DELIS

Why does BitTorrent work so well?

Some ideas from evolutionary game theory

Overview

Dynamically Evolving, Large-Scale Information Systems

Information Society Technologies

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Abstract

The BitTorrent (BT) peer-to-peer (P2P) file-sharing system attempts to build robustness to free-riding by implementing a tit-for-tat-like (TFT) strategy within its protocol. It is often believed that this strategy alone is responsible for the the high-levels of cooperation found within the BitTorrent system. However, we highlight some of the weaknesses of the approach and indicate where it would be easy to cheat and free-ride. Given that cheating of this kind currently appears rare, this motivates the question: ***why is the system not dominated by free-riders***?

* the TFT strategy can be bettered by other less cooperative strategies
* Identity can be faked by modifying the client thus circumventing TFT
* Unconditional altruism is required for BT to operate in any case

What is Tit-for-Tat?

Robert Axelrod championed the TFT strategy in his now classic, 1980's book The Evolution of Cooperation (Axelrod 1984). He held computer tournaments in which different researchers' programs repeatedly played a canonical game of cooperation - the Prisoner's Dilemma (see fig.1 below). He found that TFT performed best on average against the other strategies. TFT is relatively simple. It starts by selecting a cooperative move and then for subsequent moves copies its opponent's last move. This strategy is encapsulated in the BT tagline:

"Give and ye shall receive"

How does BitTorrent Work?

In BitTorrent, groups of peers (called swarms) with an interest in downloading a specific file coordinate and cooperate to accelerate the process (Cohen 2003). Tracker nodes store a list of peers in the swarm, thus letting new peers join the swarm. Each peer stores pieces of the file.

Given: $T > R > P > S$ and $2R > T + S$

Player 2 \ Player 1	C	D
C	R, R	T, S
D	S, T	P, P

Fig. 1. The payoff matrix for the Prisoner's Dilemma game. The values T, R, P and S must conform to the constraints shown.

