A Resource Discovery with Data Dissemination over Unstructured Mobile P2P Networks

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Abstract

Recently, along with the innovative development of wireless communication techniques and mobile devices, mobile P2P services in mobile wireless networks have gained a lot of attention. In this paper, we propose a resource discovery scheme with data dissemination over mobile P2P networks. In the proposed scheme, each peer manages a local information table, a resource index table, and a routing table in a local database to enhance the accuracy and cost of resource discovery. The local information table stores the status of a mobile peer, and the resource index table stores the resource information of the neighbor peers via the ranking function. The routing table is used to communicate with the neighbor peers. We use a timestamp message to determine whether or not the resource index table will be changed before the resource information is exchanged. Our ranking function considers the interest and mobility of the mobile peer and prioritizes the resource information transmitted from the neighbor peers. It is shown via various experiments that the proposed scheme outperforms the existing scheme.

Keywords: Mobile P2P, local database, data dissemination, resource discovery

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1. Introduction

Along with the development of mobile devices such as mobile phones, smart phones, and PDAs, mobile services have gained a lot of attention. Mobile Peer-to-Peer(MP2P) has also been studied to improve the scalability and reliability of client-server architectures [1]. Important applications of MP2P include social networks [12], file sharing [1][4][5][18], instant advertising [13], vehicular network services [19][20], and so on. In MP2P environments, each peer communicates with neighbor peers via wireless technologies such as IEEE 802.11, Bluetooth, Zigbee, and UWB(Ultra Wide Band) [2][3]. MP2P has constraints such as communication range, bandwidth, energy, and dynamic topology [1][3]. To overcome the constraints and support MP2P services, various studies have been conducted on P2P architecture [4][5][7][22], routing [14][15][16][17], data dissemination [10][11][21][23], and query processing [9][24][25].

Recently, the hierarchical structures have been proposed to reduce data dissemination costs and the number of query messages for resource discovery [1][4][6][7][22]. D. T. Ahmed proposed a two-level hashing scheme [7]. The P2P network consists of a set of home regions, where peers are within close proximity form a home region. The first level maps a content request to a region that reduces the routing overhead. The second level discovers the content location. The hierarchical mobile P2P architectures use the concept of a super peer that manages the information of its sub peers [6]. R. Haw proposed the parent-child peer group network that distinguishes Parent Peer(PPR) from Child Peer(CPR) [4]. PPR manages CPR's information and each P2P group communicates with the others. To search a file, CPR sends a query message to its PPR. If a file does not exist in PPR, then the PPR broadcasts a query message to its neighbor PPRs.

The resource discovery schemes are immensely related to data dissemination. In MP2P, each mobile device has a local database that stores resource and routing information via multi-hop transmission with neighbor peers [2]. To efficiently support resource discovery, an index structure is managed by the local database. The index structure provides reference information of the resource that indicates what resources are stored in the neighbor peers [3]. The resource discovery can be classified into the reactive scheme and proactive scheme according to the delivery types of dissemination messages [23]. In the reactive scheme, each peer does not construct an index structure in advance to efficiently search the resource information and broadcasts a message when the resource discovery is required by reactive routing. ORION uses the flooding scheme to search files[27]. Whenever a certain peer wants to find a file, the peer first checks its file routing table to locate the file. If there is no entry for the file in the table, then the peer broadcasts a request message to all its neighbor peers to search for the file. If the peer that receives the request message knows the information of the file, then it sends the reply message back to the request peer. However, the reactive scheme decreases the search efficiency. The proactive scheme improves the search efficiency because a peer index is constructed in advance. T. Repantis proposed adaptive content-driven routing and data dissemination mechanisms [11]. In [11], each peer builds and maintains the content summaries of their local data and adaptively disseminates them to the most appropriate peers. A peer can then use these summaries to determine if one of its peers can provide the requested resource. However, the proactive scheme increases the cost of data dissemination.

In MP2P, each peer has various constraints such as memory and bandwidth. To efficiently process the resource discovery, data dissemination should deal with the following issues:

'when to communicate', 'how much to communicate', 'how and what to communicate', and 'what to store' [8]. In [26], the authors proposed the Sector Heads Aided Flooding Technique (SHAFT) to reduce the unnecessary transmissions of resource information. SHAFT restricts the number of mobile nodes that forward data by geometrically arranging data placement in the area. Since each peer has limited memory, 'what to store' is very important. Generally, a ranking function is used to store the resource information of neighbor peers in the limited memory. O. Wolfson proposed Rank Based Broadcast(RBB) [10] and RANk-based Dissemination(RANDI) [8] for resource discovery in MOBI-DIK. RBB is a hybrid approach between push and pull. In RBB, a peer periodically selects the k-1 most relevant reports in its database and its native query, and broadcasts them to its neighbors. RANDI determines how to prioritize the reports in terms of their relevance, when to transmit the reports, and how many to transmit. Z. Chen proposed an opportunistic gossiping model for data dissemination [13]. The distinct items of interest for users are used to eliminate unnecessary data dissemination. But they do not completely eliminate unnecessary dissemination because they do not consider seriously the timestamp.

The major problem of the existing schemes is that the cost of data dissemination is significantly increased because they do not consider the state change of the peer according to the mobility or the interests of the peer. And they degrade the accuracy of the resource discovery and increase transmission costs because each peer does not store the recent information and the items of interest due to the limits of the peer's local storage and network bandwidth. In this paper, we propose a new resource discovery scheme with data dissemination over unstructured mobile P2P networks. To efficiently support the resource discovery, we propose the data dissemination scheme when a peer has limited bandwidth and memory. We first define the timestamp message to prevent data dissemination when the resource information is not updated, and we propose the ranking function to determine what to store in the local database. The proposed scheme organizes a local information table, a resource index table, and a routing table with the data dissemination in a local database. In order to show the superiority of the proposed resource discovery scheme, we compare it with the existing scheme through various experiments.

The remainder of the paper is organized as follows. In Section 2, we review related works to resource discovery in mobile P2P networks. Section 3 presents the mobile P2P architecture and the proposed resource discovery scheme. Section 4 shows a performance evaluation, and section 5 concludes this paper.

2. Related Work

J. S. Han proposed mobile P2P systems using super peers [6]. The peers are classified into super peers and sub-peers. The super peer collects the appropriate information from each sub-peer such as its id, address, and a file list. Each sub-peer also has to know the id and address of its super peer. In order to establish connections among super peers, when a peer is selected as a super peer, it asks its sub-peers to find other super peers in the near vicinity. Each sub-peer searches other peers that belong to different super peers and requests the ids of their own super peers.

R. Haw organized thegroup P2P network that distinguishes a Parent Peer (PPR) from a Child Peer (CPR) in Mobile Ad-hoc Networks to reduce the cost of network management and the number of query messages in file searches [4]. PPR manages CPRs' information and each P2P group communicates with each other. The group range is determined by PPR's RSSI. PPR manages a CPR and registers CPR's file information into the table in the peer group.

B. Qureshi proposed a content sharing method based on social networks in mobile P2P [12]. Each node periodically broadcasts an announce message containing the profile of the user of interest. Neighbor peers receive the announcement and compare their own profile keywords of interest. Each peer maintains a list of interests containing the various interest topics that they are interested in. Peers sharing similar interests share contents. The shared contents can be passed to other peers in different locations provided that they have similar interests enabling them to store and forward properties of a delay tolerant network.

