Mobile Ad hoc P2P File Sharing

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***Abstract*— *We propose two efficient search schemes that use query messages filtering/gossiping and adaptive hop-limited search, respectively, for peer-to-peer (P2P) file sharing over mobile ad hoc networks. While the former does network-wide flooding of query messages and is suitable for the applications requiring file update, the latter uses local broadcast transmission and exploits the degree of replication. We compare the first scheme with a Gnutella-like P2P file sharing system [1] in a MANET environment via simulation, and show that the proposed schemes offers less transmission overhead and better scalability. We also qualitatively compare both proposed schemes with ORION [2].*

I. Introduction

A mobile ad hoc network (MANET) consists of a group of mobile nodes that autonomously establish connectivity via multihop wireless communication without relying on any existing, pre-configured network infrastructure or centralized control. A peer-to-peer (P2P) file sharing system autonomously connects a dynamically changing set of nodes to allow the discovery and transfer of information among them. Together, a mobile ad hoc peer-to-peer (MAP) file sharing system exhibits common characteristics of having rapidly and unpredictably changing users and not having fixed infrastructure. Moreover, mobile devices are constrained by battery energy and computation capabilities, and communicate via low bandwidth wireless links. Therefore, optimization of transmission overhead and message processing workload becomes crucial.

In general, a MAP file sharing system consists of a search (lookup) mechanism to transmit queries (lookup) and search results, and a transfer protocol to download files matching a query. For instance, ORION [2] is a pioneering work.

In this paper, we propose efficient search schemes for mobile ad hoc peer-to-peer file sharing systems. Specifically, the first scheme uses query messages filtering and gossiping [3] when performing network-wide flooding of query messages, and the second scheme conducts adaptive hop-limited search with local broadcast transmission. In particular, the first scheme benefits applications that require file update.

We compare, via simulation, the performance of the proposed first scheme with a Gnutella-like P2P file sharing system (with network-wide filter-less flooding) in a MANET environment with respect to transmission overhead. The proposed approach offers better performance for all degree of replication and especially for high mobility speed. We also qualitatively compare both schemes with ORION.

The remainder of the paper is organized as follows. Section 2 reviews related work in the area of P2P systems. In Sections 3 and 4, we present the proposed two search schemes, respectively. In Section 5, the performance of the proposed first scheme without gossiping is compared with an off-the-shelf P2P approach in a simulation study. Section 6 concludes the paper with future work.

II. Related Work

Napster [4] and Gnutella [1] are some of the most popular solutions for P2P file sharing in wireline networks. Gnutella implements a fully distributed search scheme, where queries are broadcasted to all peers via a multi-hop flooding mechanism that transmits queries from device to device. Such a decentralized scheme provides a high degree of fault tolerance. However, the global flooding mechanism used for search requires each device to maintain a connection to at least one other peer, which limits Gnutella's scalability [5].

In [6], the concept of Passive Disributed Indexing (PDI) was presented. Traffic-intensive routing was replaced, by exploiting peer mobility. All messages were exchanged using local broadcast transmissions. The paper claimed that forwarding messages for more than two hops was not necessary for most applications. The index cached at every device was used to store pairs of keywords and document identifiers. However, [6] didn't present a solution for implementing efficient network-wide flooding of messages which are required to perform file update. Several methods (such as tree based approaches [7] and clustering algorithms [8]) for reducing the network traffic generated by flooding a mobile ad hoc network with messages have been proposed. Moreover, [9] proposed an approach based on context-awareness to allow peer-to-peer applications to exploit information on the underlying network context to achieve better performance and better group organization. In contrast, this paper presents effective solutions to implement efficient network-wide flooding of messages.

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In [10], the similarities and differences of P2P and MANET networks were made clear. In [11], the use of a brocade secondary overlay network on a collection of well-connected supernodes to improve point-to-point routing performance on peer-to-peer overlay networks is proposed. The brocade layer uses Tapestry location service to direct messages to the supernode nearest to their destination. In [12], P2P routing algorithms for DHTs and some open questions are discussed.

