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모바일애드혹 네트워크에서의 2계층 피어-투-피어 시스템

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요 약

모바일 기술이 발전함에 따라 모바일 장치들간의 파일 검색 문제가 더욱 중요한 문제로 부각되었다. 본 논문에서는 2계층 구조를 갖는 모바일 애드혹 네트워크에서 파일을 효율적으로 검색하기 위한 *uniform grid, greedy, MIS* P2P 시스템들을 제안한다. 이 시스템들에서 피어들은 슈퍼 피어와 서브 피어 2가지로 분류되고, 각 슈퍼 피어는 주변의 서브피어들을 관리한다. 제안하는 시스템들에서 피어가 파일 검색을 요청할 때, 검색 쿼리 메시지는 네트워크의 슈퍼 피어들을 통해서 전달되며, 이를 위해 각 슈퍼 피어는 이웃 슈퍼 피어를 연결하는 경로 역할을 하는 서브 피어들을 유지한다. 따라서 제안하는 시스템들은 멀티 브로드캐스팅을 피할 수 있고 네트워크 오버헤드를 줄일 수 있다. 실험 결과 제안하는 시스템들은 원하는 파일을 찾기 위한 평균 메시지 수를 통하여 1계층 P2P 시스템보다 좋은 성능을 보였다. 특히, 그 중 MIS는 동일한 탐색 정확도를 유지하면서 평균 메시지 수가 48.9% 줄어드는 성능 향상을 보였다

키워드 : 2계층 시스템, 슈퍼 피어, 피어-투-피어, 모바일 애드혹 네트워크

Double-layered Peer-to-Peer Systems in MobileAd-hoc Networks

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ABSTRACT

As the mobile technology advances, file searchingamong the mobile device users becomes more important. In this paper, we propose *the uniform grid, greedy,* and *MIS* P2P systems that have double-layered topologyto search files efficiently for mobile ad-hoc networks. In these systems, peers are classified into two groups, super-peers and sub-peers, and each super-peer manages its neighboringsub-peers. In the proposed systems, each super-peer maintains the appropriate information of its sub-peers so that when a peer requests a file, the request is sent to its super-peers and then to neighboring super-peers. Hence the proposed systems could avoid multi-broadcasting and reduce network overheads. The experimental results show that the proposed systems outperform a single-layered P2P system in terms of the average number of messages to find target files. Especially the MISsystem improves by reducing the average number of messages by 48.9% while maintaining the same search accuracy.

Keywords : Double-Layered System, Super Peer, Peer-To-Peer, Mobile Ad-Hoc Network

1. Introduction

Faster data communications among mobile devices such as cell phones and PDAs are always welcomed by mobile device users for exchanging data like favorite movies, music, images, and text files. In order to develop more efficient mobile peer-to-peer (P2P) systems, various researches have been made. One of the most typical mobile P2P systems from previous researches is ORION (Optimized Routing Independent Overlay Network) [1]. However, it is not efficient in searching the target files, since it sends messages by multi-broadcasting.

In this paper, we propose three different file sharing systems that have double-layered topology. In these systems, a peer is classified into either a super-peer or a sub-peer, and a super-peer has zero or more sub-peers. Such classifications are made during the initial phase of the network establishment step. After the classifications all the routes among super-peers in the network are established. Note that one or two sub-peers may be used to connect two neighboringsuper-peers in case when there is no direct connection between them. Hence the network can be viewed as having a double-layered topology that super-peers seem to be connected each other in the upper level and sub-peers in the bottom level are

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hanging under their own super-peers. In the proposed systems when a peer requests a file, it requests the file to its super-peer. If the supper-peer finds that neither it has a copy nor all of its sub-peers have it, then it requests only to its neighboring super-peers. Hence there is no need for multi-broadcast communications in the proposed systems.