T. Repantis proposed adaptive content-driven routing and data dissemination algorithms to intelligently route search queries in a peer-to-peer network [11]. In [11], each peer maintains a local content synopsis as well as the content synopses of remote peers. Each peer uses the bloom filter to build a synopsis of the content in each peer's local storage. The Bloom filter uses k hash functions to hash the store content into an m bit string. In order to store multiple content synopses, each peer stores two types of filters, a local filter for the objects available locally at the node, and remote filters for objects stored in remote peers. When a peer receives a query, apart from searching its local contents, it also searches the stored content synopses of other peers. If there are no matches in its local contents, then the peer forwards the query only to its immediate peers.

In wireless network, energy efficiency is one of the most critical issues[30][31][32]. [30] proposed a P-EASE to reduce the query error of EASE in object-tracking sensor networks. In [30], each node can obtain its own location by GPS or other localization algorithms. The sensor network is organized into clusters. P-EASE improves the trade-off between the query precision and the energy conserving by using prediction method to return the approximate querying result dynamically.

O. Wolfson develop a Database Management System called MOBIle DIscovery of local-resource Knowledge(MOBI-DIK) [2][8][9][10]. In MOBI-DIK, each mobile peer has a local database that stores and manages a collection of data items or reports. A report is a set of attribute-values sensed or received by a peer at a particular time. In [8], the authors proposed the RANk-based DIssemintaion(RANDI) algorithm that determines how to prioritize the reports in terms of their relevance, when to transmit the reports, and how many to transmit. Each peer uses a combination of one-to-one and broadcast communication. P2P communication is triggered by either the discovery of a new neighbor or the reception of new reports. RANDI prioritizes the reports based on their relevance. The relevance of a report depends on its hotness and size. In [9], the authors proposed a ranking method based on supply and demand. In [9], for query processing, each peer transmits directly reports and queries to neighbors, and they are propagated by multi-hop communications. In [10], the authors proposed Rank-Based Broadcast(RBB) that is a hybrid approach between push and pull, in the sense that it disseminates both queries and resource reports. The purpose of disseminating the queries is to reflect the demand on the network. In RBB, the broadcast is triggered when a peer receives enough new reports that ensure that new information is communicated to the neighbor peers, or when it travels for a long enough distance such that the peers within its transmission range have changed. Each peer selects the k-1 most relevant reports and its native query to broadcast.

3. The Proposed Resource Discovery Scheme

3.1 The Mobile Peer-to-Peer Architecture

In mobile P2P environments, items of user interest and their weights may be changed according to user contexts such as location and moving direction. We assume that items of user interest and their weights are important factors to efficienctly support resource discovery. To improve the efficiency of a resource discovery, a peer performs the data dissemination among its neighbors to construct the resource index structure providing the reference information of the resource that indicates what resources are stored on peers. When a peer performs data dissemination, the cost of data dissemination is increased because the the state update of the peer is not considered. To improve the accuracy and cost of resource discoveries, the peer indexing scheme has to consider the status updates, items of user interest, and the communication status of its neighbors as well as contents.

We assume that each peer has a local database and memory, and knows its current location and velocity vectors through a positioning system like GPS [17][28][30]. We can use unstructured mobile P2P networks that consist of super peers and mobile peers to process resource discovery. We organize groups according to the direction and RSSI(Received Signal Strength Indication) of peers and select a super peer among mobile peers within a group. When each mobile peer joins the mobile P2P environment, it must register itself in a group by transmitting its information(location and resource information) to the group. A super peer manages the resource and routing information of all mobile peers. Mobile peers partially manage the resource and routing information of their neighbor peers through data dissemination. In the mobile P2P environment, a peer's items of interest and its neighbors are changed over mobility as time passes. Therefore, the states of peers are continuously updated. If the state of a peer and its mobility are not considered, then accuracyis reduced and cost of resource discovery is increased.

Each peer disseminates its resource information to neighbor peers using short range wireless technologies such as IEEE 802.11, Bluetooth, and Zigbee. It proactively stores resource and routing information in the local database. When a mobile peer joins a group and its resource and connection information is changed, it broadcasts the resource and routing information stored in the local database to its neighbor peers with data dissemination, and it then registers its status to its super peer. **Fig. 1** shows how a new peer joins a group. We suppose that a mobile peer P_8 joins the mobile P2P environment, P_8 broadcasts a timestamp message in order to notify its status to its neighbor peers and to know its connectivity. Neighbor peers that receive a timestamp message sendreply timestamp messages to P_8, and P_8 then determines a participating group by the reply timestamp message of P_1 and P_7. P_8 disseminates the resource information to P_1 and P_7. If P_8 determines that it has joined group 2, then it sends a register message to a super peer P_5 for registering its information.

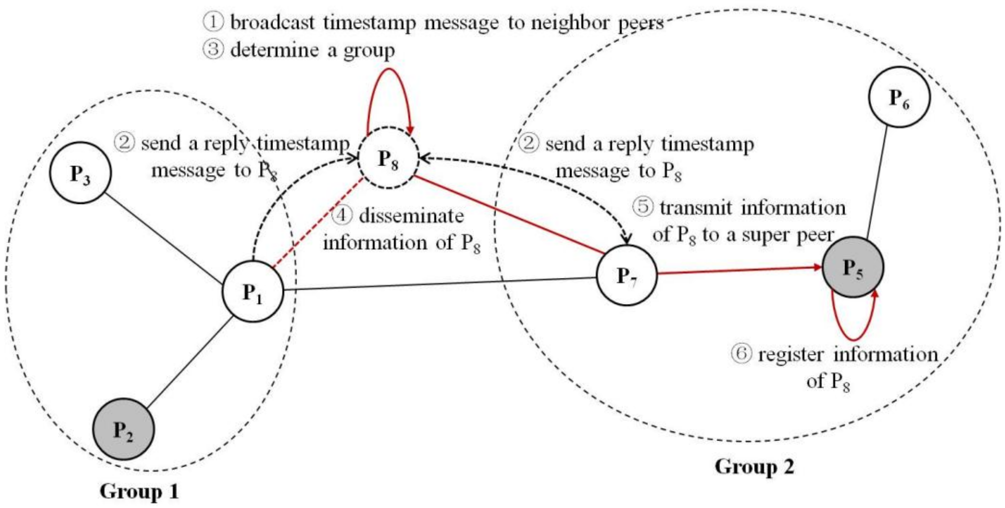


Fig. 1. The unstructured mobile P2P architecture

We manage a local information table, a resource index table, and a routing table in thelocal database to improve the accuracy and performance of resource discovery by considering the interests, locations, and moving directions of the peers. Each mobile peer maintains a local information table to store its state. The resource information of its neighbor peers with data dissemination is stored in the resource index table. We store the routing information and communication status for receiving the resources from another peer in the routing table. **Table 1** shows a local information table. In the local information table, *TS* is the latest update time of the resource index table via data dissemination from the neighbor peers and is used to determine data dissemination. *II* is the list of items of interest that describes the interests of a mobile peer. *PLI* is the location information of the mobile peer that consists of a current position and a direction. *W* is the weight of a ranking function to store the resource information of neighbor peers in the restricted storage. A super peer manages all the resource information and routing tables within a group. To search the resource, a mobile peer first examines its resource index table. If the resource information required by the mobile peer does not exist in the resource index table, then it should transfer the query to its super peer. Therefore, each mobile peer has *SPID*. *SPID* consists of *PID* and *PLI*, where *PID* is an identifier of the super peer and *PLI* is the location information of the mobile peer. *PLI* consists of *TS*, *P*, and *D*, where *TS* is a time sending location information, *P* is a position (x_i, y_i), and *D* is a moving direction (v_{xi}, v_{yi}).