Optimized Routing Independent Overlay Network (ORION) [2] is a special P2P file sharing system tailored for MANET. It integrates application-layer query processing and overlay network construction with the network layer process of route discovery, and transparently aggregates redundant transfer routes on a per-file basis. Unlike ORION [2], the proposed first approach does network-wide flooding of query messages and is suitable for the applications requiring file update. In particular, the proposed first approach employs query filtering/gossiping, while ORION uses response filtering. ORION does local broadcast transmission, similar to the proposed second approach. However, the proposed second scheme integrates adaptive hop limit with query filtering. In addition, the proposed schemes borrowed the idea of ORION Transfer Protocol which enables efficient file transfers on top of the overlay connections established by the search algorithm.

III. Main Protocol Description

The proposed first scheme is motivated by the following observation. We define the degree of replication to mean the percentage of the nodes storing copies of a given document. Let the degree of replication be d. The probability that a node has all the requested files is at least d^m, where a QUERY contains at most m requested file identifiers. For example, when d is 0.8 and m is 3, the probability that a node has all the requested files is at least 0.512, which can be exploited. Consider a node having all the requested file identifiers. When the node has n neighbors in its transmission range, there will be $2n$ unnecessary messages (QUERY and RESPONSE), unless there is QUERY filtering.

Each mobile device maintains a Local Repository, a Response Routing Table and a File Routing Table. Local Repository contains a set of local files. Response Routing Table is used to store the node from which a query message has been received as next hop on the reverse path. File Routing Table is a data structure storing alternative next hops for file transfers based on the file identifier.

In the proposed first approach, a node floods a QUERY message with requested file identifiers. The QUERY message is distributed via link-layer flooding. The QUERY message triggers the construction of the reverse paths to the querying node in the Response Routing Tables of all intermediate nodes, while it propagates through the network.

Any node receiving a QUERY message first checks its local files before broadcasting. When the degree of replication is high and the number of requested files in the QUERY is low, most probably the node has most of the files. When only some of the files exist in its Local Files Repository, it will update the QUERY message, and broadcast the 'reduced' QUERY.

During filtering of RESPONSE messages, Response Routing Table is used instead of File Routing Table. Additionally, we apply the GOSSIP1(p,k) protocol [3] for the network-wide flooding of QUERY messages to provide scalibility, where $p = 0.6$ if $d > 0.6$, otherwise $p = 0.8$. We gossip with probability 1 for the first k hops before continuing to gossip with probability p. We know from [3] and test that the usage of gossiping probability between 0.6 and 0.8 suffices to ensure that almost every node gets the message in almost every execution. For large networks, the simple gossiping protocol uses up to 35% fewer messages than flooding, with improved performance.

To illustrate the operation of the proposed search scheme without GOSSIP1(p,k), we present two examples with 5 nodes. For both examples, we assume that node B is in the transmission range of node A, and nodes C, D, and E are in the transmission range of node B. Node A floods a QUERY message. E responds first to the QUERY message of B, D responds second, and C responds last. The rectangles beside the nodes are parts of the local repository and the file routing table, respectively.

Example 1. Consider the scenario shown in Figures 1 and 2. Node A issues a query to lookup files 1, 2 and 3 in Figure 1. Node B sends a RESPONSE message containing all of the matched file identifiers, in Figure 2, after searching its local repository. Node B doesn't forward the QUERY message, since it has all of the file identifiers. In contrast, ORION allows node B to forward the QUERY to nodes C, D and E, since it doesn't perform QUERY filtering.

