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A Virtual Currency Based Incentive Mechanism in P2P Network

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Abstract. In order to restrain free-riding behavior existing in P2P file sharing system, on the basis of some specialized optimization and design to the calculation of the file price according to the new features of mobile P2P networks, we propose a novel incentive mechanism based on virtual currency. In this mechanism bandwidth is allocated and download priority level is set according to the peer's virtual currency, and peers can choose the service peers by itself according to its preferences to the file price and the download speed. We demonstrate that this research can distinguish various types of services provided by different peers and motivate peer to provide better services so that enhance the stability and balance the network load effectively through simulation experiments and analysis of the results.

Keywords: incentive mechanism, mobile P2P, virtual currency.

1. Introduction

With the rapid development of mobile Internet and the continuous improvement of the performance of mobile devices, P2P technology will be widely usedin mobile Internet. Mobile devices can join in the P2P system in Internet via mobile Internet. This session layer overlay network superimposed on the network layer of mobile Internet is called Mobile P2P Network (MP2P), which aims at data resource sharing and service collaboration by direct exchange among mobile devices [1]. Different from the peers in the traditional P2P network, most mobile peers have low battery power, slow processors and limited memory, and join or leave MP2P more randomly and frequently. Because of its limited hardware resources most mobile peers may not share the file or leave directly after downloading. So the efficiency of the network may be reduced significantly. It is very necessary to do some specialized optimization anddesign to incentive mechanism of Mobile P2P Network.

Through generally research and analysis of the incentive mechanism in the traditional P2P network, this paper proposes a novel incentive mechanism based on virtual currency. The price of file is set dynamically according to the field popularity and the availability. And then, according tothe peer's contribution value to allocate bandwidth and setdownload priority level and so on to achieve the goal ofcurbing free-riders and bad behaviours of malicious peers .

2. Related Works

Similar to the economic activity, the information is not symmetrical between two sides of the transaction in the P2P network. Therefore, how to set the file price appears to be critical. Two modifying factors affected the file price are the popularity and the availability, and both of them are proportional to the price. In reference [2], Xiaonian Yi calculated the popularity and the availability of the file according to download time and the number of queries in the past period of time. Althoughmodifying factors affected the file price are detailed analysis and the calculation method is given, the new features of mobile P2P networks are left out of consideration such as low battery power, slow processors, limited memory and so on.

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On basis of giving full consideration to the new features of mobile peers, some specialized optimization anddesign have been done to the calculation of the popularity and availability. Firstly, the concept of field popularity is proposed and the cluster takes charge of statistical calculation of the field popularity so as to reducethe overhead costscaused by the frequency joining and leaving. Secondly, the policy of availability score is adopted and the download peer grades the availability score according to its semantic understanding to resource for the purpose of curbing free-riders and bad behaviours of malicious peers.

3. Network Model

Different from the stabletopology of traditional P2P network, the topology of the mobile P2P network varies continuously due to the transferability of the mobile peers so that the mismatch between overlaylayer and underlying physical network connection status may cause the inefficiency of resource discovery and data transmission [1]. For inhibiting this inefficiency, the policy is proposed that mobile peer joins the P2P network through relay peer. The network model is shown in figure (1).

The underlying routing model uses the Viceroy to overlay network (Figure 1 (1)), where each "peer" is a cluster (gathered from the login peer who has the same value in the former C of IP address)[3]. Mobile peers connect to the P2P network through relays which offer some peer services to mobile peers: firstly filter out unnecessary advertisements, and strip down those advertisements in order to save bandwidth, secondly routemessages to or from mobile peers, thirdly translate the relayed messagesin order to enable interoperability between mobile peers and ordinary peers [4].