The proposed systems have different ways of selecting super-peers. First, we partition uniformly the entire service area into a grid based on the transmission range of each mobile device so that all peers within the same ‘grid cell’ can communicate each other in one hop. A peer located near the center of a cell is selected as the super-peer of the cell. Second, we select a peer with the highest degree in the network by greedy approach as the first super-peer and let its adjacent peers become its sub-peers. Then we select the second super-peer and its sub-peers ignoring the first super-peer and its sub-peers. We repeat this process until all the peers become either super-peers or sub-peers. Third, we select super-peers based on a maximal independent set (MIS). The peers in MIS are chosen as super-peersand the peers nearby the super-peers become sub-peers.

We modified the second and third systems to reduce the number of super-peers that have less than two sub-peers. Since those super-peers with at most one sub-peer may cause communication overheads during searches. Those that are disqualified for being super-peers will become sub-peers to other super-peers nearby in the network.

In the experimental results, we show that these systems outperform ORION in terms of the average number of messages to find the target files, while maintaining the same search accuracy except for the first system. The first system may experience more search failuresdue to possible disconnection among super-peers. The performance improvement of the proposed systems is made possible since they avoid unnecessary multi-broadcast communications.

The rest of the paper is organized as follows. In Section 2 we discuss the backgrounds of mobile P2P systems. Section 3 introduces the proposed systems in detail. Section 4 provides the experimental results. Finally, Section 5 concludes the paper with future work.

2. Backgrounds

2.1 Peer-to-Peer systems

The conventional wired P2P systems and search methods are not adequate for mobile P2P environments. An ordinary P2P system is connected by peers that function as both “clients” and “servers.” Gnutella [2] and Freenet are typical networks for the systems. Some P2P systems, such as Napster [3], OpenNap [4], and IRC channels, employ a client-server structure for searching, management, and so on. However, in a mobile P2P system they cannot be directly implemented due to the dynamic characteristics of a mobile system; it has moving objects and their physical radio ranges. Hence a typical mobile P2P system like ORION was introduced a few years back.

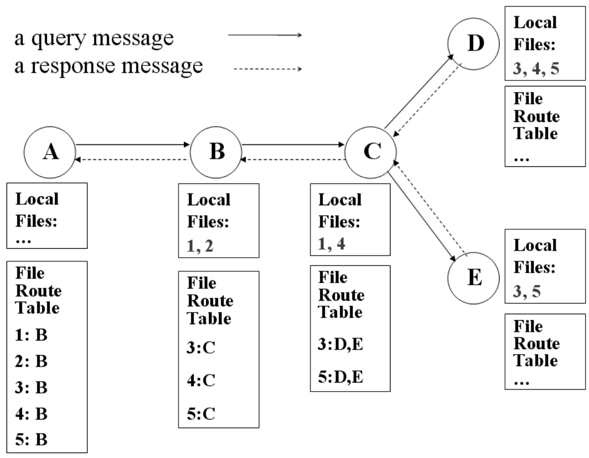
There are more researches related to mobile P2P systems. Huang et al. proposed a network-aware P2P file sharing architecture called *WMP2P* that classifies peers into peers and super-peers. In the system, peers locate files through super-peers and super-peers forward the lookup requests through the Internet [5]. Ohta et al. proposed an index-server approach for a P2Pfile sharing system in a mobile ad-hoc network [6]. An index server has the directory information about which nodes have certain files and enables peers to locate files quickly like super-peers. They used a grid model for the network topology and assumed that all index servers are connected over the spanning tree. However, there are possibilities that index servers may not communicate directly in practical environments.

Zhao et al. proposed a three-tier hierarchical architecture for ad hoc wireless networks it consists of the sensor node tier, the forwarding node tier, and the access point tier [7]. Their system utilizesaccess points and the Internet. Duran and Shenproposed two search schemes that use query messages filtering/gossiping and an adaptive hop-limited search for a P2P file sharing system for mobile ad-hoc networks [8]. They showed a way to modify file routing tables in ORION in order to reduce the number of query messages.