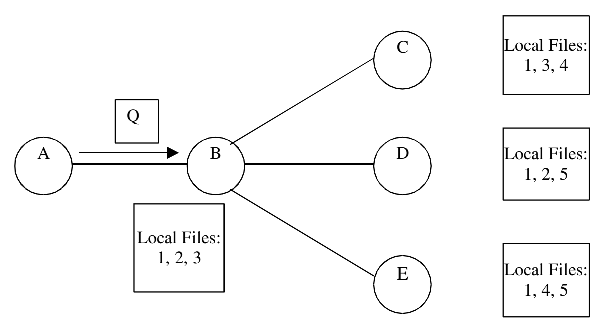

Fig. 1. Node A floods a QUERY message with files 1 to 3. Node B checks its local files and filters the QUERY message. Since node B has all of the asked files in its local files, it does not forward the QUERY to nodes C, D and E.

Example 2. Consider the scenario shown in Figures 3 to 6. Node A issues a query to lookup files 2, 3 and 4, in Figure 3. Node B checks its local files and filters the QUERY message.

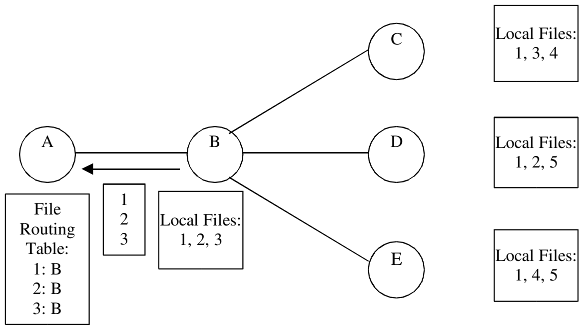

Fig. 2. Only node B sends RESPONSE message with matched identifiers of local files.

Since node B has files 2 and 3 in its local repository, it forwards the reduced QUERY having only file identifier 4 to nodes C, D and E. Node B sends RESPONSE message with identifiers of local files 2 and 3. Meanwhile, node B takes note on its Response Routing Table that the QUERY was responded for files 2 and 3. Then node A updates its File Routing Table (Figure 4). Node E sends RESPONSE message with identifiers of local files; Node B forwards RESPONSE of node E to node A (Figure 5). Node B takes note on its Response Routing Table that the QUERY was responded for file 4. The RESPONSE message isn't filtered by using Local Files, because the QUERY message was filtered. The File Routing Table of node B is updated showing that the file of identifier 4 can be obtained via node E. Later, node C sends RESPONSE message with identifiers of local file 4 (see Figure 6). Node B updates the File Routing Table. As an alternative (redundant) path, C is written after E on the File Routing Table, indicating that node E responded faster than node C, just like ORION. Since node B sends a reduced RESPONSE message to node A having only the new file identifiers by using Response Routing Table, node B doesn't forward the RESPONSE.

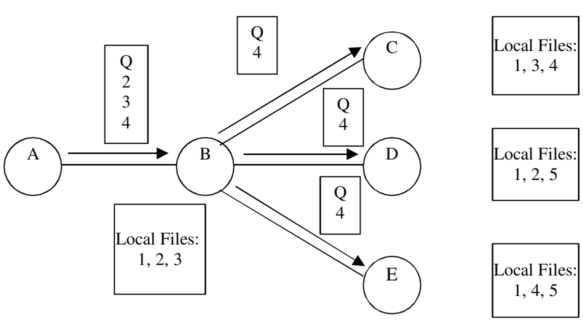

Fig. 3. Node A floods a QUERY message with files 2 to 4. Node B checks its local files and filters the QUERY message. It forwards the reduced QUERY to nodes C, D and E.

Files are transferred on top of the overlay connections estab-

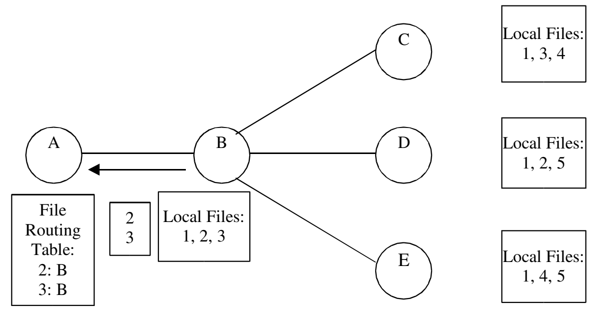

Fig. 4. Node B sends RESPONSE message with identifiers of local files.

