계층적 P2P 시스템의 효율적 관리를 위한 네트워크 거리 기반 운영 기법

論 文
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An Efficient Management Scheme of Hierarchical P2P System based on Network Distance

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Abstract

Many peer-to-peer (p2p) systems have been studied in distributed, ubiquitous computing environments. Distributed hash table (DHT)-based p2p systems can improve load-balancing even though locality utilization and user mobility are not guaranteed. We propose a mobile locality-based hierarchical p2p overlay network (MLH-Net) to address locality problems without any other services. MLH-Net utilizes mobility features in a mobile environment. MLH-Net is constructed as two layers, an upper layer formed with super-nodes and a lower layer formed with normal-nodes. Because super-nodes can share advertisements, we can guarantee physical locality utilization between a requestor and a target during any discovery process. To overcome a node failure, we propose a simple recovery mechanism. The simulation results demonstrate that MLH-Net can decrease discovery routing hops by 15% compared with JXTA and 66% compared with Chord.

Keywords : DHT, Locality, Mobile, Peer-to-Peer, Resource Management, Ubiquitous computing

I. Introduction

In distributed, ubiquitous computing environments, peer-to-peer (p2p) systems have been studied. These p2p systems are self-organizing, share resources, and cooperate among independent nodes. However, deploying a p2p overlay network in a mobile environment is challenging.

Some well-known p2p file sharing systems, such as Gnutella [1] and Napster [2], are unstructured p2p systems. In Gnutella, a flooding mechanism is used to find a resource or a node without any central organization in a p2p overlay network. In Napster, a central server is used to manage directories containing the shared files. However, these p2p systems have scalability problems.

To overcome scalability problems, distributed hash table (DHT)-based p2p systems, such as CAN [8], Chord [9], Pastry [10], Tapestry [11], Freenet [12] and JXTA [3-7] have been proposed. Chord, Pastry, and Tapestry are based on a ring-based overlay network. CAN creates an overlay network based on a virtual n-dimensional Cartesian coordinate space, and JXTA creates a DHT-based hierarchical p2p overlay network. Although these systems use different routing algorithms, they have common features such as supporting self-organizing without a centralized structure, guaranteeing fault-tolerance, and using a consistent hash function to distribute resources in a p2p overlay network. These systems cannot guarantee a physically short distance between a requestor and its target, called

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the locality problem.

DHT-based p2p systems distribute nodes and resources uniformly over a p2p overlay network. These p2p systems provide good load-balancing, but they have a locality problem. In a mobile environment, there are many mobile devices such as PDAs and cell phones, and query results from resources that are physically close to the requestor should be more efficient and useful. Therefore, we should support both locality and mobility when deploying a p2p overlay network in a mobile environment.

In this paper, we propose a mobile locality-based hierarchical p2p overlay network, called MLH-Net. It is based on the p2p overlay network of JXTA. MLH-Net is motivated to address locality problems without other external services, to provide load-balancing of DHT simultaneously, and to support mobility. In a mobile environment, there are major limitations such as limited power, computing capability, bandwidth, storage space, and an insufficient user interface. To deploy a p2p overlay network in a mobile environment, these limitations should be considered. In particular, we have considered mobility and locality as important features. MLH-Net addresses the locality problem by using mobility without any other external services such as GPS. Second, we provide a recovery mechanism within a given p2p overlay network to support mobility because the p2p overlay network should be dynamically reconfigured. Finally, we propose a locality-based list of super-nodes to provide locality-based discovery. Because the MLH-Net guarantees one hop during the locality-based discovery process, simulation results show that our p2p system can decrease discovery routing hops by 13% compared with JXTA and 69% compared with Chord. It can decrease discovery routing distance by 17% compared with JXTA and 83% compared with Chord depending on any given environment.

The rest of this paper is organized as follows. Other p2p systems for improving locality are described in Section 2. The system overview is introduced in Section 3, and the simulation results are analyzed in Section 4.

II. Related Work

JXTA [3-7] authors considered a DHT-based hierarchical p2p overlay network consisting of two layers. Rendezvous peers have super-nodes configure one layer, an upper layer, and edge peers have normal-nodes configure the other layer, a lower layer. Rendezvous peers have better performance than edge peers, have high bandwidth usage, and configure an upper layer. Shared resource distributed index (SRDI), a basic discovery model in JXTA, was proposed for the discovery mechanism. Rendezvous peers use this DHT-based scheme to find an index rendezvous peer. This peer recognizes a rendezvous peer by knowing a discovery target. When an edge peer wants to find a node or a resource, it first constructs a connection with a rendezvous peer and then sends a query to the connected rendezvous peer. The query is propagated from the rendezvous peer to the index rendezvous peer and it is propagated from the index rendezvous peer to the rendezvous peer which is connected to the target. The edge peer with the resource sends a response to the requestor. Propagation is based on the rendezvous peer view (RPV), a list of other known rendezvous peers in the upper layer. Although this discovery mechanism improves discovery time and distance, JXTA cannot support locality.