Table 1. Local information table

Field Name	Description
PID	The peer identifier
TS	The latest update time of the resource index table
II	The list of items of interest
PLI	The location information of a mobile peer
W	The weight of ranking function
SPID	The super peer information

Each mobile peer manages the resource index table to process a resource discovery in the local database or its neighbor peers and then prevents transferring all queries to its super peer.

The mobile peer receives the resource information from its neighbor peers by data dissemination and updates the resource index table by the ranking function. A tuple {*RID*, *PL*} is stored in the resource index table. **Table 2** shows the the resource index table. In the resource index table, *PL* consists of *PID* and *TS*, where *PID* is a mobile peer identifier containing the resource, and *TS* is a time created by the mobile peer or stored in the mobile peer.

Table 2. Resource index table

Field Name	Description
RID	The resource identifier
PL	The PID information containing resource

A routing table is used to request a certain resource by the neighbor peers via unicast or broadcast communications. **Table 3** shows a routing table, where *PID* is an identifier of a neighbor peer, *PLI* is the location information of the mobile peer, *CT* is the latest communication time, and *CS* is the current communication status with the neighbor peers. *NL* is a list of the connected neighbor peers within 1-hop communication range.

Table 3. Routing table

Field Name	Description
PID	The peer identifier
PLI	The location information of a mobile peer
CT	The latest communication time
NL	The connected neighbor peers
CS	Communication status(0: disconnected, 1: connected)

3.2 Data Dissemination

We manage a resource index table by accomplishing data dissemination according to the status variation and mobility of a peer. To prevent duplicated data dissemination, we broadcast a timestamp message to the neighbor peers before the resource information is exchanged. A timestamp message is a broadcast message to determine whether or not the resource index table will be changed. We should broadcast a timestamp message to the neighbor peers within 1-hop communication range when the following conditions are satisfied:

- when a mobile peer joins a new group or a new peer is created
- when a resource index table is updated by the data dissemination of neighbor peers
- when a resource is created or received from the neighobor peers

If a certain peer broadcasts a timestamp message to its neighbor peers, then the neighbor peers receiving the timestamp message check their resource index table and routing table to generate a reply timestamp message by a unicast communication. **Fig. 2** shows a timestampe message and a reply timestamp message. A timestamp message consists of *SID*, *TS*, *LI*, and *SPID*, where *SID* is the identifier of a peer sending the timestamp message, *TS* is the timstamp of *SID* in the local information table, *LI* is the location information of *SID* in a routing information table, and *SPID* is the super information of *SID*. A reply timestamp message consists fo *SID*, *DID*, *RI*, and *LI*, where *SID* is a *PID* of a neighbor peer sending a timestamp reply message, *DID* is the *PID* of a peer receiving a timestamp reply message. *RI* is the resource information transmitted to *DID*, and *LI* is the location information of *SID*. If it is unnecessary for neighbor peers to disseminate data, then the *RI* field is null. *LI* is used to update the routing table of the peer receiving a reply timestamp message.

SID	TS	LI	SPID

(a)

SID	DID	RI	LI

(b)

Fig. 2. Timestamp message and reply message;**(a)** Timestamp message, **(b)** Reply timestamp message

A mobile peer receiving a timestamp message examines the local information table and routing table to determine data dissemination for exchanging the resource information. If *CT* of a neighbor peer sending a timestamp message does not exist in the local information table, then this peer does not yet communicate with its neighbor peers. Therefore, data dissemination is performed. If *TS* of a neighbor peer receiving a timestamp message is bigger than that of a peer sending a timestamp message, then data dissemination should be performed because the neighbor peer has the new resource information. We use two lemmas to prevent duplicated data dissemination. We transmit *RI* in a timestamp reply message when *Lemma 1* or *Lemma 2* is satisfied. *Lemma 1* means that the neighbor peers have not yet communicated with the peer sending the timestamp message, the neighbor peers transmit their resource information. *Lemma 2* means that if the resource information of the neighbor peers is updated, then the neighbor peers transmit their resource information. If *Lemma 1* and *Lemma 2* are not satisfied, then the neighbor peers do not transmit their resource information.

[Lemma 1] *if CT of a request peer sending a timestamp message does not exist in the routing table of a neighbor resonse peer receiving the timestamp message, then the neighbor peer transmits a reply timestamp message with RI to the reqeust peer.*

[Lemma 2] *if TS of a neighbor peer receiving a timestamp message* is greater than *CT of a request peer sending a timestamp message, then the neighbor peer transmits a reply timestamp message with RI to the requesting peer.*

Fig. 3 shows an example of processing a timestamp message. We suppose that a mobile peer P_1 is connected with new peers P_2 and P_3 when P_1 moves from (x_1, y_1) to (x_2, y_2) at T_7. First, P_1 broadcasts a timestamp message to its neighbor peers within 1-hop communication range. P_2 and P_3 receive the timestamp message and then examine their local information and routing tables. P_2 and P_3 update the routing tables using the *LI* contained within the timestamp message. Since P_1 has not yet communicated with P_2, *CT* of P_1 does not exist in the routing table of P_2. Therefore, P_2 sends a reply timestamp message containing *RI* to P_1. However, P_3 sends to P_1 a reply timestamp message in which *RI* is null, because *CT* of P_1 exists in the routing table of P_3 and *TS* of P_3 is the same as *CT* of P_1. In other words, since P_3 is connected indirectly with P_1 via P_4 at T_5 but the resource index table of P_3 is not changed until P_1 is reconnected with P_3 at T_7, P_3 does not transmit its resource information to P_1.

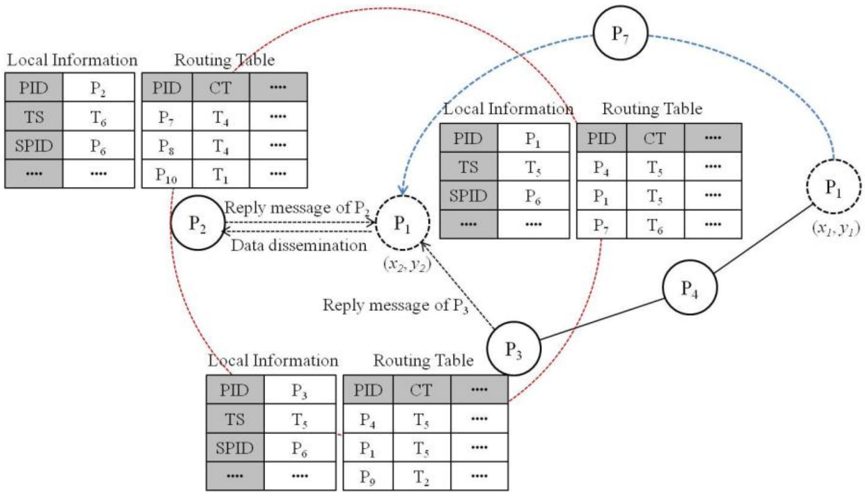


Fig. 3. An example of processing a timestamp message

We establish a resource index table in the local database by data dissemination to reduce the transmission of all resource discovery queries to the super peer. The neighbor peer sending a reply timestamp message containing *RI* has the updated resource information. The neighbor peer that has not yet communicated with the request peer has the new resource information which the request peer does not contain. The request peer receiving a reply timestamp message stores the updated resource information and the new resource information received from its neighbor peers into a buffer and merges them. If the space of the local database is sufficient, then all resource information is stored in the local database. Otherwise, a ranking function is performed to store the resource information in the local database.