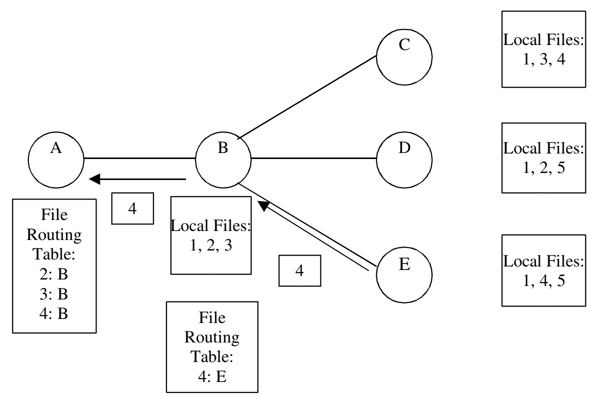

Fig. 5. Node E sends RESPONSE message with matched identifier of local file; Node B forwards RESPONSE of node E to node A.

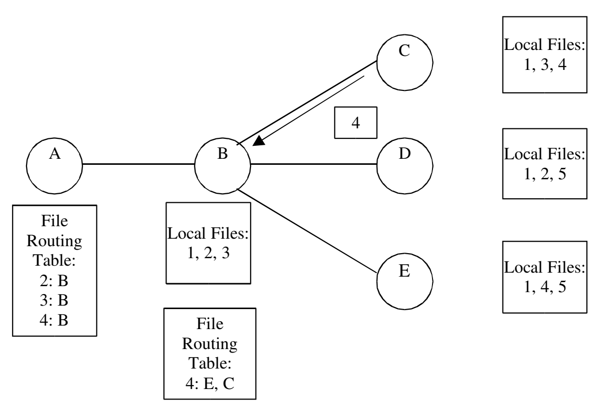

Fig. 6. Node C sends RESPONSE message with matched identifier of local file; Node B updates the File Routing Table.

lished by the search algorithm.

We expect this scheme to be useful for the file update of mobile ad hoc P2P file sharing systems, mainly satisfying the following features. In such a system, each file has four attributes such as name, size (in bytes), version number (start numbering from zero), owner (the name of a user or node id). The version number is incremented every time the file (or its attributes) is modified. The initial owner of a file is the user that created the file. Later, however, another user can become the owner of a file ('file adoption') after contacting the owner W of a file F. The operation update(F) finds out the owner W of file F, contact W, and load last version of F.

Advantages Of The Proposed Approach. The proposed scheme reduces the number of forwarded QUERY messages and corresponding transmission overhead. Filtering QUERY messages decreases the transmission volume of QUERY and RESPONSE messages. Filtering QUERY messages reduces workload of processing the corresponding possible RESPONSE messages. Filtering QUERY messages prevents from unnecessary connectivity. During filtering of RESPONSE messages, Response Routing Table is used instead of File Routing Table. Then, File Routing Table is updated for alternative paths. This is crucial for handling more than one QUERY messages having similar files and coming from different nodes at the same time. For example, both node A and node C can send QUERY to node B for file 2. The proposed approach preserves some advantages of ORION as well. For instance, against flow disruption attack, employing multi-path routing is a good solution. The proposed approach and ORION can provide overlay routing. It significantly increases search accuracy and reduces overhead for searching. It enables reliable file transfers with lower overhead.

IV. The Second Protocol Description

We propose a second approach, adaptive hop limited search using local broadcast transmission, especially for the cases such that the number of partial filtering of QUERY messages is high, or the mobile ad hoc network is heterogeneous with respect to degree of replication.

