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A TOPOLOGY-AWARE PEER-TO-PEER PROTOCOL APPLICABLE TO WIRELESS NETWORK

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Abstract

Aiming to eliminate the mismatch between structured peer-to-peer (P2P) network's logical topology and physical topology, which exists in these classic wired P2P protocols, the representative P2P protocol-Chord which is hardly suitable for wireless network is modified, and an approach of getting optimal node identifier (ID) to realize topology awareness is proposed by exploiting nodes' relative location information. Simulation shows that the wireless P2P network in the proposed method can reduce Packet Loss Rate and minimize the number of hop to locate file effectively.

Keywords: Peer-to-peer(P2P), topology aware, cross layer, MANETs

1 Introduction

In recent years, P2P applications have got significant growth [1-4]. It is believed that P2P will be the dominant communication model in LAN in the near future. Nowadays, there have been several classic P2P lookup protocols, which provides infrastructure for wired P2P networks. And in these protocols, Chord [5] 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.

With the recent advances in wireless communication technologies, it is widely envisioned that P2P applications will be popular in wireless networks. However, if the traditional P2P lookup protocols, such as Chord[5], CAN[6], Tapestry[7], and Pastry[8], 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, in order to improve lookup efficiency, many smart methods have been presented. In [9] and [10], the researchers combine node's IP address and geographical information to form clusters, in which super nodes assist other nodes to fulfill file locating and routing when resource locating occurs. Another method to construct a topology-aware P2P model is presented in [11], in which the author exploits the latency to the predefined landmarks to construct nodes into clusters, but the process is coarse and it needs the landmark nodes keeping steady. Though these methods get high performance for unstructured P2P system, they do not break away from the fatal drawback of single point failure.

The research of topology awareness in structured P2P is the dominant research orientation. In [12], 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 [13]. 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 administers 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 [14] and [15], the researchers try to modify the original Chord structure through increasing node's finger table in which its neighbor proximity information is stored. In this way, some

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improvement to solve the mismatch phenomena has been achieved, but it is far from the topology-aware motivation and they increase the maintenance overhead.

In some new methods, some future protocols are exploited, such as in [16-17]. In these literatures, all the methods are based on some special protocols. For example, in the literature [17], the researchers use IPV6 to realize their construction. If the proposed protocols are good performance and easy to realize, higher efficiency can be achieved. But they do not provide authentic methods which can be used in wireless P2P application currently.

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 consumed or the drawback of single failure. Consequently, in this paper, we propose a new method to construct the 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 2, the construction of lookup ring is presented. In section 3, the proposed topology-aware wireless P2P model is described in detail. Simulation results and its performance analysis are presented in section 4. Finally, some concluding remarks and a brief lookout of our future work are given in section 5.

2 Lookup ring construction

The efficiency to locate the desired files in P2P networks depends on the performance of lookup protocols. Our research is focused on shortening accessing path to save bandwidth and maximize system capacity in a simple way during file locating.

2.1 Structure of finger table in lookup ring

In Chord[5], node's finger table records only its successors without predecessors, and it is unimportant for wired P2P network because of the server's assistant. But it is very important to realize topology awareness in wireless P2P network, in which the nodes' 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:

$$\left(i-2^{x-1/2}\right)\bmod 2^{x-1/2},\cdots\left(i-2^{2}\right)\bmod 2^{x-1/2},$$

$$\left(i-2^{1}\right)\bmod 2^{x-1/2},\left(i+2^{1}\right)\bmod 2^{x-1/2},\cdots$$

$$\left(i+2^{x-3/2}\right)\bmod 2^{x-1/2},\left(i+2^{x-1/2}\right)\bmod 2^{x-1/2}$$ respectively, which is shown in Figure 1, where ID space is denoted in 6 bits.