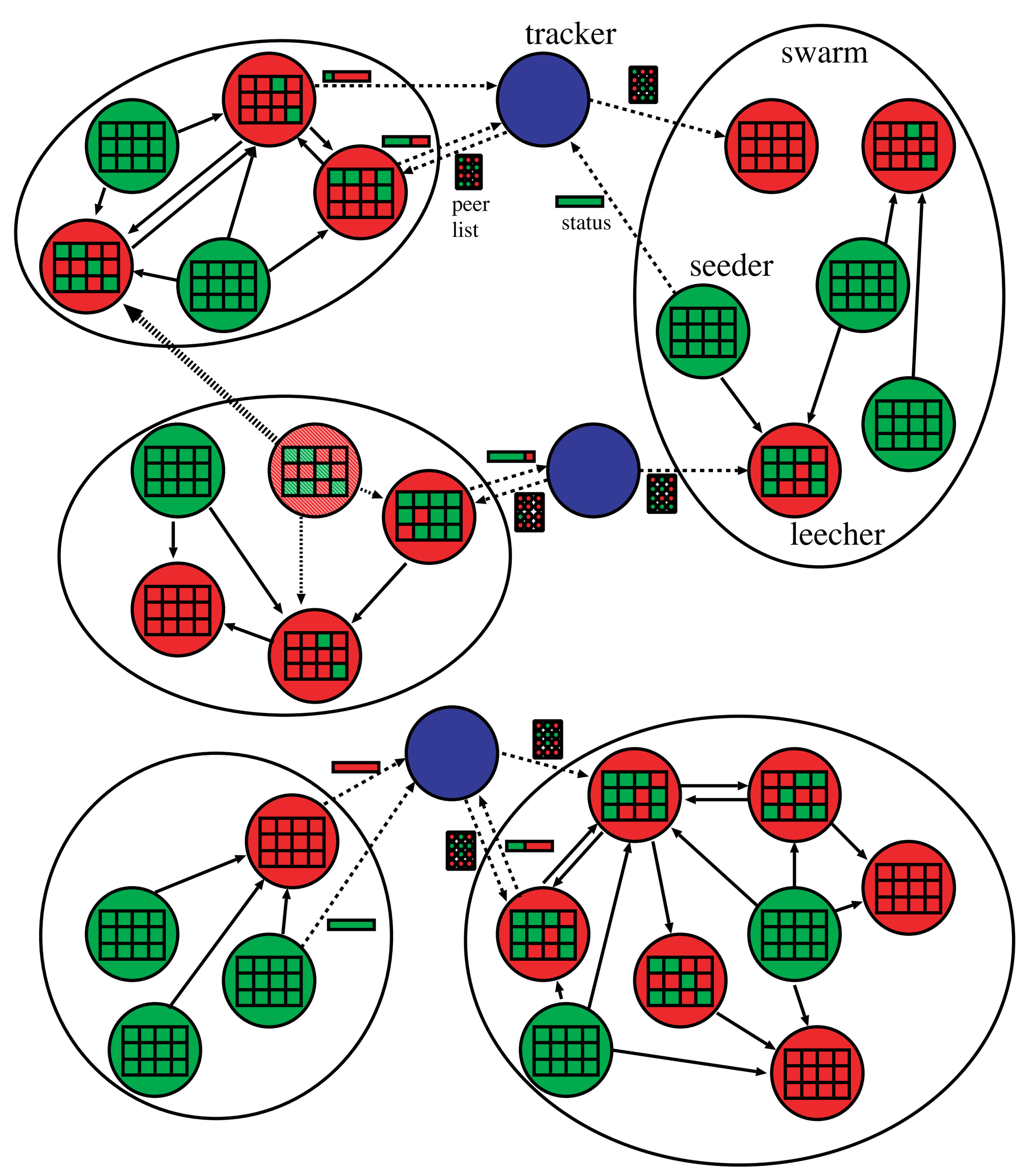

Fig. 2. BitTorrent Interactions. Peers ask trackers for swarm membership lists. They report to the tracker their status (number of bytes downloaded/uploaded). Within a swarm, peers exchange data. Seeders are peers that hold the entire file, otherwise the peer is called a leecher.

Cooperating peers download and upload required pieces. If a peer stops uploading, other peers will likely "choke" it; that is, they stop uploading to it. This implements the TFT-like process. Seeders, peers that store the whole file, are crucial to a swarm's functioning. If a swarm contains no seeders, eventually some pieces of the file might be completely missing from the swarm. Because peers gain nothing themselves by being seeders, the system requires some altruistic behavior from peers. This requirement is reflected by the mantra often repeated on BT Web sites: leave your download running for a little while after you've got the entire file (see fig. 2).

Hypothesis: Group-like selection

We hypothesize that BT might resist freeloaders and support altruism, at least partly, in a way that hasn't been previously fully comprehended (Hales and Patarin 2005). Ironically, this process relies on what is commonly believed to be a weakness of BT — the lack of integrated metadata search. One consequence of this is the BT network's partitioning into numerous isolated swarms — often with several independent swarms for an identical file. Such partitioning is a necessary condition for a kind of novel group-like selective process recently identified in similar simulated systems in the context of both computational sociology and simulated P2P file sharing (Hales 2004). Fig. 3. shows how this process works when nodes play the Prisoner's Dilemma game (fig. 1).

