a natural number indicating the weight of the evidence on a scale of 1 to 10. A non-exhaustive list of possible evidences, assigns a value to each of the above listed actions. Intuitively this metric can be thought of as counts of a criminal charge (or conversely counts of generosity). The character '+' indicates that the weight (generosity count) is applied towards altruism, that is, increasing the cooperativeness measure. '-' does the converse. It is not possible just to assign positive and negative numbers to the possible evidences to denote the bias and use a formula similar to (1), since some of the evidence gathered only indicates that the users can be motivated by fair compensation, which has to pull the cooperativeness measure towards 0 (receptive-giver). Of course, there are probably many other possible ways to compute the user cooperativeness.

The user type is calculated as a function of the user's cooperativeness and the overall balance of all of his/her relationships. In this way the model gathers evidence both at runtime and also cumulatively, over the long-term.

$$userType = (cooperativeness + overallBalance) /2 \qquad (3)$$

If *userType* is in [-1, -0.5) then user is Selfish, if it is in [-0.5, 0.5] then user is a Receptive-Giver, and if it is in (0.5, 1] then user is Altruistic.

A larger interval for receptive-givers and smaller, but equal intervals for both extremes are defined since altruists and selfish users are assumed to be more rare. Although empirical studies [1] indicate that most participants on P2P file-sharing networks are selfish, it is more likely that they are receptive-givers who haven't yet learned the rules or simply haven't been offered sufficient incentive to cooperate. Empirical testing will be required to fine-tune the classification for a particular user population.

3.4. Adaptation

Adaptation in COMTELLA has two aspects:

1) rewarding with higher QoS the users who have many strong relationships in a given community of shared area of interests, and
2) selection of appropriate motivational strategies to encourage higher levels of participation.

Since the focus of this paper is on 2), the remainder of this section only briefly sketches the approach for achieving 1). More details are available in [20].

Better QoS i.e. faster finding of higher quality files and services is achieved by:

- Adaptively selecting the servents that form the neighbourhood among those involved in strong positive relationships with the user in the area of search.
- Prioritizing transfers according to the balance of relationship with the user requesting the file.
- Not decrementing the time to live of the 5-6 best friends' queries, which leads to increase in their search horizon.

Since the success of searches and transfers is based on the user's relationships, users who are cooperative and create strong positive relationships, i.e. who contribute a lot of high quality resources that are in demand in their areas of interest will be rewarded with a higher QoS. The remainder of the paper focuses on the second part of the adaptation process - the selection of appropriate motivational strategies to promote higher levels of participation and cooperativeness in the user.

4. Persuasion Strategies for Participation and Cooperativeness

Persuading the user to participate in a P2P environment is similar to teaching him/her to be a good net citizen. Cultivating greater user understanding of his/her role in the sharing community is approached in two ways:

- exposing users to attractive and informative visualizations of their community, and
- using affective images to teach cooperative behaviour.

Modelling of user levels of cooperativeness enables the servent to adapt the interface to the individual user.

4.1. Visualizing the user's belonging to the community

The community is visualized according to an astronomical metaphor using stars and galaxies. It provides both an informative and an aesthetic incentive to pique user interest. Radio buttons offer a choice of three views of the network community, organized by connectivity, rank and interest clusters.

The connectivity view shows the hop-graph of the current network architecture [12]. Each node represents a peer that is currently reachable from the servent. This view targets the user's need for current information [4] by adapting to the changing topology of network.

The rank view allows two types of peer ranking: based on their contribution and ranking of friends based on the strength of the user relationships with them. In both cases the peers are represented as a star with a different size. In the contribution ranking view, a star representing "me" provides a basis for comparison between the contributions of the user and that of other users. In the ranking of friendships view (presented in Figure 2) the most prominent stars are the peers who have been of greatest utility to the user.

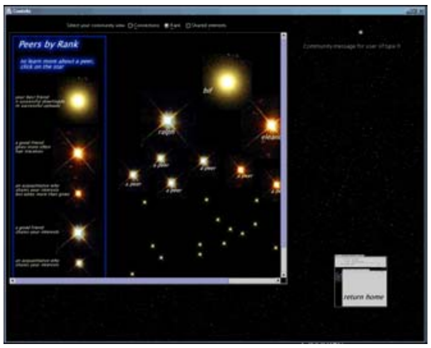

Figure 2: Rank visualization

Figure 3: Interest clusters

The ranking views are targeted at reputation-motivated and socially motivated users: reputation-aware users to gain visibility on the community stage, and socially motivated users to build up and maintain relationships, for example, by not interrupting transfers of friends or by serving help requests.

Figure 3 shows the peers grouped by shared interests. Clusters of peers with strong interest in different areas are represented as galaxies from the Hubble heritage collection [10]. Each cluster represents a single interest category, so peers can appear in more than one context. When the mouse is hovered over a galaxy icon, the full name of the interest category and the number of members is displayed. When clicked on, each galaxy icon explodes to show a detailed cluster of the stars / peers in that group. The visualization of interest clusters targets altruistic users, who tend to be motivated by a common cause. In each of the views, the user can click on a star to access information about the represented peer.