2.2 ORION

ORION is one of the typical P2P file sharing systems. In ORION, each peer has two tables, a routing table and a file route table. Note that a routing tableis similar to the ad-hoc on-demand distance vector [9]. It also has a local file table whose entries are the files that it currently owns. The file route table stores the *id*s of the peers who hold the files that the current peer doesn’t have.

Whenever a peer A wants to find a file, A first checks whether its file route table has the file or not. If the file cannot be located in the table, A broadcasts to all of its adjacent peers for searching the file. They will send re-



(Figure 1) Searches in ORION

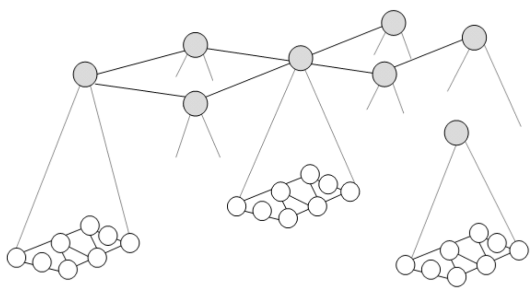
spond messages later back to A only if they have the file. As soon as a peer gets the response messages from other peers, it records where the response messages came from.

(Figure 1) illustrates how ORION performs the file searches. Suppose that A wants files 1, 2, 3, 4, and 5. Then Abroadcasts the query message to B. Next B broadcasts it to C, and finally C to both D and E. During such broadcasting, each peer looks up its ownlocal file table whether it has the requested files. Thesemessage transmissions can be viewed as a flooding mechanism, since the same messages are sent to all the connected peers. Hence, the network overheads of ORION due to the increase of message counts get much larger.

2.3 Super-peers

Shin et al. introduced a wired network structure called *Grapes* [10]. In this P2P networking, a super-peer works as one of the network's relators, handling data flow and connections for other peers. In a wired system, a super-peer requires too much CPU time as well as a wide bandwidth, because there are a largenumber of data passes through each super-peer.

(Figure 2) shows the topology of Grapes. The shaded circles represent super-peers in the figure, each of which has several sub-peers. If a sub-peer requests some files to its super-peer, the super-peer determines whether its sub-peers have the file or not. If nobody has it, the super-peer asks other super-peers in the upper level of the network. Each of other super-peers acts similarly.



(Figure 2) Structure of Grapes

3. The proposed systems

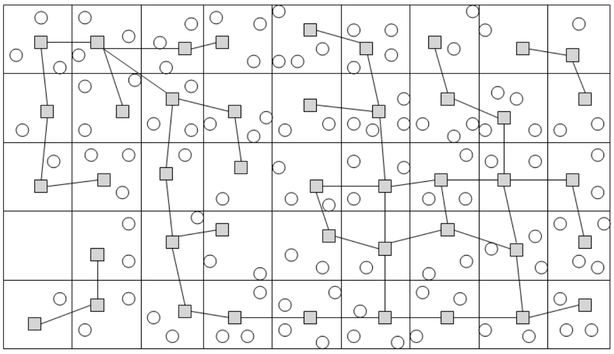
Existing mobile P2P systems assume that all peers are on a single layer. Hence, they hardly avoid multi-broadcasting which seriously deteriorates the system performance. In this section we propose a few P2P systems that have a double-layered structure like Grapes to improve the system performance. In these systems we classify peers into two groups, super-peers and sub-peers. The purpose of maintaining super-peers on the upper level is to manage their sub-peers. Each super-peer has the information such as *id, address* and *file list* of each sub-peer. Such information is stored into the file routing table.

When a sub-peer A wants to find a file, A asks its super-peer for it. If the super-peer finds it in its routing table, the super-peer informs $A$where the file is located. Otherwise, the super-peer sends a message to other neighboring super-peers to locate the file. If any of the super-peers finds the file in its file routing table, it sends the *response* message (the *id* of the peer who has the file) to A's super-peer. This routing table mechanism allows us to avoid multi-broadcasting through communications among mostly super-peers.

