Future Generation Computer Systems 29 (2013) 361–369

Contents lists available at SciVerse ScienceDirect

Future Generation Computer Systems

journal homepage: www.elsevier.com/locate/fgcs

A novel bartering exchange ring based incentive mechanism for peer-to-peer systems

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ARTICLE INFO

Article history:
Received 2 December 2010
Received in revised form
31 May 2011
Accepted 29 June 2011
Available online 8 July 2011

Keywords:
Free riding
Bartering exchange ring
Incentive mechanism
Reputation system
Peer-to-peer

ABSTRACT

Peer-to-Peer (P2P) networking is an alternative to the cloud computing for relatively more informal trade. One of the major obstacles to its development is the free riding problem, which significantly degrades the scalability, fault tolerance and content availability of the systems. Bartering exchange ring based incentive mechanism is one of the most common solutions to this problem. It organizes the users with asymmetric interests in the bartering exchange rings, enforcing the users to contribute while consuming. However the existing bartering exchange ring formation approaches have *inefficient* and *static* limitations. This paper proposes a novel cluster based incentive mechanism (CBIM) that enables dynamic ring formation by modifying the Query Protocol of underlying P2P systems. It also uses a reputation system to alleviate malicious behaviors. The users identify free riders by fully utilizing their local transaction information. The identified free riders are blacklisted and thus isolated. The simulation results indicate that by applying the CBIM, the request success rate can be noticeably increased since the rational nodes are forced to become more cooperative and the free riding behaviors can be identified to a certain extent.

1. Introduction

Cloud computing has recently drawn great attention to the opportunity that serious business can be done in a secure and efficient way. Peer-to-Peer (P2P) networking has been used as one of its resource discover techniques [1]. In this paper, P2P is considered to be an alternative to the cloud computing for the relatively less formal business. One of the major obstacles to the development of P2P systems is the free riding problem [2]. That is, a certain portion of the users only consume resources from the system but do not contribute to the others. Therefore, the success of the requests largely depends on the level of altruism of the system. A number of measurements [2,3] discover that in P2P systems, only a small number of altruistic nodes serve the majority of the system requests. As a result, the network topology is transformed to *scale-free* [4], degrading the network scalability and fault-tolerance. More significantly, the free riding problem also results in low content availability, which is contrast to the sharing philosophy of P2P systems.

To solve the problem, extensive researches have been conducted in order to introduce incentives to the systems and thus influence the users to cooperate with each other. One of the most common solutions is the Reputation-based Systems [5–7], which use a reputation value to represent nodes' contributions in their past transactions. A requester, with higher reputation value, will be allocated more resources or services with better quality. However, most of such reputation systems are impractical due to the complexity of rating collection, source validation and information aggregation [8].

Recently, the *Bartering Exchange based*approach has drawn increasing attention [9,10]. Barter is one of the oldest human economic activities. In the barter economic system, services are directly exchanged for other services without a medium of exchange, such as money [11]. In P2P systems, the nodes with mutual or asymmetric interests can be organized in a ring structure where every node provides one service to its successor and receives one service from its predecessor. This scheme enforces the nodes to contribute while consuming. Therefore the free riding nodes cannot gain any complete services and have to adapt their strategy to more cooperative ones or simply leave the network. The existing bartering exchange ring formation approaches only rely on the past search attempts for supply and demand information collection. This is *inefficient* since the messages of the Query Protocol are not informative. Moreover, this *static* approach takes the risk that the supply and demand information would be out of date. More importantly, the bartering exchange ring based incentive mechanism inherently is not effective against the malicious nodes. For instance, a free riding node can intentionally try to break the rings by refusing to leave the network.

This paper presents a novel cluster based incentive mechanism (CBIM) that overcomes the above problems. It proposes a cluster

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doi:10.1016/j.future.2011.06.005

based dynamic bartering exchange ring formation method that enables the nodes to form a ring during the search by modifying the Query message to be the medium through which the nodes can publish their requests and provisions. It also proposes a lightweight reputation system that allows the nodes to account the misbehaviors. Every node records the performance of their transaction partners and works out a reputation value for each of them by only using the local transaction information. The nodes increase the reputation value of a specific node after having a successful transaction with it and decrease its reputation value vice versa. Each node maintains a blacklist that only records those with lowest reputation values. The nodes can then predict and isolate the potential free riders by refusing to participate in the same rings with them.

The rest of the paper is arranged as follows: Section 2 presents two typical bartering exchange ring formation approaches and discusses their limitations. Section 3 explains the cluster based ring formation approach, including the modified query protocol specification, graph theoretical representation of cluster and rings, ring identification algorithm and Queryhit Caching mechanism. The proposed reputation system is demonstrated in Section 4 and the evaluation of the CBIM is presented in Section 5, which is followed by a conclusion in Section 6.