To address the locality problem, p2p systems such as Grapes [13], SkipNet [14], Brocade [15], and Jelly [16] have designed their own approaches. Grapes uses a hierarchical virtual network to support lookup services. The hierarchical virtual network consists of sub-networks which consist of physically close nodes and a super-network which consists of the leaders of sub-networks. Resources and nodes increase in a sub-network and then the leader of that sub-network sacrifices load-balancing in a super-network. Our goal is to deploy a p2p overlay network for improving locality in a mobile environment. These systems cannot support both locality and mobility.

SkipNet [14] uses a scalable overlay network to provide two kinds of locality: content locality and path locality. Content locality distributes data to a specific node in a given organization, and path locality prevents messages between two nodes in the same organization from being routed outside that organization. To provide efficient message routing, they use two separate, but related address spaces: a string name ID space and a numeric ID space. The string name ID space is mapped by node names and content identifier strings, and the numeric ID space is mapped by hash values of the node names and content identifiers. SkipNet cannot provide load-balancing for the overall system but instead provides constrained load-balancing for a subset of nodes in a system.

Jelly [16] proposed a dynamic hierarchical overlay network to address locality problems and to guarantee load-balancing. It is based on Grapes. It utilizes the physical distance information among nodes to construct a two-layered overlay network. When a node joins a p2p overlay network, the physical distance to each leader is checked and the size of the sub-network is limited. The joined node either joins the sub-network or becomes a new leader. To rebalance a p2p overlay network, a dynamic checking mechanism was proposed. Each leader in a sub-network checks the size of its own sub-network periodically. If the size is lower than a limit, the sub-network merges with another close, small sub-network. It can guarantee locality for a sub-network in a p2p system during the discovery process but not for an overall p2p system. Although the number of nodes is load-balanced, the number of resources is not considered.

III. System Overview

In this section, we overview the proposed p2p system, a mobile locality-based hierarchical p2p overlay network. Specifically, its structure and management mechanism are explained. MLH-Net is constructed as two layers, i.e., the upper layer and the lower layer. The upper layer is configured with super-nodes and the lower layer is configured with normal-nodes, where each normal-node is connected to its associated super-node.

An example of the proposed p2p system, as shown in Fig. 1, shows the basic structure of MLH-Net. As in Fig. 1, a super-node is connected to a group of normal-nodes, which are connected to each other. When a normal-node needs to identify some specific resources, a discovery query is propagated through the upper layer. If this request can be serviced by any specific target, which is physically close to itself, propagating this query may waste network bandwidth and cause unnecessary traffic. The main goal of MLH-Net is to prevent a discovery query from being propagated through the overall p2p overlay network and thus to guarantee a physically short distance between requestor and target. The distance is defined as the number of network hops between any two nodes. To achieve this goal, a group of

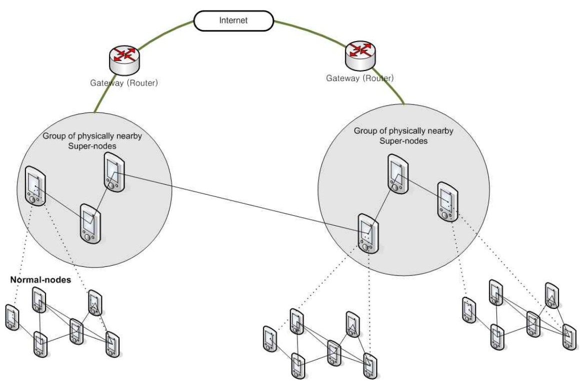

Fig. 1. An example of the proposed p2p system

physically close super-nodes is constructed for efficient management. The mechanism for this group will be discussed in the next section.

1. The mechanism of PCSN-List

For the upper layer configuration of MLH-Net, a physically close super-nodes list (PCSN-List) is specified to be a set of information about physically close super-nodes in a p2p overlay network. The PCSN-List is configured with two sub-lists, i.e., within max-hop super-nodes list (WMSN-List) and out of max-hop super-nodes list (OMSN-List). The max-hop is the maximum hop value over a p2p overlay network as a standard value to determine whether super-node data are maintained in the WMSN-List or in the OMSN-List. Those super-nodes, whose hop values are equal to or less than the max-hop value of a PCSN-List owner, can be maintained in the WMSN-List.