If the resource information received from each peer P_j is RI_j and P_j is the peer sending the timestamp message, the total resource information $TRI(P_i)$ is $RIT(P_i)+\sum_{j=1}^{n} RI_j,\ j \neq i$, where $RIT(P_i)$ is the resource index table of P_i. A ranking function prioritizes $TRI(P_i)$ based on its interest and mobility. A mobile peer P_i processes the ranking function of $TRI(P_i)$, the ranking function $R(C_i, P_i)$ is defined as Equation (1), where $C_i \in TRI(P_i)$ and $P_j(C_i)$ is the peer identifier containing C_i. $SIF(C_i, P_i)$ is the similarity of items of interest between the subject of C_i and the items of interest of P_i. $SD(P_j(C_i), P_i)$ is the similarity of moving direction between P_i and P_j. and $RP(P_j(C_i), P_i)$ is the similarity of distance between P_i and P_j. In Equation (4), T_{start} is the first time that $Dist(Pos_t(P_i), Pos_t(P_j)) \le R$ is satisfied. T_{end} is the end time that $Dist(Pos_t(P_i), Pos_t(P_j)) > R$ is satisfied. Here, $Pos_t(P_j)$ is the position of P_j at a future time t that is cacluated by the velocitiy vector of P_j, and $Dist(Pos_t(P_i), Pos_t(P_j))$ is the distance from P_i to P_j at t. ε is a threshold and *MaxTime* is $Max_{i\in k}(SD(C_i, P_j))$. In Equation (5), *MaxDist* is $Max_{i\in k}(SD(P_j(C_i), P_i))$. The ranking value of a ranking function is 0~1.

$$R(C_i, P_i) = \{w_1 SIF(C_i, P_i) + w_2 SD(P_j(C_i), P_i) + w_3 RP(P_j(C_i), P_i)\}/3 \quad (1)$$

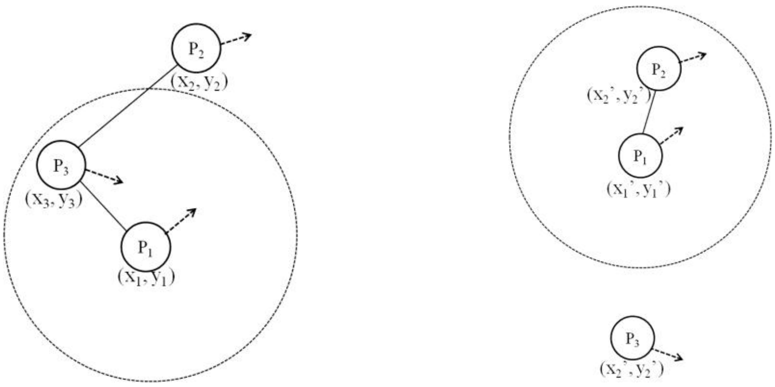
$$w_1 + w_2 + w_3 = 1 \quad (2)$$

$$SIF(C_i, P_i) = \begin{cases} 1, & if\ the\ subject\ of\ C_i\ is\ IS\ of\ a\ request\ peer\ P_i \\ 0, & else \end{cases} \quad (3)$$

$$SD(P_j(C_i), P_i) = \begin{cases} T_{end} - T_{start} / MaxTime, & if\ Dist(Pos_t(P_i), Pos_t(P_j)) \le \varepsilon, where\ t \ge T_i \\ 0, & else \end{cases} \quad (4)$$

$$RP(P_j(C_i), P_i) = 1 - Dist(Pos_t(P_i), Pos_t(P_j)) / MaxDist \quad (5)$$

The resource information is stored in the resource index table by the ranking fuction considering interest, distance, moving direction. For example, we suppose that P_1 is connected to P_2 at T_1 and P_3 has exchanged the updated resource information with P_2 via data dissemination at T_0 as shown in **Fig. 4**. P_1 receives a timestamp stamp message containing *RI* from P_3. P_1 performs the ranking function to store the resource information into its resource index table. If P_3 and P_2 have the same interest items, then it is a better choice to store the resource information of P_3 in the local database of P_1 at T_1. If P_1 requires the resource information of P_3 at T_3, then P_1 can accomplish a multi-path routing to receive the required resource from P_3 because P_1 is disconnected from P_3. We consider the moving direction of the neighbor peers containing resources. However, in the near future, the current positions of the neighbor peers are important when the peer communicates with the neighbor peers. Therefore, in the ranking function, we consider both the current positions and moving directions of peers to enhance the resource accessibility.



(a) T1 **(b)** T3

Fig. 4. Resource accessibility according to the mobility of peers

After a mobile peer stores the resource information of the neighbor peers in the resource index table by the ranking function, then it should determine the resource information sent to its neighbor peers. We can know all neighbor peers within the 1-hop communication range and the last update time of the resource index table of each neighbor peer by a reply timestamp message. The certain peer P_i transmits the resource information received from its neighbor peers and the updated resource information after data dissemination to another neighbor peer P_j. A data dissemination message consists of *PID* and URI_j. *PID* is an identifier of a peer receiving the data dissemination message. URI_j is the new updated resource information of P_i and the received resource information received from its neighbor peers except P_j after P_i processed data dissemination with P_j .

Fig. 5 shows that P_2 disseminates the resource information to its neighbor peers. We suppose that *TS* of P_2, P_1, and P_3 are T_6, T_4, and T_4,respectively. *TRM* of P_3 does not contain *RI* because P_3 is not updated after T_4, but the the reply timestamp message of P_1 contains RI={(C_1, (P_1, T_2)), (P_8, T_4)), (C_5, (P_9, T_3)), (C_6, (P_8, T_4))}. P_2 performs the ranking function of $TRI(P_2)$ by Equation (1) to store the resource information of the neighobr peers in the resource index table. **Table 4** shows $TRI(P_2)$ and ranking values at time *11*, where *IS* of P_2 is {s_1, s_2} and *PLI* is {*10*,

($1,2$), ($1, 1$)}. We suppose that the subject types of C_1, C_2, C_4, C_5, *and* C_6 are S_1, S_3, S_2, S_1, and S_3, respectively, and *PLI*s of P_1, P_3, P_5, P_6, P_8, and P_9 are {9, (5,3), (1,-1)}, {8, (5,5), (-2, 2)}, {8, (8,4), (-2,1)}, {7, (6,6), (-1,-2)}, {9, (4,1), (-2,-1)}, and {9, (5,5), (-1,-2)}, respectively. If we can store 5 resource information in the resource index table, then (C_1, P_1), (C_1, P_8), (C_1, P_3), (C_4, P_6), and (C_5, P_9) are stored in the resource index table, where ε is 8 and $w_1=0.5$, $w_2=0.3$, and $w_3=0.2$.

