A Content-Based Locality-Aware Collaborative P2P Lookup Algorithm

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***Abstract*—In structured systems, classical routing algorithms such as Chord, Pastry can always find resources within lower logic hops. However, they are independent of the physical network, so that they often find resources in a long delay due to undesirably long distances in some physical links. Resources are always stored in the simple form of <key,value> pair in these systems. Similarly, it will result in a long delay due to not considering the semantic properties of data objects and the data searched by clients. In order to solve the problems in peer-to-peer (P2P) networks, such as the mapping problem of mismatching between physical and logical network topology, and the problem of resource storage. Based on self-organizing content-aware collaborative P2P network, a new content-based locality-aware collaborative P2P lookup algorithm (CLP2P) is presented, which comprehensively considers the users' physical locations and interests. It maps nodes of physical proximity and same interest to proximal location in overlay network, and stores the resources on the interested nodes. The proposed algorithm has been assessed through a collection of numerical simulation experiments and the results show that the average hop count and the average routing latency among nodes are reduced, the performance of average resource search success rate is kept high, and the average resource search latency is reduced.**

Keywords- P2P network; autonomous system; interest

I. INTRODUCTION

As a structure of distributed resource usage and shared file system, P2P has many potential advantages, such as high scalability, cost effectiveness. P2P is widely used as it reflects the fundamental meaning of Internet freedom. German Internet research firm ipoque says, P2P has been completely dominated today's Internet, and 50% -90% of the total traffic is from P2P programs [1]. At the same time, more and more P2P applications come out, and the types of resources become more diversified.

The most attractive feature of P2P is that nodes do not need to directly interact with the underlying physical network, which provides many opportunities for the development and application in the user layer. Because of these P2P applications choose logical nodes arbitrarily, lack of understanding of the underlying network, these will result in a mismatch between P2P overlay network and bearer network, further directly affects resource search, increase resource search delay. In addition, with the widespread usage of P2P, the type of network resources is also showing a variety, and different resource has different popularity. At the same time, the demand for network resources of users is showing a variety and different user has different interest for different kinds of resources. However, in these DHT (Distributed Hash Table) systems, each resource is associated with a key and the key/value pair is stored in the node to which the key maps, not considering the data semantic and the demand characteristic of the resource that user searches. According to the resource placement policy in DHT network, interested resources may be stored on logical nodes far away in the physical network. On the contrary, the resources which nodes are not interested in are stored nearby. Therefore, it needs large search hop counts to reach the node which the resource is stored on. It can't achieve the purpose of rapid retrieval resources, and affects the performance of resource search. If nodes frequently access resources which they are interested in, the backbone network link load will increase rapidly.

How to improve P2P resource search performance is currently a hot research. Current studies mainly focus on one aspect of the problems mentioned above. In practical application, the nodes which in physical proximity have the resources may be far away in logical network, while the nodes in logical proximity may not have the resources that the node needs. Therefore, comprehensively considering the bearer network and the users, we can better optimize resource search. Based on studies previous, the content which users interested in is always nearby [2,3]. To solve the problems above, this paper still quotes the thought of resource classification in [4]. Collaboratively considering user's interest and location and resource location and type, we propose a new P2P lookup algorithm CLP2P. Proximal nodes in the physical network are mapped to the proximal location in the identifier space, and the nodes which have the same interest are also mapped to the proximal location in the identifier space. Resources which nodes interest in are stored on the nodes which have the same interest. Experiments show that the algorithm not only solves the mismatch problem between physical network topology and logical network topology, but also has high resource location rate, reduces resource search time, and avoids search information frequently traversing the backbone network effectively to reduce network load.

II. RELATED WORK

In allusion to these problems above, scholars have presented lots of different approaches. The approaches can be divided into two kinds. First, they are presented to solve the mismatch between the physical network topology and logical network topology. SUN Mingsong et al. [5] proposed a physical topology aware structured P2P network, in which the network coordinate system was used to measure the distance between nodes, then Cantor space filling curve was used to convert the 2-dimensional space into 1-dimensional. According to Cantor value, Chord ring was structured. Simulation results showed that this algorithm could reduce network latency and network traffic. Guangyu Shi et al. [6] used a trace route to track the delay between nodes. Through calculating the delay "nearby", clusters were built. Simulation experiments showed that the performance of P2P system achieved through this method was similar to the method based on GNP (Global Network coordinates). Weiyu Wu et al. [7] proposed a location-aware distributed hash table, which assigned the node identifier according to the autonomous system number (ASN) of the node. It proved that this method was suitable for various DHT routing algorithms and the results showed that the end-to-end delay had been significantly improved without increasing the cost. The common problem in the aforementioned approaches is only from the mismatch between the physical network topology and logical network topology to consider, however, the resource which user is interested in may be not nearby. In CLP2P, we cluster the nodes with the help of their ASN.