The data structure of PCSN-List is shown in Table 1. WMSN-List is the list of super-nodes that are physically close to the owner for sharing resources, formed as two fields, 'bExtend' and an array of super-nodes, which are constructed as 6 fields as shown in Table 2. OMSN-List is the list of super-nodes that are physically close to the owner but cannot be maintained in the WMSN-List for the same purpose, formed as one field which is an array of super-nodes. Data fields in Table 2 are formed to be the minimum information about physically close super-nodes required to configure the PCSN-List for efficient resource sharing between super-nodes. The 'bExtend' in Table 1 refers to whether the WMSN-List is full or not. WMSN-List can be extended to its limit continuously. So, if the WMSN-List cannot be extended anymore, the 'bExtend' value is set for false. The 'name' denotes the name of a super-node, 'identifier' is a unique identification value in a p2p overlay network, 'IP address' is the IP address of a super-node, 'hop' is an overlay network hop value between super-nodes, 'max-hop' is an overlay network boundary value, and 'time stamp' is the last updating time of a super-node data.

Table 1. The data structure of PCSN-List

PCSN-List				
WMSN-List	bExtend	array of super-node	OMSN-List	array of super-node

Table 2. The data structure of a super-node

super-node	name	identifier	IP address	hop	max-hop	t-stamp

In Table 2, the hop value refers to an overlay network hop value from the PCSN-List owner to another super-node in the PCSN-List. It can be calculated from the exchange of PCSN-List between any two super-nodes when a normal-node moves from the sub-network of a super-node to the sub-network of another super-node. For example, suppose there are super-nodes A, B, and C. If the PCSN-List of A maintains the data for A and C, where their hops are zero and one respectively, and if the PCSN-List of B maintains its own data: hop is zero, and a node moves from A to B, then A and B exchange their PCSN-Lists. When a super-node receives the PCSN-List from another super-node, the receiving super-node stores the received PCSN-List to its own PCSN-List, and the hop value of each super-node increases by one. Now, we can see that the hop value of the super-node A data in the PCSN-List of B is one and the hop value of the super-node C data in the PCSN-List of B is two. Because we cannot be sure that C is right next to B, assigning the hop value of the super-node C data to be two is correct until B and C exchange their PCSN-Lists directly.

2. Locality-based resource discovery using PCSN-List

In this section, a locality-based resource discovery mechanism and the reason why this mechanism is needed are described.

The scenario below shows one example of when locality-based resource discovery is needed, as shown in Fig. 2.

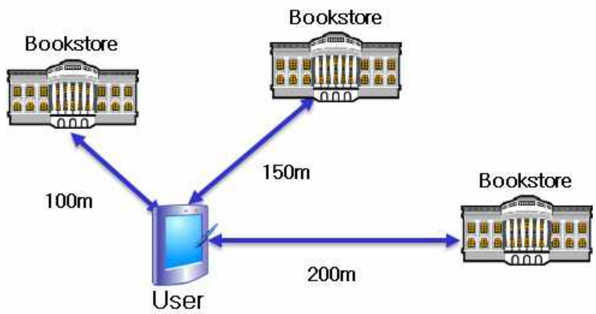

Fig. 2. An example of discovering a bookstore

Scenario

Suppose that a user seeks a nearby bookstore.

The user lacks information on this area and does not need many results. Results should identify only the nearest or a few nearby bookstores.

The query does not need to be propagated to other super-nodes in a p2p overlay network. With MLH-Net, the user can find a nearby bookstore without any other external services such as GPS. The user can find a bookstore within 100 meters as in Fig. 2. To achieve this goal, a locality-based resource discovery method is needed.

For p2p systems, the mechanisms of publishing and discovering resources are important and they are related to the routing mechanism. The number of overlay network hops, as determined by a routing mechanism, is directly related to the performance of a p2p system as measured by network bandwidth usage and discovery time. In other words, those mechanisms directly contribute to overall performance. Thus, they should be designed very efficiently.

First of all, we have to guarantee that query results do not maintain much data and that the results contain any resource which is physically close to the requestor. A DHT-based p2p system distributes resources in a general way. Therefore, a requestor and a target can be physically far away from each other. The p2p overlay network can be stressed when any discovery query is propagated through the p2p overlay network to find its target. This situation is improper when physically close resources are useful. We have to address this problem without sacrificing load-balancing.