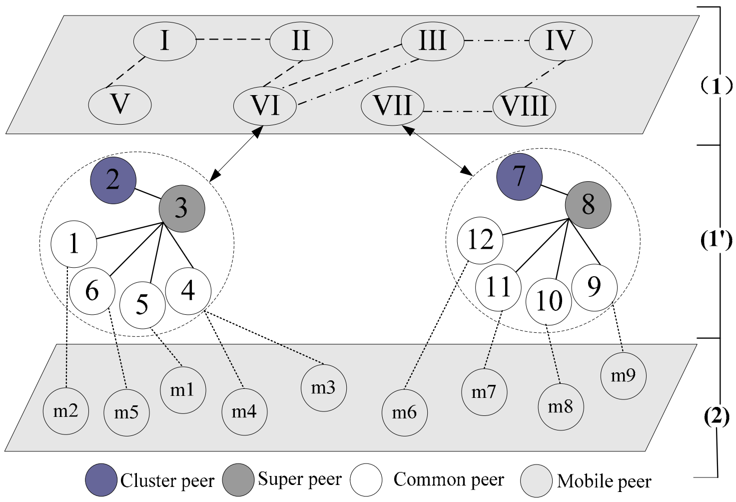

Fig. 1: The network model

In this model mobile peers can interact with the other peers through relays. The cluster peer can complete complex computations (such as the calculation of the file availability) instead of peers with poor performance and takes charge of statistical calculation of the field popularity. As figure 1 shows, when peers (such as peers 1-6) logging on to the P2P network, according to the value in the former C of IP address the system organizes them as cluster peer together. Peer V corresponds to a cluster (Figure 1 (1)), which includes eleven peers. Peer 2 is the cluster peer, peer 3 is the super peer, peers 4,5,6,7 are the common peers and the others are mobile peers. Cluster peer 2 is responsible for communication with neighbour clusters, super peer 3 links peer 2 and other common peers and mobile peers communicate with the other peers through relays.

4. The Calculation of File Price

The virtual currency is used to measure the file price. Peers obtain money by rendering services and must pay for the file to be downloaded.

4.1. The calculation of field popularity

The so-called Popularity of file is the predicted value of requested ratio next moment. The bigger the value is, the more popular the file is. As thestorage space and processing power of mobile terminal equipment are limited, calculating the popularity in various mobile devices will consume valuable network resources. This paper presents the concept of Field Popularity which is the popularity of the file in its specific field. Since all peers in the cluster are similar to interest, the statistics of the field popularity by cluster peer is more meaningful and practical reference value. The cluster peer is thepeer selected out from those with ordinary performance, the file popularity calculated by cluster peer is more credible. And this cluster-based calculation method can reducethe overhead costs effectivelycaused by the frequency joining and leaving. When a peer requests to join the system, it can get the field popularity of the shared file by questioning its cluster peer. And the cluster can regularly update the field popularity of the files by broadcasting message among the cluster.

Suppose S is the collection of files shared by all peers in the cluster with the cluster peer P, then S= $\{F_i|1\leq i\geq n\}$,n is the number of the files. We define the file i's request frequency in specific time period (t) as $F_{req}(i,t)$, and it is calculated as shown in formula (1).

$$F_{req}(i,t) = \frac{N_{req}(i,t)}{\sum_{j=1}^{n} N_{req}(j,t)} \tag{1}$$

In formula (1), $N_{req}(i,t)$is the requested times of file i during time period t.

Because of the high dynamic of P2P network it is not appropriate to test the file access frequency using a fixed period of time.The test cycle is adjusted dynamically according to the change trends of the field popularity [5], that is to say, next test cycle depends on the ratio of the request frequencybetween adjacent cycles. If the frequency goes up, the cycle will be shortened, else if the frequency goes down, the cycle will be lengthened.

We use $F_{req}(i,t_j)$ to represent the request frequency of file i in time period t, and then the next test cycle is calculated as shown in formula (2).

$$t_{j+1} = \frac{\sum_{i=1}^{n} F_{req}(i,t_j)}{\sum_{i=1}^{n} F_{req}(i,t_{j+1})} \times t_j \tag{2}$$

Field popularity of files cannot just rely ona forecast of once or twice access records. Therefore, inthis paper we predict field popularity of file by introducing timeseries smoothing algorithm in economics. We define that at time t, the field popularity of file i is calculated as shown in formula (3) below.

$$pop(i,t) = a \times \sum_{k=0}^{n} (1-a)^k \times F_{req}(i,t-k) \tag{3}$$

Where a represents the weighted coefficient of time t,and $F_{req}(i,t-k)$ represents the retrieve frequency of file i at time t. Every moment, theweighted coefficients area, a (1-a), a $(1-a)^2$ ..., etc., and sumof all the weights is 1,The weighted coefficient decaysexponentially, the nearer weighted coefficient to time t, thebigger proportion on access records is, and vice versa.

4.2. The calculation of file availability

As is implied by the name, the file availability is the dimension of file availability. Availability must be measured as close as possible to file quality, while how to measure the file quality is a question worthy of further study. In reference[6] we proposedto understand the semantic information of resources by theknowledge a peer has with domain ontology. The method isto extract specific instances of peer's resources, thenunderstand these instances by the knowledge of domainontology. In reference[7] REN Yan presents a trust mechanism, Multiple Granularity Trust Model (MGT), which is more effective on protecting the network from many malicious behaviours. Different peer desired different file, so the resource quality scorehas a high subjective contentinevitably. Using of above methodssynthetically we propose a policy of file availability score based on the cluster's feedback.

In this policy peer has the right to freely choose whether to understand the semantic information of resources or not according to its processor. Peers having superior computing performance may understand each instance by the knowledge of domainontology, and then calculate its reputation level. The cluster peer can complete the calculation of the file availability instead of peers with poor performance.