4.2. Teaching cooperative behaviour

Persuasive technologies have the potential to make users aware of cause and effect relationships [4]. Persuasive interface could be harnessed to teach norms for social behaviour in P2P computing. Our interface uses simple operant conditioning, i.e. reinforcing a behaviour that is desirable, whereas punishing a behaviour that is not desirable. The COMTELLA interface displays affective animal images as both positive reinforcement and positive punishment. Desirable level of cooperativeness, or acts showing progress towards such level are rewarded with pleasant images, and undesirable levels of cooperativeness, or uncooperative acts - punished with unpleasant images. Table 1 summarizes the reinforcement and punishment actions. Events at which the user cooperativeness model is updated are ideal for timing the delivery of persuasive messages [4]. These critical points are used to teach desired behaviour.

The interface listens for desired runtime behaviour and gives rewards in either of two situations:

- when the user has accumulated enough " good acts" to cross a type threshold, or
- when the user has committed a single significant act of generosity.

For example, when the user chooses to share twice as many resources as before, this act is heavily weighted and triggers a reinforcement action. If the same number of files was shared gradually, small positive weights would accumulate and when the model crosses the threshold from say, selfish to receptive-giver, the interface executes a reinforcement action. Similarly, the interface listens for undesirable behaviour and gives punishment both when the user type crosses a threshold and when strong evidence of uncooperativeness is exhibited. One such heavily weighted act is the choice to cancel sending a file to a close friend. This action warrants a negative update with a full weight of 10 (see section 3.3), triggering a punishment action from the interface.

Table 1: Positive and negative reinforcement and punishment in COMTELLA.

Reward/Punishment given	**Conditioning action**	**Cognitive level targeted**
Pleasant image	positive reinforcement	low
Improved quality of service	positive reinforcement	high
Unpleasant image	positive punishment	low
Degraded quality of service	negative punishment	high

4.3. Affective Images

Users are conservative with their cognitive resources; it can be assumed that they will ignore system messages in the same way that people claim to ignore television advertising. Since some evidence [3, 15, 24] shows that human behaviour is dependent upon emotion rather than analysis, our method relies on repetition and emotional triggers - techniques that have proven effective in advertising because they target low level attention and long-term memory storage [9]. Animals were chosen as subjects of the affective images because they can express human-like attitudes and emotional states and because interesting images can seduce users into committing to the software [14]. It is also possible that users may find the animal images less intrusive than a human affective agent or animated avatar. While it is not essential to use animals as subjects, it is necessary that the images chosen provoke the desired emotional reaction and are subtle enough that users will not become annoyed. Photographs of real animals were cropped and retouched to subtly integrate them with the interface.

The teaching mechanism in the COMTELLA interface administers a system of rewards and punishments in the form of text/image pairs. The images provide emotional cues, targeting the low-level cognitive processes of the user, while the text targets high-level attention and appeals to the user's rational goal to maximize his or her QoS. The animals are shown morphing between postures that elicit positive or negative emotional responses from human observers. A user study with 74 student subjects helped to classify the set of images according to the immediate emotional response they evoke in the observer (positive or negative). The images are accompanied by text messages that explain the cause and effect relationship between user behaviour and changes in QoS. The text gives the reasons for changes in QoS and suggests what the user can do to improve it (share more files, allow the upload to complete. It is acceptable for users to consciously ignore the text and the affective images [2]. The images will continue to serve as emotional cues, and as in Wilde's *The Picture of Dorian Gray*, prompt users to reflect on their social behaviour.

5. Evaluation

COMTELLA can be run with or without the persuasive interface. When the persuasion is turned off, the interface only shows the tasks panel. The user models are constructed in both modes. COMTELLA will be run in the MADMUC and ARIES labs at the University of Saskatchewan with 24 graduate students for 3 months starting in April 2003; half of the students will use the program with the persuasive elements turned on, while the remaining students will use the non-persuasive version. A central "spy" server is added to the decentralized Gnutella network. This server will be running for the duration of the experiment and will collect statistics from servents about their cooperativeness measures, overall balance of relationships, as well as login/logout times, number of files and disk space shared, number of completed downloads, speed of transfers.

To demonstrate the effectiveness of our approach, COMTELLA's motivational interface will be evaluated to answer the following questions:

- Does average uptime (users leaving their servents running) increase?
- Does membership stabilize at a critical mass with persuasion turned on?
- Does QoS (speed of finding and downloading acquiring files) improve?
- Are users satisfied with the functionality of the system?

The evaluation has to look for changes over time in each user, because of effects resulting from the complexity of the system [11]. For example, altruists may be turned off by the interface, but other users could be stimulated to participate more, thus free riding may remain the same globally, but different users may be involved.

6. Conclusions

Free riding, while perhaps not disastrous in P2P systems for sharing replicable resources (files), is a serious problem for bootstrapping a system especially when there are costs associated with sharing, e.g. in P2P systems for sharing services such as processor cycles or bandwidth. This paper proposes applying user modelling and adaptation techniques in the area of P2P systems and is the first one to suggest modelling the user cooperativeness and relationships with other users. User modelling and operand conditioning is utilized in a system called COMTELLA to help users realize their changing role in the community. It still remains to experimentally evaluate this approach to assess its effectiveness with respect to stimulating participation, improving QoS and ensuring user satisfaction.

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