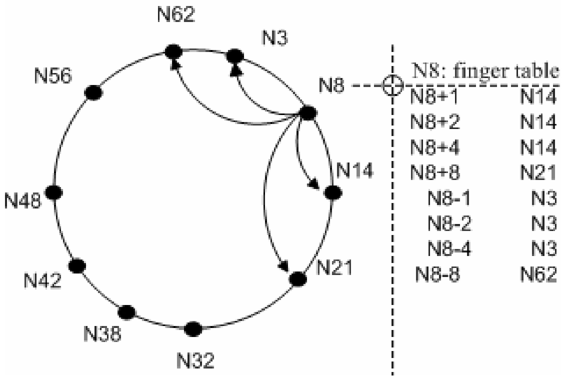

Figure 1. Modified Chord structure

2.2 ID distribution during network Initialization

In local area, when a wireless terminal wants to construct a P2P network, it will launch its neighbors to enter the invitation by broadcasting and get their position information. In order to realize load balance and minimize consumption when some other node joins the network, the ID space must be divided averagely by the original participant nodes according to their interrelation in position when the P2P network is constructed originally. At the initial stage, suppose there are four nodes, noted as A, B, C and D, and the distance between them are equal, which is shown as Figure 2. Consequently, the IDs allotted for nodes are 0x2000, 0x6000, 0xA000, 0xE000 respectively (the ID space is denoted in 16 bits, which is motivated to convenient for describing). Of course, the node IDs are allocated by the sponsor, and they construct a small P2P network according to Chord lookup protocol.

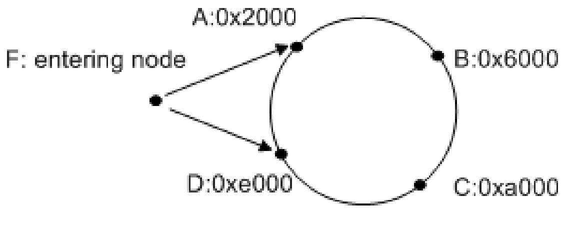

Figure 2. Process to enter existing network

3 Realization of file location

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), shown in Figure 2 (suppose node F wants to join P2P network), it will broadcast its request, which will be received by all the member nodes in its radiation area (In Figure 2, in F's radiation area, there are two member nodes, A and B). It can be shown by $S = \{u_i \mid i = 1,2\cdots, N\}$, where S denotes member-node set in applicant's radiation area, and u_i denotes the corresponding member node. The entering process is as follow.

Step 1: obtaining neighbor information.

After initial network has been set up, if some node wants to join existing wireless P2P network, it 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, shown as Figure 2, in which node F broadcasts its application and waits for reply.

When nodes receive the entering application, they respond with the following information besides their node IDs and IP: (In Figure 2, node A and B are located in the radiation area, so they receive the request).

(1) The received signal energy strength, denoted as. 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 $pr = p_t(1/d)^n$, and which is the nearest can get;

(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 $d_{i,-1}, d_{i,-2}, \cdots d_{i,-\log 4} M, d_{i,1}, d_{i,2}, \cdots, d_{i,\log 4} M$.

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).

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

Step 2: selecting the optimal node to ask for ID

Received energy strength information and margin space information are considered together, and the most appropriate node to ask for node ID is chosen. Before determine which node is most appropriate for allotting node ID, parameters must be normalized. 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 $\overline{pr_i} \ge pr_{th}$ or $\overline{d_i} \le d_{th}$, the i node should be eliminated from candidates, and the integrated parameter is calculated in formula (3), in which $\alpha \ge 0, \beta \ge 0$, 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: getting ID from system

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 $d_{i,0} - d_{i,-1} \ne 0$, or $d_{i,1} - d_{i,0} \ne 0$, then the allocated ID is $ID = RND\left(\frac{d_{i,0} - d_{i,-1}}{2}\right)$ or $ID = RND\left(\frac{d_{i,1} - d_{i,0}}{2}\right)$, 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. 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 16in our simulation), and it is the same in the following context. Of course, when both $d_{i,0} - d_{i,-1} \ne 0$ and $d_{i,1} - d_{i,0} \ne 0$ 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 means that $d_{i,0} - d_{i,-1} \neq 0$ or $d_{i,1} - d_{i,0} \neq 0$ is guaranteed. Then, the predecessors and successors should move their IDs as $\overline{d_{i,j}} = d_{i,j} + RND((d_{i,j+1} - d_{i,j} + 1)/2)$

and $\overline{d_{i,-j}} = d_{i,-j} - RND((d_{i,-j} - d_{i,-j-1} + 1)/2)$, where $j = 2,3,\cdots,n$ 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 are 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 some 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. And the applicant node enters the wireless P2P network.