3.1 The uniform grid system

The first proposed system is called *the uniform grid system* in which the entire service area is uniformly partitioned as a grid and each square of the grid, called a *cell*, has one super-peer. The area is partitioned based on the transmission ranges of mobile devices so that all peers in the same cell should communicate each other with one hop and that super-peers in adjacent cells can also communicate each other if they are within the transmission ranges. (Figure 3) illustrates a sample uniform grid system in which super-peers are rectangles and sub-peers are circles. It only shows the connectivity among the super-peers.

In this system a peer is selected as a super-peer if it is located closest to the center of the cell among others. Once a peer is selected as a super-peer, other peers in the cell become its sub-peers. However, this system may

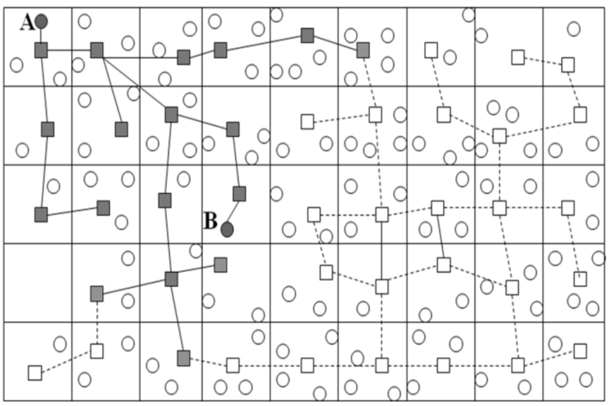


(Figure 3) A uniform grid system

not guarantee that all super-peers are connected to their adjacent super-peers, because some super-peer may be located out of the transmission range of its adjacent super-peers. Hence this system undergoes larger possibilities in search failure than others.

The uniform gridsystem requires a server and a GPS system so that the server manages peers and decides which peers become super-peers periodically. All the peers should be equipped with GPS functions to send their location information to the server as well.

(Figure 4) shows how a search proceeds to find a target file in the system. Assume that A in the leftmost-top corner of the figure requests a file and B owns the file. The super-peer of A checks its file routing table to find the file. If the file is not there, it sends a query message to its adjacent super-peers. As soon as the messages arrive at the adjacent super-peers, they check their file routing tables. If there is a super-peer who is able to locate the file, it sends a response message back. Otherwise similar steps are repeated until either the file is found or the system fails to locate. In (Figure 4), the super-peers that are connected with the solid lines are involved in communications for searching the file. The uniform grid system is quite simple and reduces a fair amount of



(Figure 4) Search for a target file in the uniform grid system

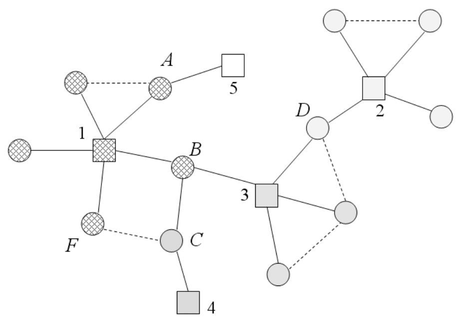
messages for searches, although it suffers from higher failure possibilities in the searches than other systems.

3.2 The greedy system

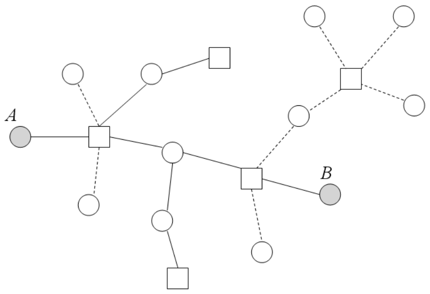
The second proposed system is called the *greedy system* since the way we select super-peers is the same as finding a set cover in a graph using the greedy approximation algorithm in [11]. For selecting super-peers, we first find a peer who has the largest number of adjacent peers that are reachable with one hop. This peer becomes the first super-peer and the adjacent peers become its sub-peers. We then ignore the first super-peer and its sub-peers from the network, i.e., we treat them as if they are not in the network until all the peers are classified. Afterwards we do the same process to find the next super-peer and its sub-peers. Such a process is repeated until there is no more peer in the network.

