Evaluating stranger policies in P2P file-sharing systems with reciprocity mechanisms

Yunzhao Li [*],[1], Don Gruenbacher [2], Caterina Scoglio [3]

ECE Department, Kansas State University, Manhattan, KS, United States

ABSTRACT

How to deal with strangers efficiently is a big challenge for designing P2P systems, as ineffective stranger policies will cause the degradation of system performance and fairness. In this work, we focus on an open P2P file-sharing environment with reciprocity incentive mechanisms, and we evaluate the impact of different stranger policies to system performance and fairness using both numerical analyses and agent-based simulations. The results reveal that there exist tradeoffs between system performance and fairness; the optimal performance and fairness of the system cannot be reached simultaneously; free-riders will survive when system performance is optimal. The accuracy of this evaluation is verified through the analysis of stranger policies in BitTorrent and eMule/eDonkey. Therefore, this evaluation can effectively help P2P designers select appropriate stranger policies according to their individual design goals.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Peer-to-Peer (P2P) file-sharing, which has broken through the limitation of the traditional client–server (CS) content distribution mechanism, generates most of the traffic (over 50%) on the current Internet [1]. Clients using the conventional CS method obtain resources from a certain number of servers; by contrast, peers in P2P file-sharing systems exchange content with each other. As a result, an increase in the number of users typically causes degradation of performance in a CS network, while the large number of users leads to high throughput, large scalability and strong robustness in P2P systems. Therefore, in order to maintain these remarkable properties, popular P2P file sharing systems, like BitTorrent [2] and eMule/eDonkey [3], tend to provide open environments to attract as many peers as possible, i.e., allowing peers to create their own identities independently and permitting peers to attend and leave the system freely.

The system performance of P2P file-sharing networks fully relies on each peer's cooperation on a fair foundation, due to these self-organizing and self-managing features. Otherwise, unfairly allocating the upload bandwidth of each resourceable peer will promote free-riders, and consequently harm general peers. The free-riders are peers who only consume the downloading resource without any contribution. The general peers are those who upload to other peers in exchange for downloading content from them, and they can be resourceable general peers or general newcomers. Therefore, general peers are the major contributors for the system performance, while free-riders mostly degrade the system fairness. Previous measurement study in [4] indicated that around 70% of peers in Gnutella, a famous P2P file sharing system which lacks a

---

* Corresponding author.

E-mail addresses: yzli@ksu.edu (Y. Li), grue@ksu.edu (D. Gruenbacher), caterina@ksu.edu (C. Scoglio).

[1] 2082 Rathbone Hall, Kansas State University, Manhattan, KS 66506, United States.

[2] 2061 Rathbone Hall, Kansas State University, Manhattan, KS 66506, United States.

[3] 2069 Rathbone Hall, Kansas State University, Manhattan, KS 66506, United States.

fairness mechanism, were free-riders. Maintaining fairness, which includes encouraging collaboration and preventing selfishness, therefore, plays an extraordinarily crucial role in modern P2P systems. Fairness in P2P file-sharing systems is usually maintained by reciprocity-based incentive mechanisms [5,6], because each resourceable general peer in these autonomous systems needs to make the decision of how to allocate its uploading bandwidth to others independently. These reciprocity-based mechanisms are commonly divided into two typical classes [6]: indirect reciprocity mechanisms (IRMs) widely discussed in [7–10] and direct reciprocity mechanisms (DRMs) popularly adopted in P2P file-sharing networks such as BitTorrent and eMule/eDonkey. Under the IRMs, a global reputation level for each peer is normally calculated and distributed, and consequently peer A's service to peer B could depend on B's former service to other peers. Under the DRMs, each peer merely maintains its former partner's information, and this results in A's service to B depending only on B's previous service to A.

1.1. The stranger policy

In a P2P file-sharing system, there may exist different definitions for strangers, which will introduce different factors to affect how to design stranger policies considerably. For instance, if the strangers are recognized as the peers just arriving into the system, the time factor has to be included into the stranger policies' design. If the strangers are defined as peers without any sharing behavior, the stranger policies should be requested to restrict their benefit. In this work, considering that each peer in a P2P system individually makes decisions for its most important actions: downloading and uploading, we define the stranger from the viewpoint of its direct uploader. A stranger is a peer, as a downloading requestor, who has been unknown by its requested peer (its uploader) no matter how long it stays into the system. The word 'unknown' here means either they have not exchanged content before, or the requested peer cannot obtain the behavior information of this requestor from other peers. Compared with strangers (the unknown peers), we define a known peer as a peer, who either exchanged content with this uploader, or its sharing information with other peers can be obtained by this uploader. Since a known free-rider cannot be serviced by its uploader, the known peers in the following parts will refer to the known general peers. That is, in the following sections, the word "strangers" are used to represent the unknown peers; and the word "known peers" are used to represent the known general peers. Due to the property of reciprocity, the reciprocity-based mechanisms are helpful to manage those known peers, but incapable of tackling the strangers, who are the following peers in a typical P2P file-sharing system with a reciprocity mechanism.

- Under the IRMs, the strangers can be new arrival general peers (general newcomers) or whitewashers. The general newcomers are peers who just arrive into the system for the first time. Consequently, they have not exchanged data to others and are considered being

strangers by their current partners. However, the general newcomers can potentially become known peers after uploading content to their partners. The whitewashers [11] are free-riders (the relationship of free-riders, strangers, and whitewashers is shown in Fig. 1) who pretend to be newcomers for more benefit by leaving and rejoining the system with new IDs. This whitewashing behavior makes them be strangers to their partners. Note that to obtain the benefits intended to strangers, free-riders in a P2P system with the IRM have strong motivations to whitewash. Otherwise, they could be easily recognized and isolated by this indirect reciprocity-based global incentive mechanism.

- Under the DRMs, the strangers can be divided into three categories: general newcomers; free-riders who have not downloaded content from their current partners earlier (otherwise, they will be recognized as free-riders by these partners); general peers who have not exchanged content with their current partners before (but they have exchange content with other peers). Note that free-riders do not need to whitewash for the benefit under the DRMs. The reason is that the local knowledge of general peers is not spread to others, and accordingly free-riders do not have to worry about their selfish behavior for one peer being known and punished by other peers.

Since every resourceable general peer (the uploader) faces the issue on how to deal with such strangers efficiently in an open P2P environment, treatment policies are needed to be established. Even though the impacts of stranger policies to general newcomers and free-riders are respectively intuitive, the impacts of different stranger policies to system performance and fairness cannot be decided easily. This is due to the fact that we cannot distinguish free-riders from general newcomers in a typical P2P environment [11]. For system fairness, restricting strangers policy is not necessarily better than rewarding strangers policy. This is because the policy of restricting strangers fairly treats free-riders but unfairly treats general newcomers; while the policy of rewarding strangers fairly treats general newcomers but unfairly treats free-riders. Similarly, for performance, rewarding strangers is also not necessarily better than restricting them. As we know, promoting the potential contribution of general newcomers will also promote selfish consumption of free-riders. Thus, rewarding strangers provides more uploading
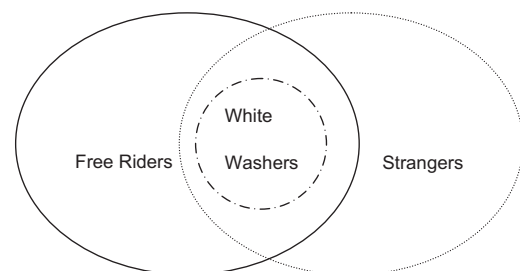

Fig. 1. The relationship among free-riders, strangers, and whitewashers.