Reputation System and Incentive Mechanism to Handle The Malicious Peers and Free-riders in Peer-to-Peer Networks

Sateesh Kumar Awasthi and Yatindra Nath Singh
Indian Institute of Technology, Kanpur
sateesh@iitk.ac.in,ynsingh@iitk.ac.in

Abstract **- The open and anonymous environment of peer-to-peer (P2P) networks gives an opportunity to everyone to interact with the others; at the same time it brings new security threats. The malicious peers or the peers having conflict of interest can easily put inauthentic contents in the network. This can easily sabotage the system. Further, lack of central control leads to the problem of free-riding, i.e., peers download the resources without contributing anything back to the network. This leads the large difference between amount of upload and download of resources in the peers. In such a situation, downloading speed for non-free-riders becomes very slow. The implementation of reputation system and incentive mechanism have been proposed by many authors in past to resolve this problem. In this paper we will discuss some popular reputation systems and incentive mechanisms.**

Index Terms - P2P networks, trust, reputation, DHT.

I. INTRODUCTION

The peer-to-peer (P2P) networks attract a significant amount of traffic on Internet due to its inherent advantages over traditional client-server networks, e.g., scalability, robustness and diversity of data. Every peer in P2P network can initiate the communication and each peer can act both like client as well as server, and has equal responsibility. But due to lack of functionality of central control, some peers can easily sabotage the network by putting inauthentic contents in the network. Such peers are called malicious peers. Furthermore, rational behavior of peers encourages them only to draw the resources from network without sharing anything. These types of peer are called free-riders. In such a situation, P2P network functions like a poor client-server system where only few peers act as server with much less upload bandwidth and storage capacity. The success of P2P networks largely depends on the policy by which these two issues can be handled.

II EXPERIMENTAL STUDIES

Adar *et al.* [1] conducted a survey on Gnutella network in 2000. They observed that, 70% users did not share any file, 70% of files are shared by 5% of the peers. Top 1% peers shared 25% and top 25% shared 98% files. Free-riders were distributed uniformly through the network.

Another study was conducted on Gnutella and Napster network by Saroiu *et al.* [2] in 2002, which shows that 25% users in Gnutella did not share any file, 75% of users in Gnutella shared 100 or less number of files and 7% of peers shares majority of files, 40% - 60% users shared 5% - 20% of total files in Napster.

Cuevas *et al.* [3] conducted another study on popular file sharing P2P network BitTorrent in 2013. Which conclude that 3% of publishers are responsible for 67% of the contents and 75% of download session. Antipiracy agencies or malicious users are responsible for 30% of contents and 25% of download session.

These experimental studies show that malicious peers and free-riders are major problems in P2P networks. It attracted the attention of many researchers in the recent past and many solutions have been proposed for it. The implementation of reputation system and incentive mechanism has been suggested by many authors. In this paper, we will critically analyze the some of the reputation system and incentive mechanism.

III. BACKGROUND

Let us define some definitions which will be used throughout the paper

Definition 1. A numerical value, which models the past behavior of peers in the network, is defined as trust.

Definition 2. The value of trust, evaluated by any peer based on the direct interaction it has had with evaluated peer, is defined as a local trust.

Definition 3. The value of trust, system as a whole keeps on any peer, is defined as a global trust.

IV REPUTATION SYSTEM

A. EigenTrust Algorithm

The EigenTrust, algorithm was proposed by Sepandar *et al*., [4] of Stanford university in 2003. The basic idea of EigenTrust is taken from Google's PageRank [28] algorithm.

In EigenTrust [4] algorithm, each peer *i* keeps the record of all transactions it has had with peer *j*. Then it calculates the local trust, T_{ij}, of peer *j* as follows:

$$T_{ij} = sat(i,j) - unsat(i,j)$$

Where, *sat(i, j)* and *unsat(i, j)* are the number of satisfactory and unsatisfactory transactions of peer *i*, which has had with peer *j*, respectively. For the purpose of aggregation, they used normalized local trust instead of local trust, which is defined as follows:

$$T_{ij}^{norm} = \frac{\max(T_{ij}, 0)}{\sum_{j=1}^{N} \max(T_{ij}, 0)} \qquad (1)$$

Here, N is the number of peers in the network. This normalization process makes the trust matrix, T_{norm}, as a row stochastic matrix. Global trust vector, t, is calculated as a left principal eigenvector of transpose of normalized trust matrix.

$$t=(T^{norm})^{tr}.t \qquad (2)$$

It can also be interpreted as the weighted average of normalized local trust of peers where weight factor is given by the global trust of local trust assigning peer. If there is no interaction of peers they give zero local trust to each other. Some pre-trusted peers are assumed to be in the network and they are trusted by all the peers in the network. To include the impact of pre-trusted peers' global trust is modified as:

$$t=(1- a)(T^{norm})^{tr}.t + ap \qquad (3)$$

Where p is some distribution over pre-trusted peers. By normalizing the trust matrix, global trust can be calculated by iterative method and it converge at left principal eigenvector of transpose of normalize trust matrix. The major limitation of EigenTrust [4] algorithm is that it gives only ranking of peers without any absolute interpretation of their past.

B. Power Trust

PowerTrust was proposed by Zhou *et al*., [5] in 2007. The basic idea of aggregation of local trust in this algorithm is same as in EigenTrust [4], i.e., using normalized trust matrix. It used some higher reputable nodes known as power nodes in place of pre-trusted nodes. These power nodes are searched and elected dynamically in the whole network. Thus, pre-trusted nodes are free to leave the network unlike in EigenTrust [4]. This method used the enhanced trust matrix for the purpose of aggregation of local trust. Enhance trust matrix is the square of trust matrix. Speed of convergence of PowerTrust [5] is higher than EigenTrust [4]. In both, EigenTrust [4] and PowerTrust [5] distributed hash table (DHT) is used to locate the peer who is calculating and managing the global trust.