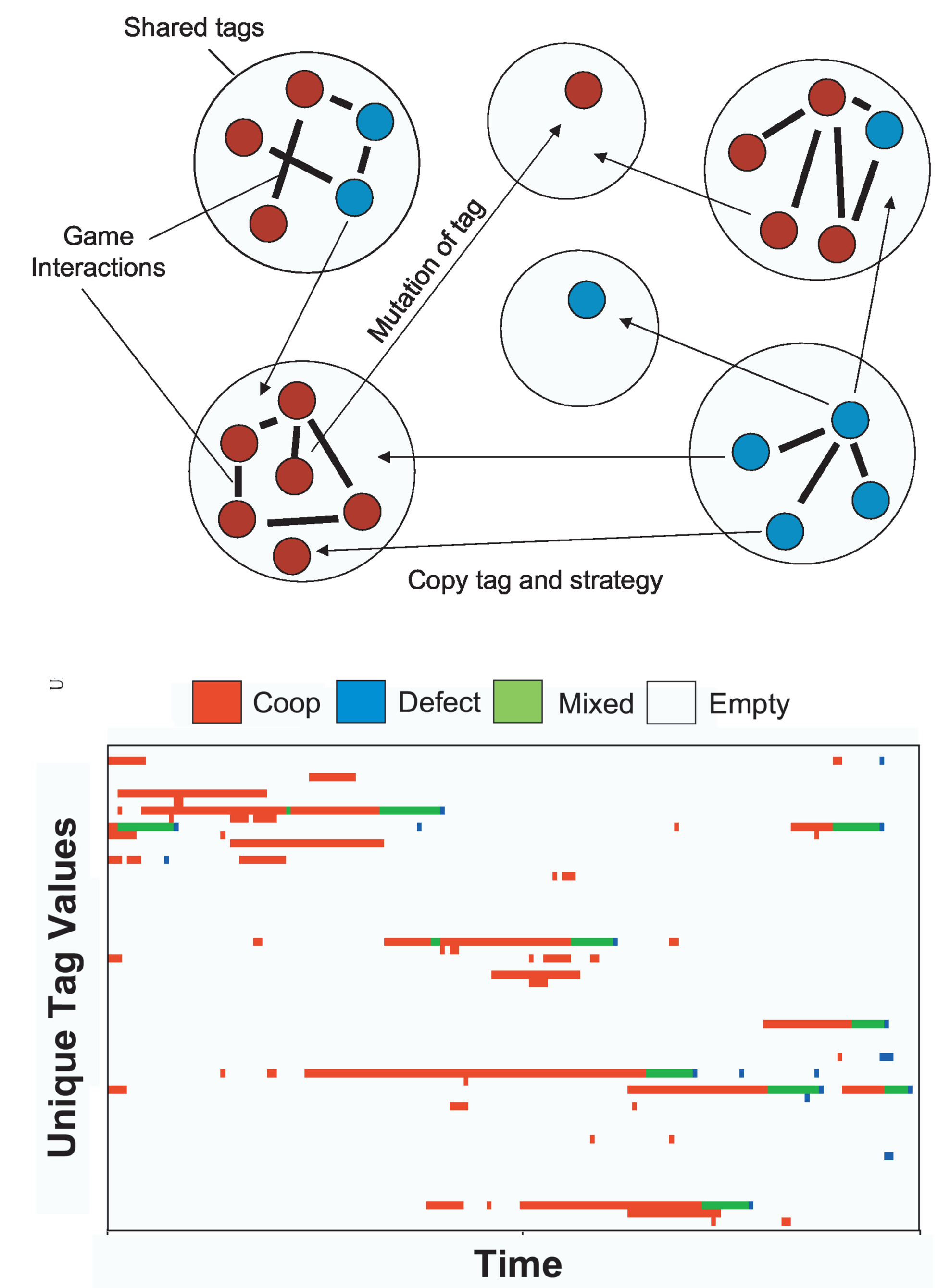

Fig. 3. A schemantic of gourp-like evolution (above) and output from a simulation model (below). Red indicates cooperation, blue defection.

If users move between swarms (leave one swarm and enter another) on the basis of the quality of the service they receive, swarms containing many freeloaders will tend to "die" as peers leave the swarm for better swarms. Swarms that contain altruists will tend to grow because they support a quality service. Computational-sociology researchers have advanced similar models (Riolo et al 2001).

Future Work

Given the choice, users might choose unconditional altruism rather than the more restrictive reciprocal approach. This is because the group-selective process selects for pure altruism—peers acting for the group's benefit at their own individual cost. One way to test our hypothesis empirically would be to implement and distribute a modified BT client that lets users select pure altruism. This might be the subject of future research.

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