This system also needs a server and each peer should be equipped with the GPS function. The server has to classify peers according to the aforementioned greedy method periodically to reorganize the structure. Hence the server should be informed with the location of every peer through the GPS function of each peer.

(Figure 5) shows a sample network constructed with the greedy method. The rectangles and circles indicate super-peers and sub-peers, respectively. The numbers next to the super-peers show the sequence of being chosen as super-peers with the greedy method. Solid lines in the figure will be used for communications in the system, while the dotted lines will not be used. Notice that we ignore the connection between a pair of sub-peers under the same super-peer, and in case that there ismore than one route between a pair of super-peers, we choose only one route arbitrarily. For example, among two routes between super-peers 1 and 4, the route 1-B-C-4 happens to be chosen while ignoring the F-C connection. As soon as a super-peer is selected, it collects the appropriate information from each sub-peer



(Figure 5) A greedy system



(Figure 6) Search for a target file in the greedy system

such as its *id, address* and *the file list*, while each sub-peer has to know the *id* and *address* of its super-peer.

The routes among super-peers are constructed right after all peers are classified. First, each super-peer asks its sub-peers to find other super-peers in the near vicinity. In (Figure 5), for example, super-peer 1 asks its sub-peers *A* and *B*, then *A*asks super-peer 5 to send its own *id*, and *B*asks both super-peer 3 and *C* to send the *ids* of super-peers 3 and 4, respectively. Note that the sub-peers connecting a pair of super-peers such as *A*, *B*, *C*, and *D*, have to record both super-peer's information to establish the connections among super-peers properly.

(Figure 6) illustrates how a file is searched in the system. Suppose that *A* wants to find a file that *B* owns. *A* firstinforms its super-peer that it wants the file. When the super-peer gets the query message, it searches its file routing table. If it finds the file there, thenit sends the location of the file to *A*. Otherwise, the super-peer sends messages to other super-peers through the solid lines in the figure. As soon asother super-peers receive the message, they look into their file routing tables. Finally, the super-peer of *B* finds that *B* has the file and then sends the locationinformation of the file back to *A*.

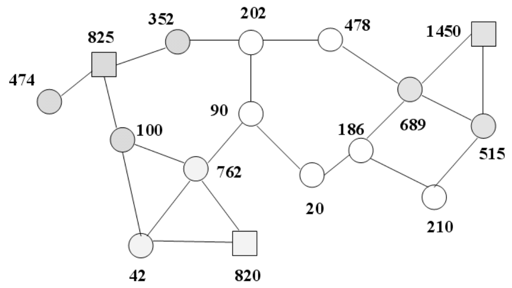
3.3 The MIS system

We call the third system *the MIS system*since super-peers are selected as the set of peers that belong to an MIS. We apply the Luby's randomized MIS algorithm in [12] on the network to obtain an MIS. The MIS system determines super-peers in a distributed manner, which is much suitable for realistic mobile P2P environments.

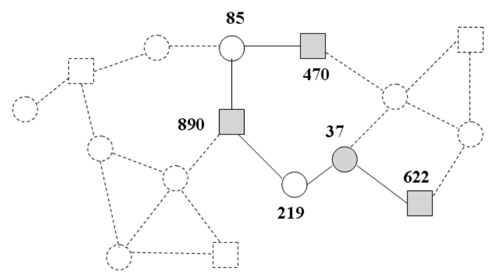
In order to establish a network for the MIS system, first we let each peer choose a random number and then compare its number with those of its adjacent peers. The integers are chosen randomly between 1 and n^4, where *n*is the number of peers in the network. Luby proved that choosing *n* random numbers independently from this range make it highly likelythat the chosen numbers are unique.