C. Flow Based reputation

Flow-Based Reputation was proposed by Simone *et al.*, [6] in 2012. They identified the problems with normalization and used basic trust matrix without normalization, for aggregation of local trust. For this purpose, they redefined the local trust of a peer by mapping a function from positive (+1), neutral (0) and negative (-1) rating to a value into the range [0,1]. Global trust vector was taken as the left principal eigenvector of trust matrix. It was calculated using power method [7]. Main drawback of this method is that it cannot be implemented in a distributed system.

D. Absolute Trust Algorithm

We Proposed Absolute Trust algorithm [8] in 2016. In this algorithm, the global trust of peers is estimated using weighted average of the local trust. The weight factor for individual peer is given by the global trust of a peer. In order to compare the global trust of any two peers, the global trust of individual peer is biased by the global trust of trust assigning set, S_i . The global trust of any peer *i* is given as:

$$t_i = \left[\left(\frac{\sum_{j \in S_i} T_{ji} t_j}{\sum_{j \in S_i} t_j} \right)^p \cdot \left(\frac{\sum_{j \in S_i} t^2{}_j}{\sum_{j \in S_i} t_j} \right)^q \right]^{\frac{1}{(p+q)}} \qquad (4)$$

Here T_{ji} is local trust of peer *i* estimated by peer *j*. The t_i is global trust of peer *i* and *p*, *q* are some suitable chosen constants. The global trust of peers depends on the global trust of the other peer. It can be calculated by iterative method thus, can be implemented in a distribution fashion.

TABLE 1: Comparison of Reputation Systems

S. N.	Reputation System	Normalization	Distributed Implimentation
1	EigenTrust	Needed	Possible
2	PowerTrust	Needed	Possible
3	Flow Based	Not Needed	Not Possible
4	Absolute Trust	Not Needed	Possible

V INCENTIVE MECHANISM

A. Tit-for-Tat

The tit-for-tat (TFT) approach is used by a most popular file sharing system named BitTorrent [9], to prevent the free-riding. In this approach, a peer cooperates with other peers in the same proportion as they have cooperated with him in the previous round. In each round, every peer updates the contributions of peers in the previous round.

To improve the performance, many variants of TFT have been proposed. Garbacki *et al.*, [10], proposed ATFT in which bandwidth is used rather than content to decide the incentives. Dave *et al.*,[11], proposed auction based model to improve the TFT. In this model, peers reward one another with proportional shares, [12], of bandwidth. Sherman *et al.*, [13], proposed FairTorrent. It is a deficit based distributed algorithm in which a peer uploads the next data block to the peer, whom it owes the most data as measured by a deficit counter. These approaches consider the peers shared history with limited number of peers.

B. Global Contribution Approach

A Global Contribution Approach (GC) for Fairness was proposed by Nishida *et al.*, [14] in 2010. This approach was used to prevent the free-riding in the network and to balance the upload and download amount in each peer. Global contribution, x_i, of any peer *i* is calculated as following:

$$x_i = \alpha \frac{\beta e_i.S.x + (1-\beta)e_i.S.e - e_i.S^{tr}.x}{e_i.(S+S^{tr}).x} + (1-\alpha) \quad (5)$$

If no transaction happened at node i then

$$x_i = \frac{2-\alpha(1+\beta)}{2+\alpha(1-\beta)} \quad (6)$$

Where, x is global contribution vector. The S is share matrix in the network with its *ij* element as the amount shared by peer *i* to peer *j*. The e_i is a row vector with its i^{th} entry as '1' and e is a column vector with each entry as '1'. The parameter α and β are some scalars decide the initial value of global contribution vector and guaranteed the convergence of it.

Any peer is only allowed to take the resources from the network if its global contribution is higher than the threshold value. Thus, peer wants to earn more global contribution. They can earn more global contribution if they upload to high contributing peer and download from low contributing peer. This method can balance the upload and download amount in the network and thus can prevent the free-riding. But this is complex to implement in real system due to its slow speed of convergence.

C. Biased Contribution Approach

We proposed a light-weight algorithm named Biased Contribution Index (BCI), [15], in 2016. This algorithm is able to balance the upload and download amount in each peer. It can be implemented in a distributed system with faster convergence speed. The BCI of any peer *i* is expressed as:

$$x_i = \alpha \frac{e_i.S.x}{e_i.(S+S^{tr}).x} + (1-\alpha) \quad (7)$$

If no transaction happened at node i then

$$x_i = (1 - \alpha/2) \quad (8)$$

The value of BCI of any peer remains in between (1 - α) to 1.

TABLE 2: Comparison of Incentive Mechanisms

S.N	Incentive Mechanism	Approach	Convergence Speed
1	Tit-for-tat	Local	-
2	ATFT	Local	-
3	FairTorrent	Local	-
4	GC	Global	Slow
5	BCI	Global	Fast

VI CONCLUSION

In this paper, we presented the problems with peer-to-peer networks with some experimental survey. We focused that the malicious peers and free-riders are two major problems with these networks. Further, we summarized the popular reputation systems and incentive mechanisms, which are proposed to handle the malicious peers and free-riders. We explained the metrics, which are used in these different approaches with their shortcomings.

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