Table 4. Total resource information and ranking values of P_2

(C_i, P_i)	*SIF*	*SD*	*RP*	*R*
(C_1, P_1)	*1*	≈0.7	≈0.4	≈0.79
(C_1, P_8)	*1*	≈0.5	≈0.5	≈0.75
(C_1, P_3)	*1*	≈0	≈0	≈0.5
(C_2, P_3)	*0*	≈0	≈0	≈0
(C_2, P_5)	*0*	≈1	≈0.5	≈0.4
(C_4, P_6)	*1*	≈0.3	≈0.4	≈0.67
(C_5, P_9)	*1*	≈0.5	≈0.7	≈0.79
(C_6, P_8)	*0*	≈0.5	≈0.5	≈0.25

Then, P_2 should disseminate the resource information to its neighbor peers. Since *CT* of P_1 does not exist in the routing table of P_3 and *TS* of P_2 is greater than *CT* of P_3, P_2 transmits the resource information received from P_3 and the new updated resource information of P_2 after T_4 to P_3. That is, P_2 transmits {(C_4, (P_6, T_6)), (C_1, (P_1, T_2), (P_8, T_4)), (C_5, (P_9, T_3)), (C_6, (P_8, T_4))} to P_3. And P_2 transmits only the resource information of P_2 to P_1 because P_3 does not have the new updated resource information after T_4. Therefore, P_2 transmits {(C_1, (P_2, T_2), (P_3, T_4)), (C_2, (P_3, T_4), (P_5, T_3)), (C_4, (P_5, T_6)) to P_1 via unicast communication.

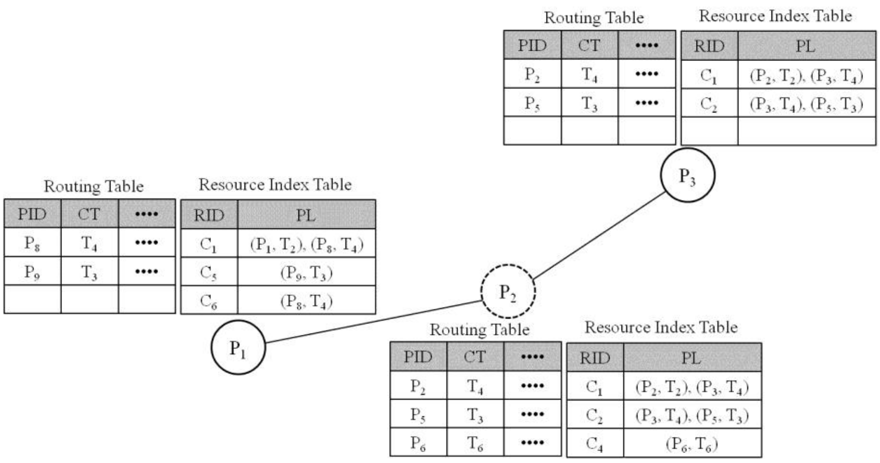


Fig. 5. An example of data dissemination

3.3 Routing Table

Each mobile peer manages a routing table to communicate with its neighbor peers. The neighbor peers update their routing tables using a timestamp message transmitted from a request peer during data dissemination. The request peer updates its routing table using the reply timestamp message returned by the neighbor peers. For example, we suppose that P_2 is connected with P_1 at T_2 and P_2 is reconnected with P_3 and P_1 at T_5, as is shown in **Fig. 6**. If P_2 broadcasts a timestamp message to P_1 and P_3, then P_1 and P_3 examine their routing tables. P_1 updates the routing information of P_2 in its routing table because the routing information of P_2 was already stored. P_3 inserts the routing information of P_2 into its routing table. P_2 stores the routing information of its neighbor peers in its routing table via a reply timestamp message.

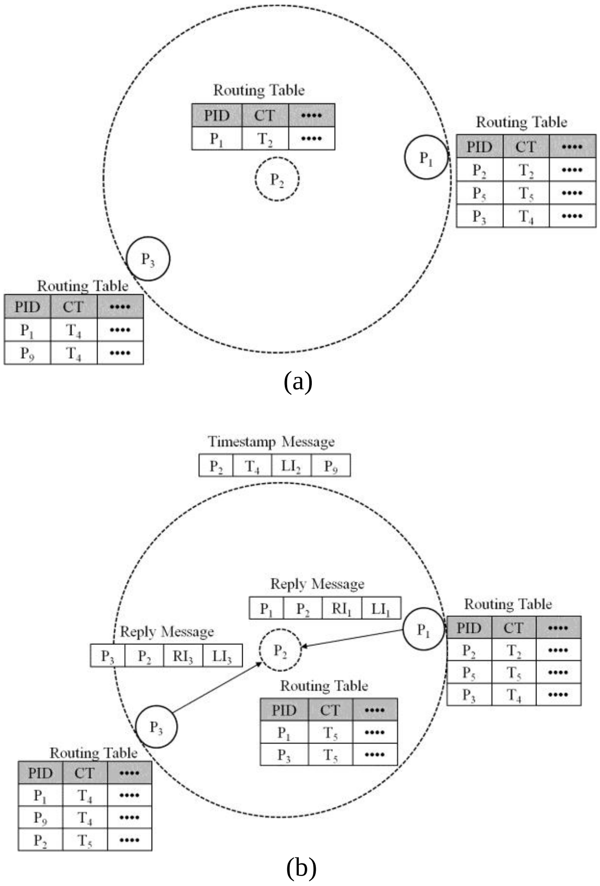


Fig. 6. Updating routing table; **(a)** The routing table at T_4, **(b)** Updating the routing table at T_5

All mobile peers can predict the current positions of their super peers to enable them to transmit their query messages to the super peers. The super peer can predict the current positions of all mobile peers to access them using a location based routing protocol. Therefore, all mobile peers and super peers store not only the position and but also the velocity vectors to predict the current positions in the routing table. A super peer broadcasts its position and velocity vectors to all its group members when the deviation between the actual value and the predicted value exceeds the threshold. A mobile peer broadcasts its position and velocity vectors to its neighbor peers within the *n*-hop communication range and unicasts its location to its super peer using the location based routing protocol.

3.4 Resource Discovery

To process the resource discovery, each peer first examines its local information table. If a resource requested by a peer is not found in its resource index table, then the mobile peer forwards its query message to its neighbor peers until the query message reaches a super peer.

The super peer searches its resource index table to process the received query and sends a response message to the request peer. If an internal peer in the routing path has the request resource, then it sends the response message to the request peer. The query message consists of *RID*, *MID*, *SN*, *Q*, and *DID*. *RID* is a mobile peer identifier requesting the resource discovery and *MID* is the identifier of query message. *SN* is a sequence number that is increased whenever a mobile peer receives the query message, *Q* is a query, and *DID* is a destination identifier that is the identifier of a super peer. A response message is similar to the request message except the fourth field. The response message is (*RID*, *MID*, *SN*, *R*, *DID*) in which *R* is the query results.

As the number of neighbor peers for forwarding the query message is increased, the cost of resource discovery grows dramatically. In order to reduce the cost of resource discovery, we propose an optimal peer selection that the query message is forwarded to the neighbors by using a routing table. **Fig. 7** shows how the query message is forwarded. If P_2 needs C_4, then P_2 first examines its resource index table. Since P_2 does not have the resource information of C_4, P_2 forwards the query message to C_4. A mobile peer manages the partial routing information of neighbor peers in the routing table during data dissemination. Therefore, P_2 forwards the query message to P_3 using the routing table. P_3 receives the query message and examines its resource index table. Since P_3 does not have the resource information of C_4 in its resource index table, it increases *SN* of the query message to prevent receiving the duplicate query message and forwards the query message to P_5. Since P_5 has the resource information of C_4, P_5 transmits the response message to P_2. If P_5 does not contain the resource information of C_4, then P_5 forwards the query message to its super peer. If the super peer P_6 of P_2 does not have the resource information for C_4, then P_6 forwards the query message to another super peer.