On the basis of reference [8], the comprehensive calculation of file availability scoreof download peer $P_j$to upload peer P_i within the transaction area k is shown in formula (4).

$$\mathrm{SC}(\mathrm{P_i},\mathrm{P_j},k)=\frac{\sum_{i=1}^{N}\left[sim\left(C(IN_{\mathrm{i}}),k\right)\times \mathrm{IN}T_{i,\mathrm{O_i}}\right]}{\sum_{i=1}^{N}\left[sim\left(C(IN_{\mathrm{i}}),k\right)\right]}\in[0,\ 1] \tag{4}$$

Where N stands for the number of instances, and $C(IN_i)$ stands for the concept of instance INi. Semantic similarity is calculated as: $sim(m,k)=5/(5+Dep_m+Dep_k-2*Anc(m,k))$. Where Dep_m and Dep_k stand for the layer of m and k indomain ontology, Anc (m, k) is the nearest common ancestorpeers of m and k in ontology layer. INT_i,O_i,stands for the trust level between instance $IN_i$and itsontology O_i and the sub-ontology, as shown in formula (5).

$$\mathrm{IN}T_{i,\mathrm{O_i}}=\begin{cases}\sum_{a_q\in A_i,q\in(1,n)}[\mathrm{w_q}\cdot \mathrm{match}(a_q)] & \mathrm{O_i}\in R\\ \alpha\times\sum_{a_q\in \mathrm{O_i},q\in(1,n)}[\mathrm{w_q}\cdot \mathrm{match}(a_q)]+(1-\alpha)\frac{\sum_{m=1}^{INH_i}\left[sim\left(C(IN_{\mathrm{i}}),C(O_m)\right)\times \mathrm{IN}T_{i,\mathrm{o}_m}\right]}{\sum_{m=1}^{INH_i}\left[sim\left(C(IN_{\mathrm{i}}),C(O_m)\right)\right]} & \mathrm{O_i}\notin R\end{cases} \tag{5}$$

Where R is a set of leaf peers in reputation Ontologytree,A_i is the attribute set of O_i, a_q is an attribute of A_i, $w_q$isthe attribute weight of a_q, and the sum weight is 1. INH_i refersto the number of sub-ontology which is closer in semanticdistance with O_i, C (IN_i) refers to the concept of instance IN_i,C (O_i) refers to the concept of ontology O_i, and $\alpha\in$ [0,1] isused to adjust the scalability of sub-ontology, generally we setthe value of α as 0.5.The field availability of file i is calculated as shown in formula (6) below.Where n is the download time of file i in all.

$$ava_k=\frac{\sum_{j=0}^{n}SC(P_i,P_j,k)}{n} \tag{6}$$

4.3. The average currency variation ofeach type of peers

Corpus of this system comes from 300 text which is searched from domestic portals (such as Sina, Sohu, Netease and etc.) and CDC military - image database, then classify and organize the vocabulary of these texts. In this paper, Protégé3.3.1 [9] constructed a body on the sports and the military field, including concept, relation, attribute and solid example, making the existing body on the sports and the military perfect. Using Jena2.4 [10] to parse the ontology and semantic annotation of text which is marked with the body text formatting test set. Each of10 network host a different port number, respectively, by login 10 different types of peers, randomly distributed in the test text each peer.The corpus of this simulation experiment is composed of these texts.

Experiments 1 simulates 1000 random transactionsbetween 100 peers, the probability of the services normal peersprovided is 90%, and normal peers also provide realresources. While the probability of services malicious peersprovided is 30%, and to a certain probability malicious peersprovide false resources. The strategic peers provide services by 80%, but providereal resources and false resources with breaks and interruptions. After every 100 rounds the average currency of each type of peers is shown in Figure 2.

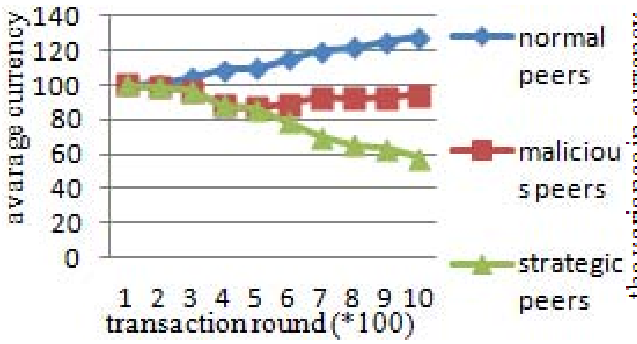

Fig. 2: The average currency variation of each type of peers to the transaction rounds