Second, approaches are presented in terms of users' interest. Juan M. Tirado et al. [4] proposed a self-organizing content-based locality-aware collaborative peer-to-peer network. It studied and researched the characteristic of resources which user interested in, and the advanced resource location algorithm greatly improved the rate of resource positioning, reduced the resource response time. Jian Xiong et al. [8] proposed a hierarchical resource sharing model, which clustered nodes according to nodes' interest. It introduced a super-node as a server in every node cluster. This model optimized resource search, but at the same time a higher performance was required for the super-node. Similarly, they only consider from user's interest, however, the resource which user is interested may be found far away in physical network. In CLP2P, we quote the thought of resource classification in [4] to classify resources and nodes. The nodes which have same interest are put in the same semantic cluster.

The work in [9] proposed a P2P routing algorithm based on the user's interest and the network topology. In terms of network link latency between landmark node and normal node, nodes were clustered. Similarly, in terms of resources characteristics, resources were clustered. It assigned a node cluster to be responsible for another resource cluster, but it does not say whether the node cluster has the same interest with the resource cluster. The node search was located to the node cluster with a cache table. Although this algorithm reduced the average routing latency, it still did not connect network topology and users' interest well. If the node cluster storing the resource cluster was far away, the resource request latency was still very long.

III. CLP2P LOOKUP ALGORITHM

A. System Architecture

The main goals of CLP2P algorithm are solving the mismatch problem between physical network and logical network, and the resource placement problem. The CLP2P system has the following major features:

- CLP2P is a Chord-like [10] algorithm with three main differences when compared to Chord. First, CLP2P logical nodes correspond to the Chord nodes, with the difference that Chord identifiers are generated through uniform hashing, while CLP2P identifiers are a concatenation of a semantic cluster identifier and a node identifier generated through uniform hashing and a physical cluster identifier generated through modular arithmetic. While Chord generates a global uniform distribution of node identifiers, CLP2P locally distributes node identifiers uniformly inside each cluster. Chord formation of the node identifier is a global uniform distribution, CLP2P locally in each cluster uniformly distributed. Second, interest-based clusters of nodes are supported by extending the identifier space with a cluster identifier field, and resource storage is optimized. Third, the distance between physical adjacent nodes are shorted in logical network with a physical cluster identifier. All the other overlay maintenance operations of Chord are preserved with the same functionality.
- Each cluster of peers is labeled with a category. Labeling a cluster with a category does not mean that all the resources of its peers are classified in the same category, but that the peers have a most number of resources classified in that category.
- Resource storage. According to the semantic properties and contributed nodes' physical locations, different semantic-based identifiers and physical clusters are allocated to resources. Resources are distributed stored on nodes of interest.
- Resource search method. Combined with the semantic properties and physical location of a node, first the resource search is located to the node cluster of interest, where the resource is stored on. And then it is located to the near physical cluster that resource is in. After that, Chord search method is used in the cluster to keep the effectiveness of the resource search.

Our system architecture builds on common overlapping network structure [11] shown in Figure.2. CLP2P network is divided into two layers, P2P semantic layer main offers basic interconnection services at semantic clusters level such as joining or leaving a semantic cluster and a physical cluster and overlay maintenance. The semantic layer provides the management of content-based information and offers high level services to the applications such as strategic node joins, efficient content-based searches.