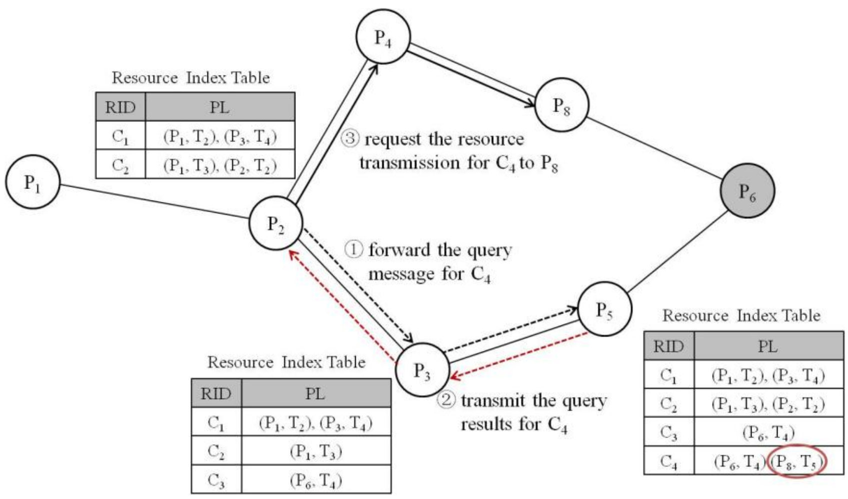


Fig. 7. Forwarding a query message

4. Performance Evaluation

To show the superiority of the proposed scheme, we perform various experiments on a a 440MHz PA-RISC machine with 4Gbytes of main memory running HP-UX. The simulation programs are developed via JAVA 1.4.2.04, and the simulation data sets are generated by Brinkhoff Network-based generator [29]. In addition, we modify the generated simulation data set to represent the weights of items of user interest. We compare our proposed resource discovery scheme with MOBI-DIK [2][8]. We choose MOBI-DIK because it is the most popular scheme that constructs the resource index table via data dissemination. We performed the experiments 20 times and measured an average value accurately. **Table 5** shows the simulation setup information. In the simulation, the mobility patterns and peer densities are determined by the Brinkhoff Network-based generator. **Table 6** shows the number of reachable peers by multi-hop communication when simulation data are generated by [29].

Table 5. Simulation setup

Parameter	Value
Network size	200m×250m
The number of peers	200~500
The ratio of updated peers	20%~50%
Communication range	10m

Table 6. The number of reachable peers by multi-hop communication

The number of peers	The number of reachable peers
200	42~159
300	43~240
500	41~390

To prove the superiority of the proposed scheme in terms of data dissemination, we evaluate the costs of data dissemination when the numbers of peers are 200, 300 and 500. **Fig. 8** and **Fig. 9** show the experimental results for the costs of data dissemination. To measure the cost of data dissemination, we observe the number of dissemination messages and the size of dissemination data. **Fig. 8** shows the number of dissemination messages per time according to the number of peers. **Fig. 9** shows the size of dissemination data per time according to the number of peers. As shown in **Fig. 8** and **Fig. 9**, our scheme outperforms MOBI-DIK because our scheme reduces the data dissemination by using a timestamp message.

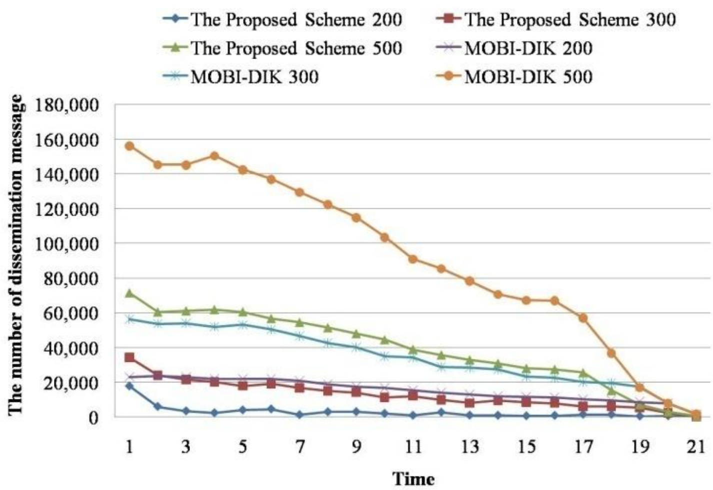


Fig. 8. The number of dissemination messages per time

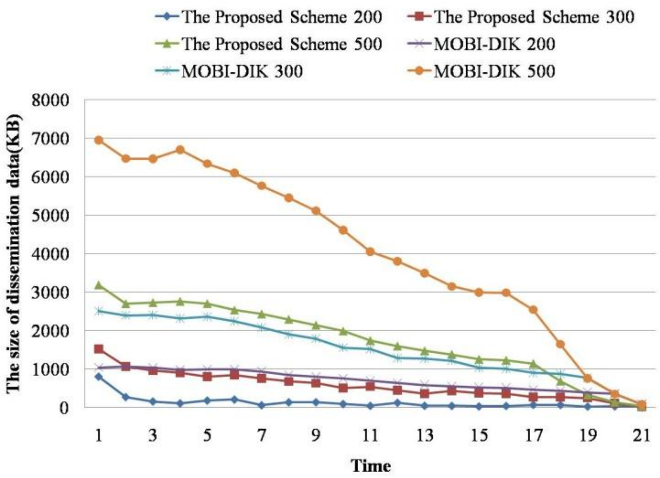


Fig. 9. The size of dissemination data per time

To prevent duplicated data dissemination, we broadcast a timestamp message to the neighbor peers before the resource information is exchanged. We evaluate the size of redundant data propagated via data dissemination. **Fig. 10** shows the size of redundant data according to the number of peers. Since our scheme uses a timestamp message and transmits the updated resource information only during data dissemination, we prevent unnecessary data dissemination. Therefore, our scheme outperforms MOBI-DIK.

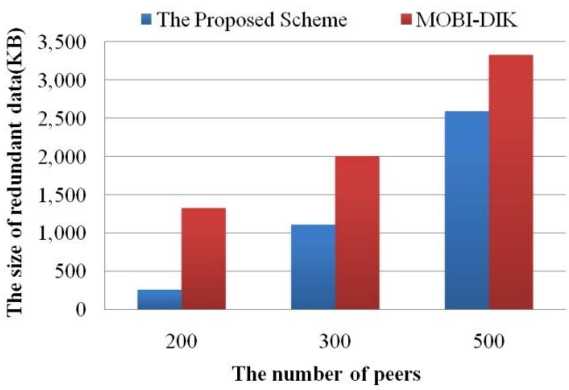


Fig. 10. The size of redundant data according to the number of peers

We evaluate the accuracy and cost of resource discovery in an un-hiarchical structure similar to MOBI-DIK. To measure accuracy, we observe the ratio of complete resource transfers. In **Fig. 11** and **Fig. 12,** accrary and cost of search are evaluated in a pure P2P structure similar to the simulation environment of MOBI-DIK. **Fig. 11** shows the accuracy of resource discovery schemes according to the number of mobile peers. Our sheme achieves about 52% accuracy improvement over MOBI-DIK. To evaluate the cost of resource discovery, we observe the number of forwarded messages for disseminating a query massage to the neighbor peers. As shown **Fig. 12**, our scheme achieves about 2.5 times better performance than MOBI-DIK. The reason is that our scheme uses the routing table that prevents sending the unnecessary query messages to all neighbors and stores the resource information in the resource index table via the ranking function considering interest, distance, and moving direction.