In the MIS system,a peer that has the largest number among its adjacent peers becomes a super-peerand the adjacent peers become sub-peers. Those peers who are determined either super-peers or sub-peers are ignored as in the greedy system. We then process the network iteratively until there is no peer in the network. Luby also proved that the expected number of iterations for finding a MIS is at most O(log *n*).

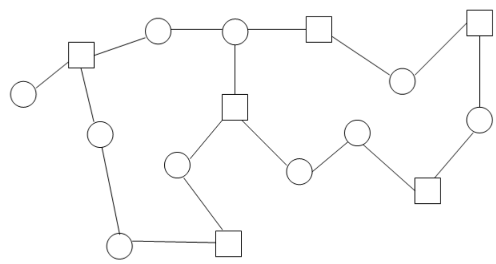
(Figure 7) shows that three peers (rectangles) become super-peers after the first iteration for the MIS system. Note that the numbers next to peers are chosen randomly as described in the Luby's algorithm. In the figure, shaded circles are sub-peersand white circles indicate the peers who are left for the next iterations. (Figure 8)-a shows a final result of the peer classification. The connections among the super-peers are established exactly in



(Figure 7) Super-peer selection after the first iteration for the MIS system



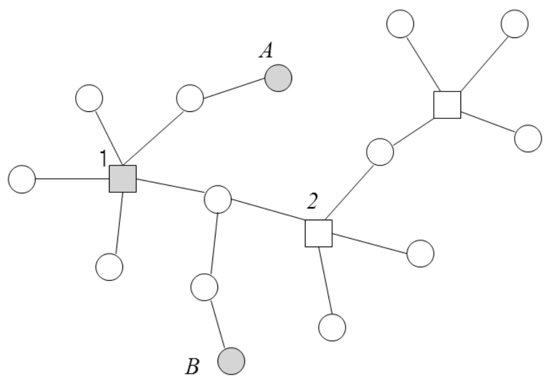
(Figure 8-a) Super-peer selection after the second iteration forthe MIS system



(Figure 8-b) The MIS system after the connections among the super-peers have established the same way as in the greedy system. (Figure 8)-b shows the result.

3.4 The reduced greedy / MIS systems

During the iterativeselections of super-peers and their sub-peers for both the greedy and MIS systems, there are some peers who become super-peers without any sub-peer or with only one sub-peer. In the reduced systems such super-peers are demoted to sub-peers to other super-peers nearby in the network. (Figure 9) shows the system after 'reducing' the greedy system in (Figure 5). Both super-peers A and B become sub-peers of super-peer 1 in this example. Note that B may become a sub-peer of super-peer 2. The main purpose of demoting "fragmented" super-peers is to reduce the traffic in the network.The reduced MIS system can also be obtained similarly.



(Figure 9) The reduced greedy system constructed from the system in Figure 5

4. Experimental results

In this section we compare the performances of the proposed systems, ORION, and the modified ORION by Duran and Shen [8]. The following table shows the parameters used in the experiments.

A text file for the input has 100 lines and each line has the *id*, *address*, *location*, and *the file list* of a peer. The location of each peer is determined randomly and the file list of a peer is also randomly constructed. We have tested 20 different text files reflecting that a system undergoes dynamic changes in its environment during 20 time units that is, the entire network is reconstructed after every 20 time units periodically by selecting new super peers and their sub-peers. Such periodic reconstructions of the network maintain stable connectivityamong all peers by repairing broken connections as possible due to

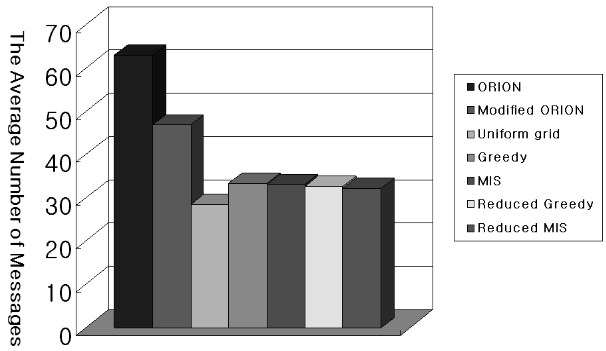
〈Table 1〉 Simulation Parameters

number of peers	100
transmission range (m)	115
simulation area (m^2)	2000 × 2000
maximum speed (m/s)	$115\sqrt{2}$