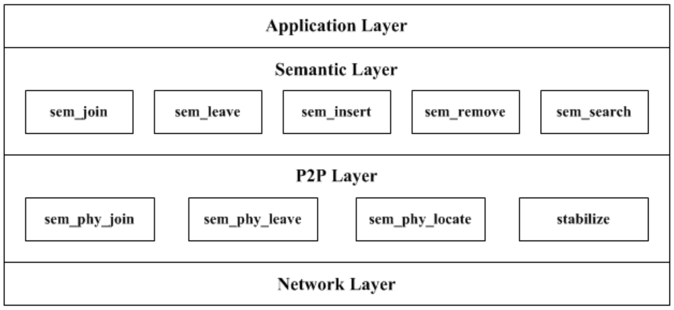


Figure 1. CLP2P system architecture

B. Basic Concepts and Definitions

The CLP2P network interconnects nodes in a ring topology in a similar manner as other overlays, such as Chord or Pastry [12]. However, it is different from Chord and Pastry. Our architecture provides support for clusters of nodes. A physical node represents a user contributing a collection of resources in the network. Any physical node joining CLP2P is assigned a unique identifier that is computed as in Chord by hashing the node's IP address. As the Internet is composed of many autonomous systems, each autonomous system has a unique ASN, ASN can be used as a node's physical location information. Nodes in the same autonomous system are divided into the same physical cluster. A node's physical identifier is achieved with modulo operator ASN. A resource is a persistent object characterized by a set of attributes, including a unique identifier. Each resource has a resource identifier that is computed as Chord by hashing the keywords of the resource. The semantic cluster identifier can be achieved by hashing the name of the semantic cluster. Every user can share resources classified in various categories. CLP2P leverages this classification for computing the degree of interest of a certain user in a cluster. Based on this information, peers self-organize into clusters by joining or leaving different parts of the overlay.

Through dividing physical cluster, semantic cluster is divided into smaller clusters, i.e. semantic + physical clusters.

Each physical node must and only join a semantic cluster, and then join a physical cluster, i.e. a semantic+physical cluster, as a logical node. CLP2P assigns $m+n+l$ (bit) identifier for a logical node. CLP2P logical node identifier is denoted by n_{kij}. For each logical node identifier, the first m (bit) is assigned to the semantic cluster identifier C_k that the node belongs to, where k= 0,1,...,(a-1), a is the total number of semantic clusters. Intermediate n (bit) is assigned to physical cluster identifier A_i that the node belongs to, which i=0,1,...,(b-1), b is the total number of physical clusters. First $m+n$ (bit) represents the semantic+physical cluster which the logical node is in. The semantic+physical cluster denoted by C_k A_i. The last l (bit) is assigned to the physical node identifier n_j, which is achieved by hashing node's IP address.

The number of resources of a node n_j classified in the category associated to cluster k is denoted by r_{kj}. Consequently, a cluster C_k can be formally defined as [4]:

$$C_k = \{r_{kj} \mid n_j \text{ is a physical node sharing } r_{kj} \text{ resource, where } r_{kj} > 0\} \quad (1)$$

CLP2P network can be defined as the union of all clusters:

$$CLP2P = \bigcup_{k=0}^{c-1} C_k \quad (2)$$

Each physical node must join a semantic cluster P_j, P_j is the semantic cluster that the highest number of its resources are classified in：

$$P_j = t \text{ such that } r_{tj} = \max_{k=0}^{c-1}(r_{kj}) \quad (3)$$

Each physical node must join a physical cluster A_j, cluster A_j is the AS which the node is in achieved through module 2^{m1} node's ASN, $m1$ adjusted accordingly with the size of the system.

Each logical node maintains a pointer table which is built as Chord. It keeps the characteristics of Chord, low overhead, high expansibility, and so on.

Each resource can be placed on multiple nodes as a logical resource. Similarly, according to the semantic features each resource as a logic resource is stored in different semantic+ physical cluster. CLP2P assigns $m+n+l$ (bit) identifier for each resource. CLP2P logical resource identifier is denoted by r_{kij}. For each logical resource identifier, the first $m+n$ (bit) is same the logical node identifier, the only difference is that the physical cluster identifier of the resource is same to the contributor node. The last l (bit) is assigned to resource identifier which is achieved by hashing keywords of the resource.