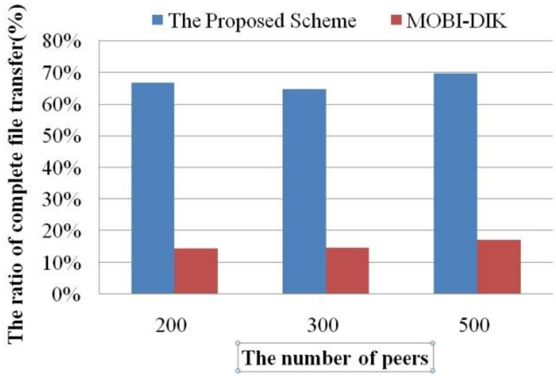


Fig. 11. Accuracy according to the number of peers

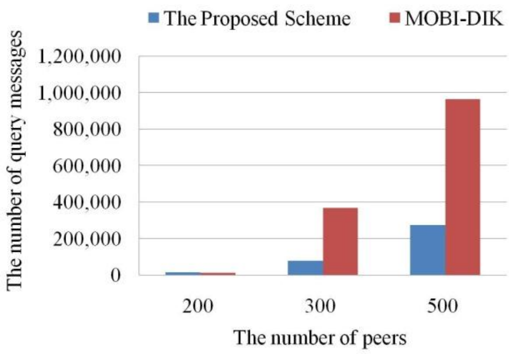


Fig. 12. The search cost according to the number of peers

We also perform a performance evaluation in dynamic environments as well as static environments. **Fig. 13** and **Fig. 14** show the experimental results in terms of the costs of data dissemination and searches when the ratios of updated peers are 20%, 30%, and 50%. In the performance evaluation, the velocities and resource information of the updated peers are changed. The resource information of the updated peers are changed randomly. The updated peers change the velocity vectors from 0m/min to 1,009m/min. In **Fig. 14**, the search cost is evaluated in a pure P2P structure similar to the simulation environment of MOBI-DIK.

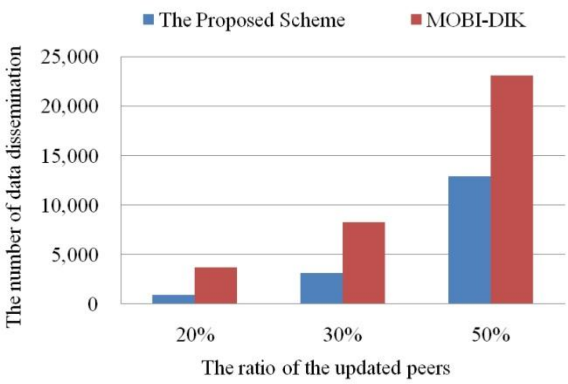


Fig. 13. The cost of data dissemination according to the ratio of updated peers

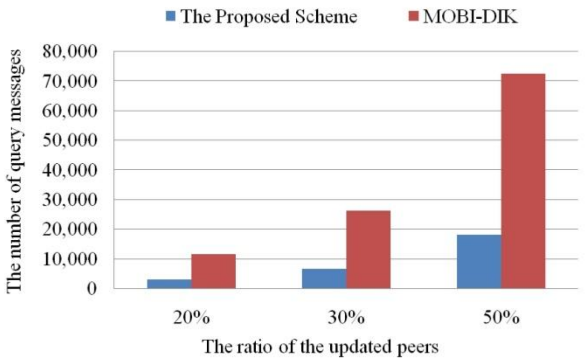


Fig. 14. The search cost according to the ratio of updated peers

We can use unstructured mobile P2P networks that consist of super peers and mobile peers to process resource discovery. We compare our scheme with Group P2P[4] and ORION [27] according to the number of peers. **Fig. 15** and **Fig. 16** show the search times and the search costs of the proposed scheme and the existing schemes according to the number of peers, respectively. In **Fig. 15**, the search time is the sum of search time of the local database and search time of super peers. In **Fig. 16**, the search cost is the number of the transmitted query messages to find the resource information requested by a peer.

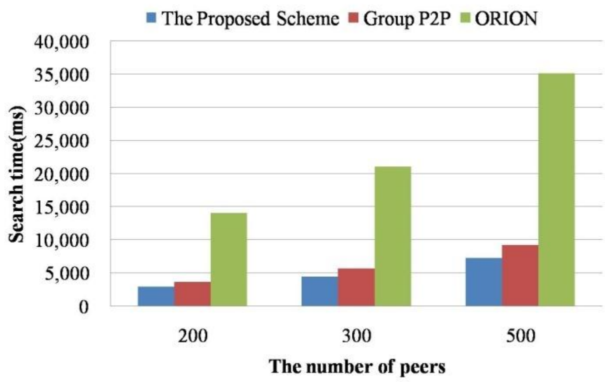


Fig. 15. The search time according to the number of peers

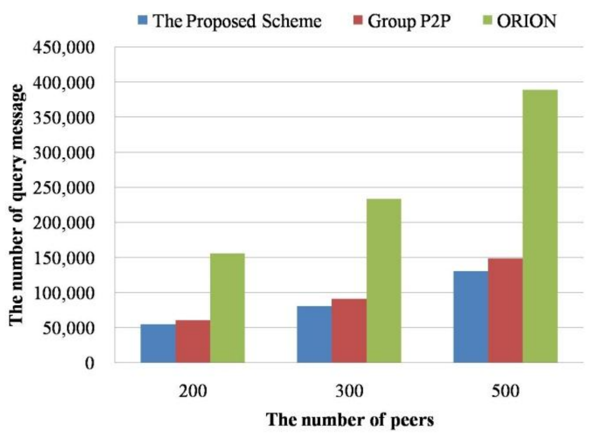


Fig. 16. The search cost according to the number of peers

5. Conclusion

In this paper, we proposed a resource discovery scheme with data dissemination via a timestamp message. In the proposed scheme, each peer partially manages a local information table, a resource index table, and a routing table for their neighbor peers. The proposed scheme uses timestmape messages to determine whether or not the local resource information of neighbor peers is changed and sotres the resource information in a location database via a ranking function considering interest, distance, and moving direction. After a mobile peer stores the resource information in the local database, the mobile peers send the chaned resource information to their neighbor peers via unicast communication. It has been shown through various experiments that the proposed scheme outperforms the existing scheme. In future works, we will apply the proposed scheme to a real system.

References

[1] M. Li, E. Chen, and Phillip C. Sheu, "A chord-based novel mobile peer-to-peer file sharing protocol," in *Proc. of Asia-Pacific Web Conference*, pp.806-811, 2006. Article (CrossRef Link).

[2] Y. Luo, O. Wolfson and B. Xu, "Mobile local search via P2P databases," in *Proc. of the IEEE International Interdisciplinary Intersociety Conference on Portable Information Devices*, pp.1-6, 2008. Article (CrossRef Link).

[3] D. T. Ahmed and S. Shirmohammadi, "Design issues of peer-to-peer systems for wireless ad hoc networks," in *Proc. of International Conference on Networking*, pp.26, 2007. Article (CrossRef Link).