2. Related work

Bartering exchange ring based incentive mechanism is the main focus of this paper. The simplest form of bartering exchange is the bilateral barter between two nodes with mutual interests. BitTorrent [12] is the most popular P2P protocol that applies the bilateral bartering incentive mechanism. All the resources are divided into small segments with equal size. BitTorrent organizes nodes with the same interest into a group and enables them to download and upload resource segments among themselves. The nodes providing more upload rate are likely to get higher download speed in return. However, the BitTorrent cannot be applied in an application with high service diversity since it requires the resources shared by the nodes to be dividable. Furthermore, the discovery of two nodes with mutual interest can be difficult. Aperjis et al. [13] states that the flexibility of the barter can be improved by increasing the size of the bartering exchange rings.

To form multiple-way bartering exchange rings, Anagnostakis et al. [9] propose a mechanism where every node has an *Incoming Request Queue* (IRQ) that maintains all the nodes that requested a local resource. Every node also has a *request tree* which has the hierarchy structure: the root of the tree is the node; the first layer child nodes are the nodes in its IRQ; the next layer nodes are the nodes registered in the current layer nodes' IRQs. The depth of the tree is limited to 5. A node keeps checking if any nodes in its request tree can satisfy its request. If so, a bartering exchange ring can be formed.

Cabanillas [10] proposes another method to form bartering exchange rings. A set of nodes is selected as *Directory Nodes* (DN). The DNs are interconnected and responsible for answering queries from the *ordinary nodes*. Every DN maintains a Have List (HL) that consists of the services available amongst its associated ordinary nodes as well as a Want List (WL) which contains the requests it received from its ordinary nodes and other DNs. When a DN cannot directly respond to a query, it forwards the query to the DN network and checks the HL and WL of the other DNs to from a bartering exchange ring.

Both of the above methods have two problems in common: (1) Inefficient, throughout a search attempt, at most one request can be served and all the nodes involved can only acquire very limited supply and demand information about the initiator and the provider; (2) Static, the nodes check historical records to form bartering exchange rings, taking the risk that the recorded information is out of date.

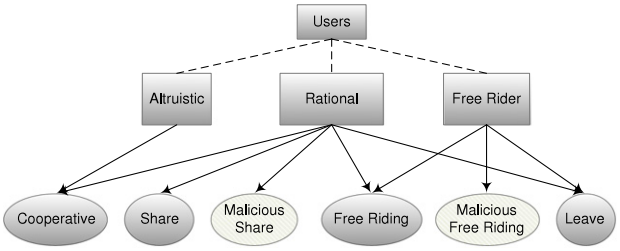

Fig. 1. Nodes classification.

In this paper, the nodes in P2P systems are classified into three categories: *Altruistic nodes, Rational nodes and Free riders*. Altruistic nodes are always *cooperative*, that is, they are always willing to answer queries. Rational nodes always try to maximize their own utility. They start with *free riding* strategy, that is, they do not provide any services to the others. If they cannot gain enough profit by free riding they will change their strategy to *share*: they participate in the service exchange but stop serving others once they receive the complete requested services. If they are not satisfied with the utility gained by using the *share* strategy, they will adapt their strategy to *cooperative*. If the Rational nodes using *cooperative* strategy still cannot gain satisfactory utility, they will leave the network. Free riders use *free riding* strategy and will leave the network if they cannot gain any profit over a certain period of time.

The bartering exchange ring based mechanism also has some inherent limitations. By using this type of incentive mechanism, the free riders should eventually leave the network since they cannot gain any services without contributing to others. The *free riding* rational nodes would change to use either *share* or *cooperative* strategy, depending on their satisfactory threshold. However, if a rational node is malicious, it can use the *share* strategy and intentionally request small resources and promise to provide bigger ones. In this case, they are highly likely to obtain complete resources before they finish serving the other ring members and thus achieve a higher request success rate. Consequently, they are less likely to change their strategy to *cooperative* than the normal rational nodes. Moreover, a malicious free rider may use a *free riding* strategy and refuse to leave the network. This could seriously affect the overall network request success rate. Fig. 1 shows the types of nodes and their strategies.

3. Cluster based ring formation approach

In this section, a novel *cluster based* bartering exchange ring formation approach is presented in detail. To overcome the inefficiency and static problems mentioned in the previous section, the Query Protocol of the underlying P2P networks is modified where the query message can be used as a medium through which any nodes on a query path can publish their requests and provisions. This modification enables the nodes to form bartering exchange rings dynamically. The search terminates when the nodes on a query path can form a cluster, that is, all the requests from the cluster members can be satisfied among themselves. The following subsections elaborate the query protocol modification, prove that a cluster consists of bartering exchange rings, describe an algorithm for bartering exchange ring identification and a caching mechanism for static ring formation.

3.1. Query protocol specification

This section presents a detailed specification of the CBIM Query Protocol by which the nodes form clusters, including the message structures and message processing procedure. Table 1 shows descriptions of the Query Protocol messages: