Realization of topology awareness in peer-to-peer wireless network

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***Abstract*—In order to match logical topology to physical topology in P2P wireless network, a new protocol based on Chord is proposed, in which a node can get a optimal node identifier(ID) to realize topology awareness by exploiting nodes' relative location information, which is reflected on the energy strength of received signal and the distribution density of P2P member. Simulation results show that the wireless P2P network in the proposed method can avoid route being accessed iteratively. Therefore, it can effectively shorten the time to locate desired file and reduce Packet Loss Rate as well.**

***Index Terms*—Peer-to-peer(P2P), topology aware, Chord**

I. Introduction

P2P applications have got significant growth recently [1] [2]. It is believed to be the dominant communication model in LAN in the near future. Nowadays, there have been several classic P2P lookup protocols, such as Chord [3], CAN [4], Tapestry [5], and Pastry [6], which provides infrastructure for wired P2P networks. And in these protocols, Chord is the most prevalent one, in which node identity(ID) is obtained through hashing its Internet Protocol(IP) address, which makes the adjacent nodes in physical topology scattered in logical topology randomly, resulting in mismatch between overlay network and physical network. Therefore, it leads to path being accessed redundantly during file being located. Consequently, much bandwidth resource is wasted, and collision among sessions occurs much more frequently.

In wireless network, if the traditional P2P lookup protocols are used into wireless communication directly, the performance of the wireless P2P network will decrease greatly because of the great wireless bandwidth wasted, which is not evident in wired P2P network owing to the severs' assistant. Therefore, how to realize the topology awareness in wireless P2P network to improve its performance is hot topic in recent research, which can be classified two branches, named as unstructured manner and structured manner respectively.

In unstructured P2P model, many improved methods have been presented. In [7] and [8], the researchers combine node's IP address and geographical information to form clusters, in which super nodes assist other nodes to fulfil file locating and routing when resource locating occurs. And in [9], author exploits the latency to the predefined landmarks to construct nodes into clusters. Though these methods get high performance for unstructured P2P system, they do not break away from the fatal drawback of single point failure, and it isn't suitable for large scale network.

Because of its good inherent characteristics, the research of topology awareness in structured P2P is the dominant research orientation. In [10], the author tried to enhance locating efficiency by adding a secondary lookup overlay, which is composed of high-capacity nodes, and the close peers in position are grouped into the same Autonomous System(AS). It can reduce the underlying physical routing delay, but it needs some super nodes to manage the system. The method of getting an appropriate node ID by considering the nodes' position in structured P2P is first proposed in [11]. In this protocol, some landmark keys are given at the initialization period, and when some nodes want to join the system, it must try to find the closest landmark node, and get a node ID from its given range. The landmark node and the nodes joined the system by its allocated ID make up a cluster, and the landmark node administer all the other nodes in the cluster. The method proposed in this paper also benefit from applying the technique through which the joining node could get its appropriate ID value.

In [12] and [13], the researchers try to modify the original Chord structure through increasing node's finger table in which its neighbors proximity information is stored. In this way, some improvement to solve the mismatch phenomena has been achieved, but it is far from the topology-aware motivation and they increase the maintenance overhead.

Unfortunately, although the previous suggested protocols can realize topology awareness to some extent, they are hardly suitable for wireless P2P network owing to either the enormous bandwidth consumption or the drawback of single failure, and none of them is designed for wireless P2P network. Consequently, in this paper, we propose a new method to construct topology-aware wireless P2P protocol by exploiting location information. Extensive numerical examples illustrate the effectiveness of the proposed scheme. It is shown that latency and drop-packet rate are decreased, and load capability is improved as well.

The rest of this paper is organized as follows. In section II, the proposed topology-aware wireless P2P model is described in detail. Simulation results and its performance analysis are presented in section III. Finally, some concluding remarks and a brief lookout of our future work are given in section IV.

II. SYSTEM MODEL

The performance of lookup protocols affects the efficiency of locating desired files greatly in P2P networks, and the average hop is shorter, the performance is better. Our research is focused on shortening accessing path to save bandwidth and maximize system capacity in a simple way during file locating.

A. Modify the structure of finger table in Chord

In the finger table of Chord [3], there are node's successors' information, and it is unimportant because the logical topology is irrelevant to physical topology. But it is very important to realize topology awareness in wireless P2P network, in which the nodes's position in the logical topology is related to its actual physical position. In order to keep the storage space unchanged with Chord, in our protocol, the original finger table is divided into two parts, one for predecessors and the other for successors. Consequently, for a node with ID i in the P2P network whose ID space is noted in x bits , its finger table will include all the correspondent information of the following nodes whose IDs are: $(i-2^{\frac{x-1}{2}})|mod\ 2^{\frac{x-1}{2}}, \ldots, (i-2^2)|mod\ 2^{\frac{x-1}{2}}, (i-2^1)|mod\ 2^{\frac{x-1}{2}}, (i+2^1)|mod\ 2^{\frac{x-1}{2}}, (i+2^2)|mod\ 2^{\frac{x-1}{2}}, \ldots, (i+2^{\frac{x-1}{2}})|mod\ 2^{\frac{x-1}{2}}$ respectively.

B. Entering process for applying node

Given an initial P2P network has been formed, when some non-member node wants to join the existing P2P network (In order to convenient describing, if a node have been the network, we call it member node, otherwise, non-member node). It can be shown by $\mathbb{S} = \{u_i | i = 1, 2, \ldots, N\}$, where $\mathbb{S}$ denotes member-node set in applicant's radiation area, and u_i denote the corresponding member node. The entering process are as follow.

Step 1: getting local topology information.

The node, wanting to join existing wireless P2P network, broadcasts request (Time to Live (TTL) is set as 1, in order to guarantee the request packet has been transmitted only once), and waits for answers.

The nodes that receive the entering application responds with the following information besides their node IDs and IP.

1) The received signal energy strength, denoted as $pr = \{pr_i | i = 1, 2, 3, \ldots N\}$. By comparing the energy strength of received signal, the relation distance can be estimated, because the energy strength received at the distance d by the member node from the transmitting node is given by $pr = p_t(\frac{1}{d})^n$;
2) ID space-margin in the finger tables of member nodes, denotes with d_i, which shows how much ID space can be provided in its local area when a node asks for node ID, and it is the most important information to realize load balance.
   For member node i with ID $d_{i,0}$, the IDs of its predecessors and successors are denoted as $d_{i,-1}, d_{i,-2}, d_{i,-3}, \ldots, d_{i,-log_4 M}, d_{i,1}, d_{i,2}, d_{i,3}, \ldots, d_{i,log_4 M}$ respectively.
   During computing the ID space margin of the member node, different weights are set to show different overhead to move node ID when there is not unoccupied ID in the previous level. Consequently, it is calculated as formula (1).

$$\begin{aligned} d_i &= [(d_{i,0} - d_{i,-1}) + (d_{i,1} - d_{i,0})] \times 4^{\log_4 M} \\ &+ \sum_{j=2}^{j=\log_4 M} \left[\left(d_{i,-(j-1)} - d_{i,-j}\right) + (d_{i,j} - d_{i,j-1})\right] \\ &\times 4^{\log_4 M + 1 - j} \end{aligned} \quad (1)$$

Step 2: choosing the optimal node to ask for allocating ID

Combine the received energy strength information and margin space information, choose the most appropriate node to ask for node ID.

Before determine which node is most appropriate for allotting node ID, unitary parameters must be calculated firstly. For node i , its unitary parameters are shown in formula 2, in which $\overline{pr_i}$, $\overline{d_i}$ present the normalized parameters of received energy strength and ID space-margin respectively.

$$\overline{pr_i} = \frac{pr_i}{\sum_{j=1}^{j=N} pr_j}, \overline{d_i} = \frac{d_i}{\sum_{j=1}^{j=N} d_j} \quad (2)$$

According to unitary parameters, some member nodes are excluded from the candidates, and thresholds are denoted as pr_{th}, d_{th} respectively. When $\overline{pr_i} \geq pr_{th}$ or $\overline{d_i} \leq d_{th}$, the i node should be eliminated from candidates, and the integrated parameter is calculated in formula 3, in which $\alpha \geq 0$, $\beta \geq 0$, and $\alpha + \beta = 1$.

$$W_i = \alpha \times \frac{1}{\overline{pr_i}} + \beta \times \overline{d_i} \quad (3)$$

The parameters can be set in different value according to different emphases of network. In our simulation, we set $\alpha = 0.8$, $\beta = 0.2$, in order to emphasize topology awareness in wireless P2P network.

According to the comprehensive parameter W_i, the maximal one is selected to allot node ID.(if there is not any node appropriate, it fails to enter the P2P network, and apply again after a while.)

Step 3: Allot ID for the applicant

The applicant sends out ID allocating request, which includes all the information of other member candidate node in its radiation area. During ID allocated, an unoccupied node ID must be got, so it is probably that some node ID needs to be moved in the finger table. The process is as follow.

1) When there are not any other member nodes' information in the ID request package, in other words, there are only one member node in applicant's radiation area, then the node ID is allotted according the following situations.
   Situation 1: There are some unoccupied IDs at the first level finger table. It is say that $d_{i,0} - d_{i,-1} \neq 0$, or $d_{i,1} - d_{i,0} \neq 0$, then the allocated ID is $ID =$

$RND(\frac{d_{i,0}-d_{i,-1}+1}{2})$ or $ID = RND\left(\frac{d_{i,1}-d_{i,0}+1}{2}\right)$, which is the central ID between $d_{i,0}$ and $d_{i,-1}$ or between $d_{i,0}$ and $d_{i,1}$, where RND denotes getting the integer of expression. And when the value is less than zero, the result has to be added by 2^n, where n is the amount of ID space in bit (it is 16 in our simulation), and it is the same in the following context. Of course, when both $d_{i,0} - d_{i,-1} \neq 0$ and $d_{i,1} - d_{i,0} \neq 0$ are true, the larger one is selected to get node ID.

Situation 2: There aren't any unengaged ID at the first level finger table, that is to say $d_{i,0} - d_{i,-1} = d_{i,1} - d_{i,0} = 0$, then the first predecessor's ID or the first successor's ID must be moved until there are unoccupied ID at the first level, which is that $d_{i,0} - d_{i,-1} \neq 0$ or $d_{i,1} - d_{i,0} \neq 0$ must be guaranteed. Then, the predecessors and successors should move their IDs as $\overline{d_{i,j}} = d_{i,j} + RND(\frac{d_{i,j+1}-d_{i,j}+1}{2})$ and $\overline{d_{i,-j}} = d_{i,-j} - RND\left(\frac{d_{i,-j}-d_{i,-(j+1)}+1}{2}\right)$, where $j = 2, 3, \ldots, n$ denotes the level of predecessor and successor in finger table, until $d_{i,0} - d_{i,-1} \neq 0$ or $d_{i,1} - d_{i,0} \neq 0$ through moving node ID step by step. Of course, the phenomena is uncommon, because the whole ID space is much larger than the actual need and it is divided averagely at initialization stage.

2) If ID request package includes some nodes that are in its radiation area, but they are not in the finger table of node i, then regulation to allot ID is the same as 1) because these nodes are irrelevant to ID allocated.
3) When the request package includes some other nodes' information, some of which are the predecessors or successors of node i, these nodes must be considered during ID allocating. Among these nodes, if there are only predecessors, the nearest predecessor is selected as applicant's successor and node i as the applicant's successor. On the contrary, if there are only some successor nodes, the nearest successor is selected as applicant's successor and node i as the applicant's predecessor. When sone predecessors and successors are both in the application package, the node that has larger ID space is selected as successor or predecessor and node i is selected as predecessor or successor for the application node. Of course, when there aren't unoccupied ID at the first finger table level, it need to remove node ID, which is the same as 1).
4) When the optimal node ID is allocated, response packet is sent to the applicant. And other nodes in the system update their finger table according to the changing in the system.

Step 4: Applicant enter the existing wireless P2P network.

After receiving the allocated ID from system, the applicant broadcasts it file resource information and updates itself finger table according the modified Chord lookup protocol.

III. SIMULATION AND ANALYSIS

In this section, we illustrate the performance of the proposed scheme by simulation in NS (network simulation). In the simulation, wireless P2P network's ratio of physical hops to logical hops, Package Loss Rate and latency to locate desired files are tested, which is compared to that of PChord [12] and TCS-Chord [13]. The simulation scenario and parameters are set as follows.