4 simulation and analysis

In our simulation, all statistic data is got through NS(network simulation), in which wireless P2P network's ratio of physical hops to logical hops, Package Loss Rate are tested, which is compared to that of PChord[14] and TCS-Chord[15]. 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, and $\alpha = 0.8$ and $\beta = 0.2$.

4.1 simulation of average stretch

In order to testify the efficiency of the proposed scheme to realize topology awareness, the rate logical hops to physical hops are compared. Consequently, 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 between sent message is long enough.

During simulation, nodes are selected randomly, and they send 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 Figure 3.

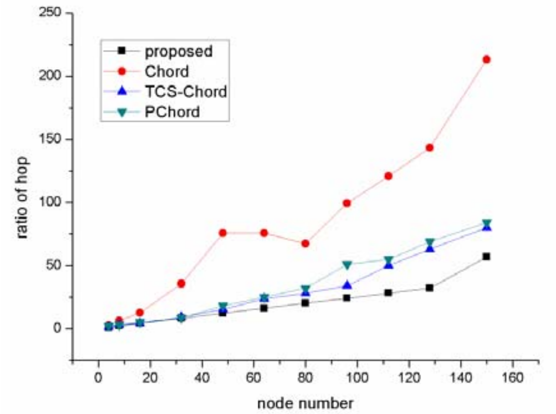

Figure 3. Ratio comparison hop number

The ratio of physical hops to logical hops in our proposed scheme is shown as Figure 3, it is clear that it is not much smaller than that of previous lookup protocols in small scale wireless P2P network, but its superiority is very obvious in large scale networks, in which the amount of nodes is more than 30. So the match between logical topology and physical topology is improved.

4.2 simulation of system load

System load is reflected on drop rate when the same assignment is implemented. Consequently, we compare its drop rate with that of other network protocol. During simulation, TTL is set as 200, and other parameters are set as default in NS. When desired files are locating, the Package Loss Rates are reckoned out respectively, which is shown in Figure 4.

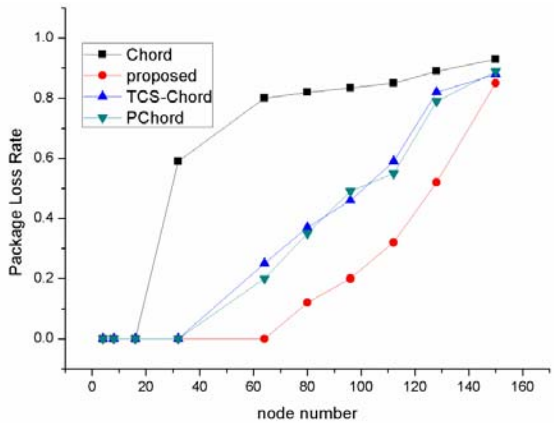

Figure 4. Package Loss Rate during file location

From Figure 4, we can see that when there is only a few nodes in wireless P2P network, there aren'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.

5 Conclusions

In this paper, 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. So the match between overlay network and physical network is realized effectively.The simulation result shows that the P2P network based on our protocol bears the following performance:

1) Avoiding node being accessed iteratively during the desired file location;
2) It is much faster to locate a file;
3) Larger capacity of the system.

We solve the problem of mismatch when the P2P system is constructed over Ad Hoc network in an effective way when the nodes are static. But, the nodes in Ad Hoc perhaps move randomly, so the topology must change as some nodes move or some nodes depart from the network. So we will study the realization of topology-aware P2P in dynamic scenarios in the next step.