[4] R. Haw, C S. Hong and D. S. Kim, "Group P2P network organization in mobile ad-doc network," in *Proc. of Asia-Pacific Network Operations and Management Symposium*, pp.477-480, 2009. Article (CrossRef Link).

[5] N. Shah and D. Qian, "An efficient overlay for unstructured P2P file sharing over MANET using underlying cluster-based routing," *KSII Transactions on Internet and Information Systems*, vol.4, no.5, pp.799-818, 2010. Article (CrossRef Link).

[6] J. S. Han, K. J. Lee, J. W. Song and S. B. Yang, "Mobile peer-to-peer systems using super peers for mobile environments," in *Proc. of International Conference on Information Networking*, pp.1-4, 2008. Article (CrossRef Link).

[7] D. T. Ahmed and S. Shirmohammadi, "Multi-level Hashing for Peer-to-Peer system in wireless ad hoc environment," in *Proc. of IEEE International Conference on Pervasive Computing and Communications - Workshops*, pp.126-131, 2007. Article (CrossRef Link).

[8] O. Wolfson, B. Xu and R. M. Tanner, "Mobile Peer-to-peer data dissemination with resource constraints," in *Proc. of International Conference on Mobile Data Management*, pp.16-23, 2007. Article (CrossRef Link).

[9] B. Xu, F. Vafaee and O. Wolfson, "In-network query processing in mobile P2P databases," in *Proc. of ACM International Symposium on Advances in Geographic Information Systems*, pp.207-216, 2009. Article (CrossRef Link).

[10] O. Wolfson, B. Xu, H. Yin and H. Cao, "Search-and-discover in mobile P2P network databases," in *Proc. of IEEE International Conference on Distributed Computing Systems*, pp.65, 2006. Article (CrossRef Link).

[11] T. Repantis and V. Kalogeraki, "Data dissemination in mobile peer-to-peer networks," in *Proc. of International Conference on Mobile Data Management*, pp.211-219, 2005. Article (CrossRef Link).

[12] B. Qureshi, G. Min, D. D. Kouvatsos and M. Ilyas, "An adaptive content sharing protocol for P2P mobile social networks," in *Proc. of IEEE International Conference on Advanced Information Networking and Applications Workshops*, pp.413-418, 2010. Article (CrossRef Link).

[13] Z. Chen, H. T. Shen, Q. Xu and X. Zhou, “Instant advertising in mobile peer-to-peer networks,” in *Proc. of International Conference on Data Engineering*, pp.736-747, 2009. Article (CrossRef Link).

[14] R. Schollmeier, I. Gruber and M. Finkenzeller, “Routing in mobile ad-hoc and peer-to-peer networks. A Comparison,” in *Proc. of NETWORKING 2002 Workshops on Web Engineering and Peer-to-Peer Computing*, pp.172-186, 2002. Article (CrossRef Link).

[15] J. H. Lee, J. W. Song, Y. H. Lee and S. B. Yang, “An energy-effective routing protocol for mobile P2P systems,” in *Proc. of International Symposium on Wireless Pervasive Computing*, pp.1-5, 2009. Article (CrossRef Link).

[16] X. Yang, J. Yin and S. Yuan, “Location-Aided opportunistic routing for mobile ad hoc networks,” in *Proc. of International Conference on Wireless Communications, Networking and Mobile Computing*, pp.1-5, 2009. Article (CrossRef Link).

[17] N. Meghanathan, “A location prediction based routing protocol and its extensions for multicast and multi-path routing in mobile ad hoc networks,” *Ad Hoc Networks*, vol.9, no.7, pp.1104-1126, 2011. Article (CrossRef Link).

[18] J. Jia and C. Meng, “A Cluster-Based Peer-to-Peer file sharing protocol for mobile ad hoc networks,” in *Proc. of International Symposium on Computer Network and Multimedia Technology*, pp.1-4, 2009. Article (CrossRef Link).

[19] N. Dutta, “A peer to peer based information sharing scheme in vehicular ad hoc networks,” in *Proc. of International Conference on Mobile Data Management*, pp.309-310, 2010. Article (CrossRef Link).

[20] J. Rybicki, B. Scheuermann, M. Koegel and M. Mauve, “PeerTIS : A Peer-to-Peer traffic information system,” in *Proc. of International Workshop on Vehicular Ad Hoc Networks*, pp.23-32, 2009. Article (CrossRef Link).

[21] D. Qu, X. Wang, and M. Huang, “Research on locality for resource discovery over mobile P2P networks,” in *Proc. of International Communication Conference on Wireless Mobile and Computing*, pp.425-428, 2009. Article (CrossRef Link).

[22] H. Wu, C. Cheng and Z. Zhong, “A resource discovery strategy for mobile Peer-to-Peer networks,” in *Proc. of International Conference on Wireless Information Networks and Systems*, pp.42-46, 2010. Article (CrossRef Link).

[23] J. Kurhinen and J. Vuori, “Information diffusion in a single-hop mobile peer-to-peer network,” in *Proc. of IEEE Symposium on Computers and Communications*, pp.137-142, 2005. Article (CrossRef Link).

[24] P. Galdames, K. Kim and Y. Cai, “A generic platform for efficient processing of spatial monitoring queries in mobile Peer-to-Peer networks,” in *Proc. of International Conference on Mobile Data Management*, pp.1-10, 2010. Article (CrossRef Link).

[25] P. Wang, L. Shou, G. Chen and J. Dong, “MIME : A dynamic index scheme for multi-dimensional query in mobile P2P networks,” in *Proc. of International Conference on Database Systems for Advanced Applications*, pp.576-585, 2007. Article (CrossRef Link).

[26] H. Meyer and K. A. Hummel, "A Geo-location based opportunistic data dissemination approach for MANETs," in *Proc. of ACM workshop on Challenged networks,* 2009. Article (CrossRef Link).

[27] A. Klemm, C. Lindemann and O. Waldhorst, "A Special-Purpose Peer-to-Peer file sharing system for mobile ad hoc networks," in *Proc. of the Vehicular Technology Conference*, vol.4, pp.2758-2763, 2003. Article (CrossRef Link).

[28] V. Govindaswamy, W. L. Blackstone and G. Balasekara, “Survey of recent position based routing mobile ad-hoc network protocols,” in *Proc. of International Conference on Modelling and Simulation*, pp.467-471, 2011. Article (CrossRef Link).

[29] http://iapg.jade-hs.de/personen/brinkhoff/generator/

[30] Y. Xie, W. Xiao, D. Tang, J. Tang and G. Tang, “A Prediction-based energy-conserving approximate storage and query processing schema in object-tracking sensor networks,” *KSII Transactions on Internet and Information Systems*, vol.5, no.5, pp.909-937, 2011. Article (CrossRef Link).

[31] X. Ge, C. Cao, M. Jo, M. Chen, J. Hu and I. Humar, "Energy efficiency modeling and Analyzing Based on Multi-cell and Multi-antenna cellular networks," *KSII Transactions on Internet and Information Systems*, vol.4, no.4, pp.560-574, 2010. Article (CrossRef Link).
[32] I. Humar, X. Ge, L. Xiang, M. Jo, M. Chen and J. Zhang, "Rethinking energy-efficiency models of cellular networks with embodied energy," *IEEE Network Magazine*, vol.25, no.3, pp.40-49, Mar.2011. Article (CrossRef Link).

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