1) Each node is configured using the 802.11 MAC layer;
2) simulation takes place in a rectangular area measuring 800 by 800 square meters, where nodes are distributed randomly;
3) Wireless propagation model is Two-ray Ground Model, the application flow model are CBR. Packet size is 512 bytes, and it is sent every two second with transmitting power 100mW.
4) Set $\alpha = 0.8$ and $\beta = 0.2$

A. simulation of average stretch and average latency

To test the efficiency of our proposed scheme to realize topology awareness, which is reflected on the ratio of the physical hops to logical hops during all desired file located, we assume that all the file locating are successful, so TTL(Time To Live) of data package is set to be infinite (in our simulation, it is set at 10000), and the interval of sending message is enough.

In our simulation, node is selected randomly, and it sends message every two seconds, until all nodes in the network have located all the files in the system. In contrast with previous lookup protocols, such as Chord, PChord and TCS-Chord in wireless scenario, the average the ratio of physical hops to logical hops and latency are shown in Fig.1 and Fig.2.

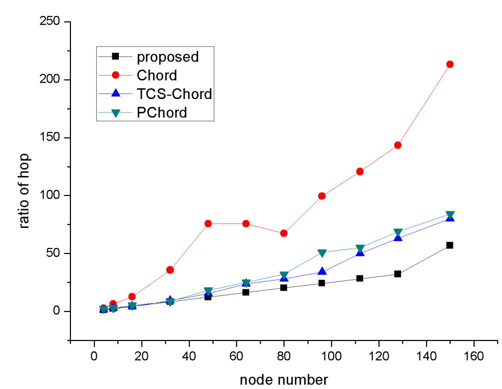

Fig. 1. ratio comparison hop number

Fig.1 shows that though the ratio of physical hops to logical hops in our proposed scheme is not much smaller than that of previous lookup protocols in small scale wireless P2P network, its superiority is very obvious to large scale networks, in which the amount of nodes is more than 30. So the match between logical topology and physical topology is improved.

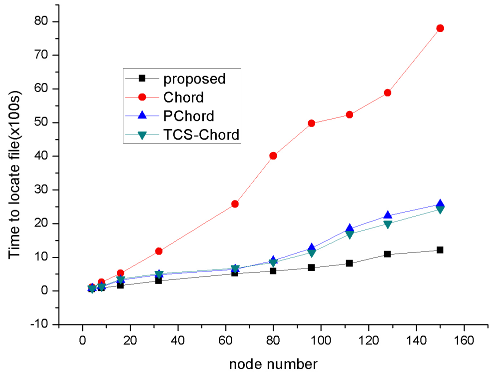

Fig. 2. average time to locate file

The average time to locate a file in the assumed system is shown in Fig.2, which is compared with that of protocol Chord, PChord and TCS-Chord. It is clearly that the time in our proposed protocol is decreased greatly, which is owing to improvement of topology awareness in the proposed P2P protocol, in which the path being accessed redundantly during file locating is avoided.

B. simulation of system load

In order to compare the system's load when the same assignment is implemented, TTL is set as 200, and other parameters are set as default in NS. During locating desired files, the Package Loss Rates are reckoned out respectively, which is shown in Fig.3.

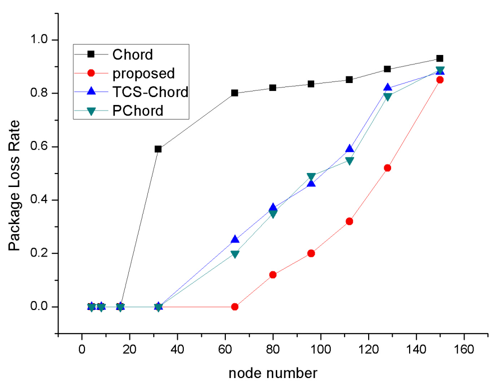

Fig. 3. Package Loss Rate during file location

It is obvious that when there is only a few nodes in wireless P2P network, there are't any packages being dropped in all the four protocols. However, when scale becomes larger and larger, the drop-package rate increases rapidly. But the increased speed in the proposed scheme is much slower than that of all the previous protocols, as the probability to collide during package transmitted is decreased greatly. Of course, it is owed to the saving of wireless bandwidth resource by eliminating the phenomena of path being accessed iteratively during the same file location. Consequently, the wireless P2P network in the proposed protocol has greater capacity in the same network scenario.

IV. Conclusion

The node's position information is exploited when new node applies for joining the exiting P2P network, through which adjacent nodes get similar node ID, and match between overlay network and physical network is realized effectively. So wireless bandwidth is saved and system performance is improved.

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