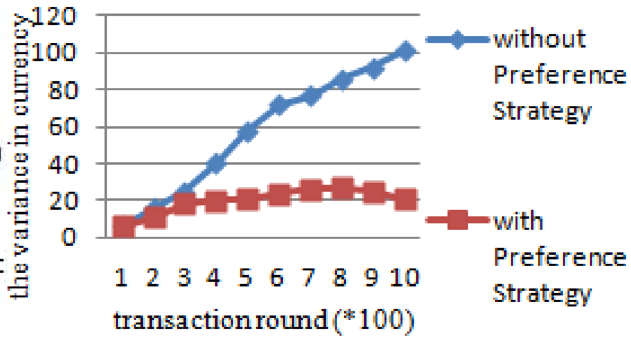

Fig. 3: The changes of the variance in currency to the transaction rounds

In figure 2 the average currency of normal peers will continue increasing andtend to be stablewith the increase of the member oftransaction rounds, while the average currency of malicious peers declines sharply. Because of providing false resources at first the average currency of strategic peers declines sharply just like malicious peers and have to costmuch more transaction rounds to revert to quondam level.The figure shows that thismethod effectively distinguishes the three different types ofpeers, incant peer to provide resources of high quality and curb free-riders and bad behaviours of malicious peers.

5. Incentive Mechanism

It's true that the peer’s currency won’tincrease until it provides resources for others, that is to say, contribution to the other peers will appear on the peer’s currency. Based on the file price calculation method inprevious section, this section proposed an incentive mechanismwhich provides differentiated services in accordance with thepeer’s currency.The differentiated services are transparent to the request peers, and they can choose the service peers by themselves according to their preferences to the file price and the download speed. The differentiated services includethe allocation of bandwidth and download priority for peer, and both aspects will be covered.

5.1. Bandwidth allocation

Bandwidth allocation refers to allocate a download speedof some resource for a request peer in the network, whichdepends on the ratio of the peer’s contribution to thetotal request peers. $S_{BD}(i,t)$ stands for the bandwidth obtained by peer i at time t, as shown in formula (7).

$$S_{BD}(i,t) = \frac{sum(i,t)}{\sum_{i=1}^{m} sum(i,t)} \times BW_{\max} \tag{7}$$

Where BW_{max} is the service peer’smaximum upload bandwidth and m is the number of peers downloading the resources. sum(i,t) is the total currency of the peer i at time t. if sum(i,t) is equal to zero, then peer i can’t download this resource. If $S_{BD}(i,t)$ is less than δ, then peer i would be blocked and ordered into waiting queue, where δ is the smallest unit of the bandwidth allocation.

5.2. Priority Allocation

The peers in the waiting queue will be order into processing according to the policy of dynamic priority scheduling. Priority allocation not only considers the value of their contributions, butalso the length of waiting time.$S_{PRI}(i,t)$ stands for the priority of peer i at time t, as shown in formula(8).

$$S_{PRI}(i,t) = sum(i,t) \times \frac{T_{wait}(i,t)}{\sum_{i=1}^{m} T_{wait}(i,t)} \tag{8}$$

Where $T_{wait}(i,t)$ stands for the length of time the peer i has been in the waiting queue, and there are m peers in the queue.

5.3. User Preference Strategy

After sent a query request for file a, the request peer i may receiveseveral response messages which contain the price of file and the performance parameter of response peers. Peer i may choose the response peers by itself, and formula (9) shows that Peer i chooses Peer j to download file a.

$$select_j = \alpha R_a + (1-\alpha) MAX\left\{S_{BD}(i,t), \delta\right\} \quad (9)$$

Where αis the preference to the file price and the download speed, R_a is the price of file a calculated according to the availability and popularity.

Experiment 2 mainly investigates the influence of the user preference strategy.The experiment simulates 1000 random transactions of 80 normal peers, 10 strategic peers and 10 malicious peers.The variance in currency is studied among peers with the user preference strategy or not. The experiment results are shown in Figure 3. Figure 3 indicates that:with the increase of the member oftransaction rounds the variance in currency increases sharply without the user preference strategy which means that the gap is being enlargedrapidly. For the long run there will be a lot of peers that have no currency to receive service, and this is bad for the aim of incenting peer. The introduction of user preference strategy can make the variance retaining about the same differential so that so that enhance the stability and balance the network load effectively.

6. Summaries

This paper proposes an incentive mechanism in which the price of file is calculated according to the availability and popularity. Thebandwidth and download priority is allocated in accordance with thepeer's currency, and user preference strategy is introduced to balance the network load. We demonstrate thatthis research can distinguish various types of servicesprovided by different peers and to effectively incent peer toprovide better services and share more resources so thatenhance the stability through simulation experiments and analysis ofthe results.

7. Acknowledgment

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