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References

[1] Andrew Ka-Ho Leung, Yu-Kwong Kwok. On Localized Application-Driven Topology Control for Energy-Efficient Wireless Peer-to-Peer File Sharing. IEEE Transactions on Mobile Computing, VOL.7, NO.1, pp.66-80, 2008

[2] Reaz Ahmed, Raouf Boutaba. Distributed pattern matching: a key toflexible and efficient P2P search. IEEE Journal on Selected Areas in Communications,Vol.25,NO.1,pp.73-83, 2007

[3] Rongmei Zhang, Charlie Hu. Assisted peer-to-peer search with partialindexing. IEEE Transactions on Parallel and Distributed Systems,VOL.18, NO.8, pp.1146-1158, 2007

[4] Szu-Chi Wang, Hong-Zu Chou, Sy-Yen Kuo. On the Fundamental Performance Limits of Peer-to-Peer Data Replication in Wireless Ad hoc Networks. IEEE Journal on Selected Areas in Communications,VOL.25, NO.1, pp.211-221, 2007

[5] Robert Morris, David Liben-Nowell, et al. Chord: a scalable peer-to-peer lookup protocol for internet applications. IEEE/ACM Transactions on Networking, VOL.11, NO.1, pp.17-32, 2003

[6] Ratnasamy S, Francis P, Handley M, et al. A scalable content-addressable network. In: Proceedings of ACM SIGCOMM. San Diego, CA, USA Aug 27-31,pp.161-172, 2001

[7] Ben Y. Zhao, Ling Huang, Jeremy Stribling, et al. Tapestry: a resilient global-scale overlay for service deployment. IEEE Journal on Selected Areas in Communications, VOL.22, NO.1, pp.42-53, 2004

[8] Rowstron A, Druschel P. Pastry: Scalable, decentralized object location and routing for large-scale peer-to-peer systems. In: Proc. of the 18th IFIP/ACM Int'l Conf. on Distributed Systems Platforms. Berlin: Springer-Verlag,Nov 12-16, pp.329-350, 2001

[9] Le,H.Hong, D. Simmonds, A. A self-organizing model for topology-aware overlay formation. 2005 IEEE International Communications Conference. Seoul, Korea, pp.1566-1571, 2005

[10] Jia Zhao, Jiande Lu. Solving overlay mismatching of unstructured P2P networks using physical locality information. Proceedings of the Sixth IEEE International Conference on Peer-to-Peer Computing. Cambridge, United Kingdom, pp.75-76, Sep 6-9, 2006

[11] Zhe Xiang, Qian Zhang. Peer-to-peer based multimedia distribution service. IEEE Transactions on Multimedia. VOL.343, NO.2, pp.343-355,2004

[12] Gisik Kwon; Kyung Dong Ryu; BYPASS: topology-aware lookup overlay for DHT-

based P2P file locating services. Proceedings of the Tenth International Conference on Parallel and Distributed Systems, Santa Fe, New Mexico,July7-9, pp.297-304, 2004
[13] Yun-Shuai Yu, Yu-Ben Miao, Ce-Kuen Shieh. Improving the lookup performance of Chord network by hashing landmark clusters. 14th IEEE International Conference on Networks, Singapore, Sept13-15, pp.1-4, 2006
[14] Feng Hong, Minglu Li, Jiadi Yu. PChord: improvement on Chord to achieve better routing efficiency by exploiting proximity. Proceedings of the 25th IEEE International Conference on Distributed Computing Systems Workshops, Ohio, USA, June 6-10, pp.806-811, 2006
[15] Liu Ye, Yang Peng, Chu Zi, Wu Jiagao. TCS-Chord: an improved routing algorithm to Chord based on the topology-aware clustering in self-organizing mode. Proceedings of the First International Conference on Semantics, Knowledge, and Grid, Beijing, China, Nov 28-29, pp.25-25, 2005
[16] Jianqun Cui, Yanxiang He, Libing Wu. More efficient mechanism of topology-aware overlay construction in application-layer multicast. International Conference on Networking, Architecture, and Storage, Guilin, China, July 29-31, pp.29-31, 2007
[17] Le Hai Dao, JongWon Kim. AChord: topology-aware Chord in anycast-enabled networks. 2006 International Conference on Hybrid Information Technology, Cheju Island, Korea, Nov9-11,pp.334-341,2006