C. P2P Layer

The P2P layer depicted in Fig. 1 provides mechanisms for the construction and maintenance of the P2P overlay network. This layer is not semantic-aware. The main operations of the P2P layer are:

- sem_phy_join: After a node n_j joins a semantic+ physical cluster C_k A_i, it return a logical node n_{kij}. First, the n_j is introduced into its physical cluster by another node n_i in the same autonomous system. And then, the node is introduced into semantic cluster by any node in the same physical cluster. The successor and predecessor nodes are informed and the Chord-like stabilize method is called in order to update the corresponding finger tables. This operation is called by the upper content-aware join operation after deciding the semantic cluster of a physical node.
- sem_phy_leave: Removing the node n_j from a C_k A_i cluster. When leaving, the successor and predecessor nodes are informed and the Chord-like stabilize function is called in order to update the finger tables of all involved nodes.
- sem_phy_locate: Locating and returning an arbitrary node from the cluster C_kA_i. This operation works similarly to the key retrieve algorithm from Chord. The invoking node looks at its finger table for an entry from the target cluster. This operation is used by

joining and stabilizing operations from P2P layer and the search operation from the semantic layer.

- Stabilize is similar to the method with the same name from Chord

D. Semantic Layer

Semantic layer is designed to optimize resource placement, improve the resource search performance. The main operations of semantic layer are as follows:

- sem_join: After node n_j joins the physical cluster through node n_i, according to (3) node n_j computes the kind which the highest number of its resources are classified in, and make sure the semantic cluster that node n_j is be long to.
- sem_insert: Adding a resource r_g to resource library. When adding a resource r_g, it needs to classify the resource r_g according to its main features, and assigns the corresponding semantic cluster identifier to the resource r_g. At the same time, it needs to assign the physical cluster identifier to the resource r_g according to the contributed node n_j.
- sem_search: The node n_j searches a resource r_g. First, according to semantic features of node n_j and resource r_g, if they have same semantic feature, the same semantic cluster identifier and physical cluster identifier as node n_j are assigned to resource r_g. If not, the same semantic cluster identifier and physical cluster identifier as proximal node in finger table whose semantic feature is same to resource r_g is assigned to resource r_g. Subsequently, the remaining resource search process is same as Chord algorithm. If the resource r_g does not be found, it needs to reassign resource's physical cluster identifier.

IV. SIMULATION EXPERIMENT

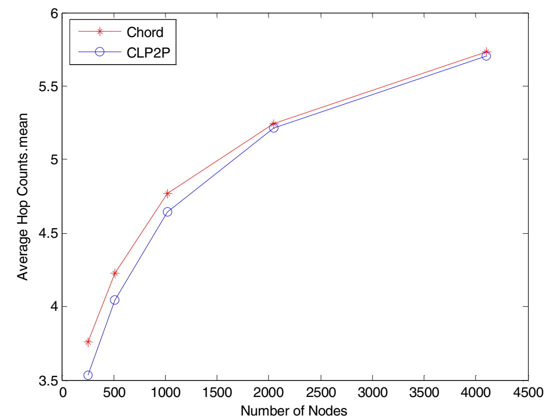
A. Simulation Setup

To illustrate the superiority of CLP2P algorithm, this paper simulates and analyses CLP2P algorithm mainly from four aspects, the network average hop count and the average delay value between nodes, the average resource search success rate and the average resource search delay. CLP2P algorithm which bases on user's interest and the physical location, and classical routing algorithm Chord are simulated and compared. The experiments are completed on OMNET++ + INET + OverSim simulators, we use GT-ITM topology generator to generate the underlying network topology. The underlying network topology consists of 16 autonomous systems, setting transit-transit link delay is 100ms, transit-stub link delay is 20ms, stub-stub link delay is 5ms. Each node randomly joins in one autonomous system. Setting the number of nodes is 256, 512, 1024, 2048, 4096, respectively, simulation time is 5000s.

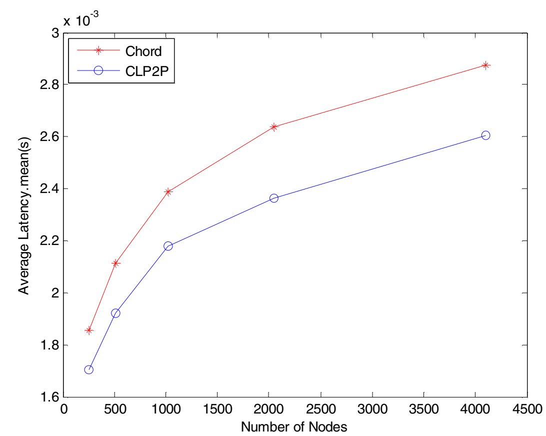
B. Routing Performance Evaluation

A major goal of CLP2P is to solve the mismatch problem between logical network and physical network, consequently reduce the routing cost of P2P system and reduce the network load. Shown in Figure 2 are the routing performances comparison of Chord and CLP2P. From the figure, we can see with the growth of the node, the average routing delay and the average hop count reduced in both CLP2P and Chord system, but CLP2P has better performance.