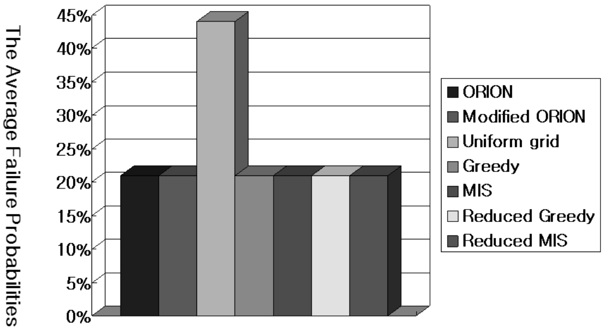
peers' movementsin the network area. Five different query files are used in the experiments and each query file consists of 256 queries that are also chosen randomly.

(Figure 10) compares the systems in terms of the average number of messages to find target files. The average numbers of messages made by ORION, the modified ORION, the uniform grid system, the greedy system, the MIS system, the reduced greedy, and the reduced MIS systems are 63.01, 46.89, 28.42, 33.31, 33.11, 32.70, and 32.21, respectively. All the proposed systems outperform ORION and the modified ORION, since they could avoid multi-broadcasting. The modified ORION is better than ORION, because it could reduce multi-broadcasting partially. However, since it still relies on multi-broadcast communication, the result is not as good as those of our proposed systems. The uniform grid system shows the best result, but it suffers from higher failures in searching target files due to possible disconnection among super-peers. Other proposed systems showedsimilar results, but the reduced systems showed little improved results. The reason that the performance improvement for the reduced systems is not noticeable is that the number of demoted super-peerswas quite small throughout the experiments. The reduced MIS system showed the best performance and improved the performance by 48.9% over ORION.

(Figure 11) compares the search accuracy of the systems. The uniform grid system showed only the highest average miss ratio because super-peers may be disconnected and hence some searches couldn't continue.



(Figure 10) Performance comparison of the systems



(Figure 11) The search accuracy of the systems

Other systems showed the same accuracy. This is because they maintain the same reachability among peers in the network.

5. Conclusions

In this paper, we have proposed a few mobile P2P file sharing systems that have double-layered topology. The uniform grid system partitions the service area into small cells, each of which is a square. Each super-peer is locatednear the center of a square and other peers in the square become sub-peers of the super-peer. In the greedy system, the greedy approximation set cover algorithm is applied for selecting super-peers. The MIS system uses the Luby's randomized MIS algorithm to obtain super-peers. Both reduced systems limit the number of super-peers by demoting "fragmented" super-peers to sub-peers in the hope that the network traffic is minimized.

As shown in the experimental results, the average numbers of messages for the proposed systems are quite smaller than those of ORION and the modified ORION. Such improvement was possible because they could reduce the network traffics successfully by forcing super-peers to communicate among themselves instead of multi-broadcasting. The MIS and reduced MIS systems can be more suitable for mobile environments, since selecting super-peers can be done in a distributed manner.

Servicing a role ofa super-peer requires overheads in managing their sub-peers. As ourfuture work, we will consider such overheads in the experiment as well as the cost for establishing the corresponding topology -the selection process for super-peers and their sub-peers and the construction of the routing tables. We further expand our research to evaluate all the systems on the ns-2 simulator [13] to achieve a more accurate comparison considering file transmissions as well.

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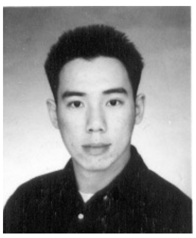

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