In MLH-Net, PCSN-List can reduce overlay network hops. The locality-based resource discovery method does not need a special mechanism because advertisements are already shared by virtue of PCSN-List before being discovered. For example, when a user publishes an advertisement, the advertisement is passed to the connected super-node and shared with the super-nodes in the PCSN-List. The locality-based resource discovery method can be executed just like any ordinary discovery method. Although the process of propagating advertisements requires some overhead, the locality-based resource discovery method does not cause a large burden on a p2p overlay network and it provides more advantages. First, it guarantees that the discovered resource is physically close to the requestor. Second, the query is not propagated to other super-nodes through a p2p overlay network. Finally, user mobility and location are considered. The simulation results in the next section show the performance of our locality-based resource discovery method.

IV. Evaluation

The fundamental p2p overlay network of MLH-Net is based on JXTA. In this section, we describe the basic discovery mechanism, SRDI of JXTA, and then discuss simulation results.

In the experiments, when a node moves, a moving node is selected in random order and when a node discovers a resource, the discovering node and its target resource are also selected in random order.

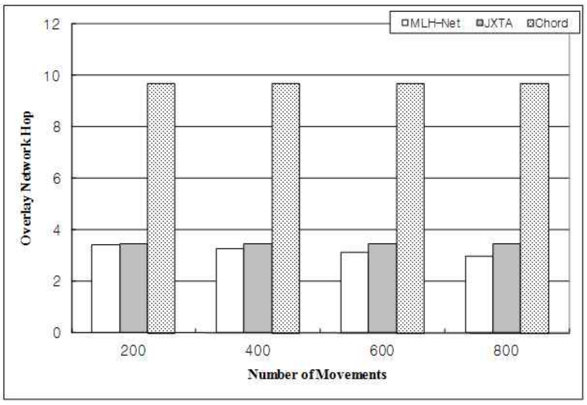

Fig. 3. Hops for an increasing number of nodes

When the number of nodes increases, simulation results for the overlay network hop and the average total distance to the target are obtained as in Fig. 3 and Fig. 4. In this experiment, some parameters are chosen to have limited values, namely a map size of 200.200. The percentage of super-nodes is 20% over the total number of nodes. The max-hop value in MLH-Net is two on average. The number of movements is 300, and the number of discoveries

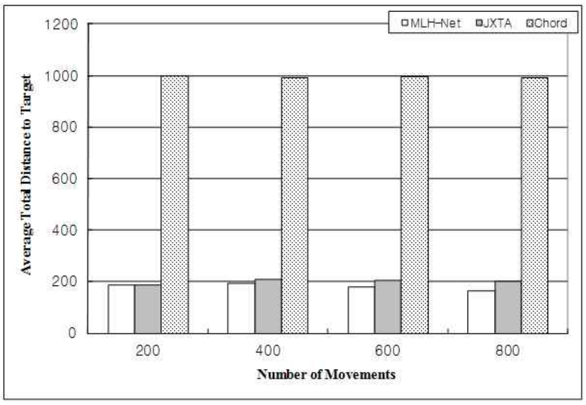

Fig. 4. Average distance for an increasing number of nodes

is 700.

In Fig. 3, the gap between MLH-Net and Chord increases when the number of nodes increases. Although discoveries are made randomly, because some discoveries are handled in a locality-based manner, the hop values of MLH-Net are not greater than 4 hops. For the first graph of 500/100, the hop value of MLH-Net is 2.92. This is a 15% decrease compared with JXTA, which is 3.45, and a 66% decrease compared with that of Chord, i.e., 8.84.

In Fig. 4, the y-axis shows the average total distance to target for any discovery query that is being propagated. When the number of nodes increases, the y-axis value of Chord increases and the gap between MLH-Net and Chord increases. For the first graph of 500/100, the y-axis value of MLH-Net is 162. This is a 23% decrease compared with that of JXTA, which is 211 and an 82% decrease compared with that of Chord, which is 906.

V. Conclusion

To deploy a p2p overlay network in a mobile environment, we must consider several features of a mobile environment. To provide a mobile p2p system, we propose an MLH-Net. This is a mobile locality-based p2p overlay network that does not destroy the load-balancing advantage of DHT. MLH-Net uses mobility in a positive manner when the PCSN-List is exchanged and extended. In the experiments, MLH-Net decreases discovery routing hops by 15% compared with JXTA and by 66% compared with Chord. MLH-Net provides a locality-based discovery mechanism based on PCSN-List being configured by using mobility. It can be deployed in any mobile environment for enhancing locality without any other external services.

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