From the views of average routing count and average routing delay depicted in Fig 2, CLP2P routing efficiency is higher than Chord, especially for the performance of average routing delay. The reason is that CLP2P uses the physical location information to make the logical network and physical network to the agreement.



(a) Average Hop Count

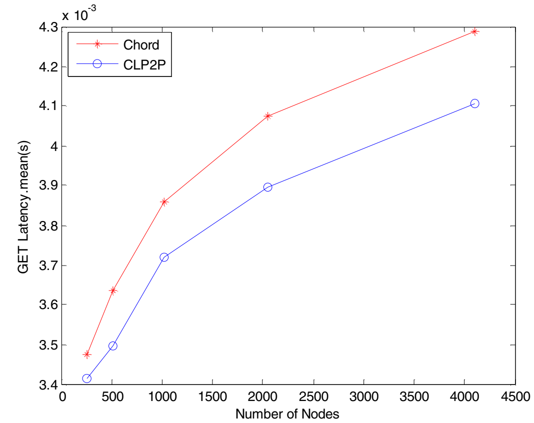


(b) Average Routing Delay

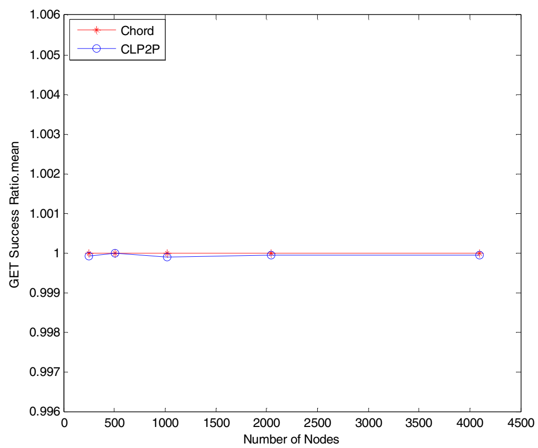
Figure 2. Routing Performance Comparison of Chord and CLP2P

C. Resource Search Performance Evaluation

Another major goal of CLP2P is to solve the resources storage problem. In CLP2P system, each resource has a resource identifier. Resource identifier is designed as the same mentioned above in Ⅱ.B. Resources are divided into 16 classes. In simulation process, the total number of resources is twice as much as the total number of nodes, and the number of each resource replication is 4.



(a) Average Resource Search Latency



(b) Average Resource Search Success Ratio

Figure 3. Resource Search Performance Comparison of Chord and CLP2P

Figure 3 shows that CLP2P proposed in this paper is better than Chord in average resource search delay, and the average rate of resource search is similar to Chord. As the number of nodes increases, the average delay value between CLP2P and Chord is slowly increased, but CLP2P increases more slowly, which indicating that as more and more nodes join the system, the performance of CLP2P is more stable, and the performance will be better. The reasons are as follow: Chord algorithm is lack of understanding of the physical network topology and the study of users' characteristics, which will result in the phenomenon of seeking far and neglecting what lies close at hand in the process of resource search. Instead, CLP2P maps nodes in same autonomous system to the same physical cluster in logical network, and maps nodes with same interest in entire physical network to the same semantic cluster. While nodes in the autonomous region always have the same interest, in the process of resource search, node always starts the search from nodes in same physical cluster of the same semantic cluster, and finds the resources in less number of hops, and thereby reduces the search time. From another side shows most of resources in CLP2P can be found in the local autonomous region, which effectively reduces resource search frequently traversing the backbone network.

V. Conclusions

In order to solve the mismatch problem between physical and logical network topology and resource storage problem in P2P network. This paper quoting the hierarchical thought, synthetically considering users' interest and location and resource location and type, proposes a collaborative CLP2P algorithm, experiments show that the algorithm can not only maintain a high resource location rate and reduce the resource search response time, but also can solve the mismatch problem between physical and logical network topology, effectively avoid the resource search frequently traversing the backbone network, reduce backbone network load, and furtherly optimize the P2P network traffic distribution.

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