Given a degree of replication d and N_{Nodes}, there is a tradeoff between providing maximal connectivity and hop limited search. Consider the worst case where the querying node and the node having the file identifier k_0 in the QUERY are far enough such that the intermediate nodes are located linearly in between and do not have the file k_0. Then, a possible hop limit will be $h = (1-d) * N_{Nodes}$ depending on the d and N_{Nodes}. In other words, QUERY will be forwarded to at most hth hop. Therefore, it is guarantee that there is at least one node having the file identifier k_0 and receiving the QUERY message containing k_0, because approximately $d * N_{Nodes}$ have k_0. However, there will be many unnecessary messages.

Parameter	Value
Transmission Range	115 m
Number of Nodes N_{nodes}	40
Simulation Area	1000 m x 1000 m
Maximum Speed s_{max}	5 m/s
Rest Time T_{hold}	50 s

TABLE I
DEFAULT SIMULATION PARAMETERS.

There will be enough alternative paths and connectivity, when we pick h according to average case. By considering our experiments and the results of [2], it is a good idea to choose h as 1 if $d > 0.7$, 2 if $0.1 <= d <= 0.7$, or 3 if $d < 0.1$. We determine the h for each node during initialization of each node only once according to the number of responses coming from the one hop neighbors. Therefore, h depends on the local density of the nodes.

Meanwhile, we prefer hop limited search, although some wired P2P protocols such as Gnutella [1] use iterative deepening search. Mobile ad hoc P2P file sharing system requires that the querying node should get response and the alternative paths for file transfer should be determined as soon as possible before the related mobile nodes move to locations out of transmission range. So we should use a probabilistic h value.

Files are transferred on top of the overlay connections established by the search algorithm, similar to ORION Transfer Protocol [2]. We expect this method is as capable as ORION which uses fixed hop limit.

V. Simulation Results and Discussion

We implemented the proposed first scheme and a Gnutella-like P2P file sharing system with filterless network-wide flooding in QualNet. Both are implemented as Application Layer protocols on top of UDP. We used the IEEE 802.11 MAC layer and the Two-Ray radio model. N_{nodes} mobile devices move in a terrain of $1000m$ x $1000m$ using the random waypoint mobility model. The speed of the device is chosen uniformly at random from $[0, s_{max}]$, where the top speed s_{max} may be different in different experiments. When a device reaches a randomly chosen destination, it pauses for a fixed amount of time T_{hold}, before it continues to move to the next destination. If not stated otherwise, all fixed parameters are set according to Table 1.

First, we initialized N_{nodes} nodes to have random files at their local reposits such that the required degree of replication is satisfied on the system. As stated earlier, the degree of replication 0.9 means that 90% of the participating nodes store copies of a given document. Then we updated the querying nodes so that

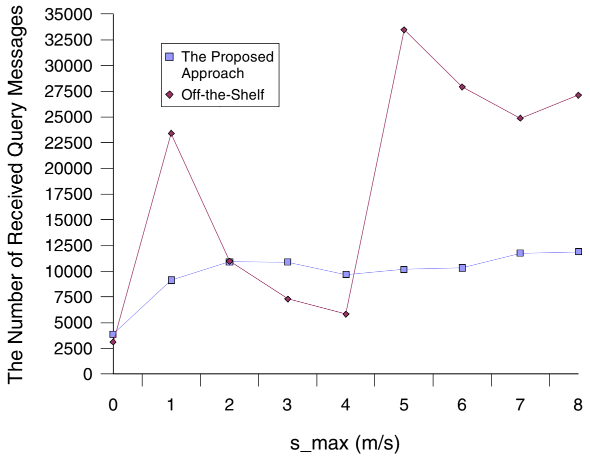

Fig. 7. The number of messages received during QUERY message broadcasting vs. mobility

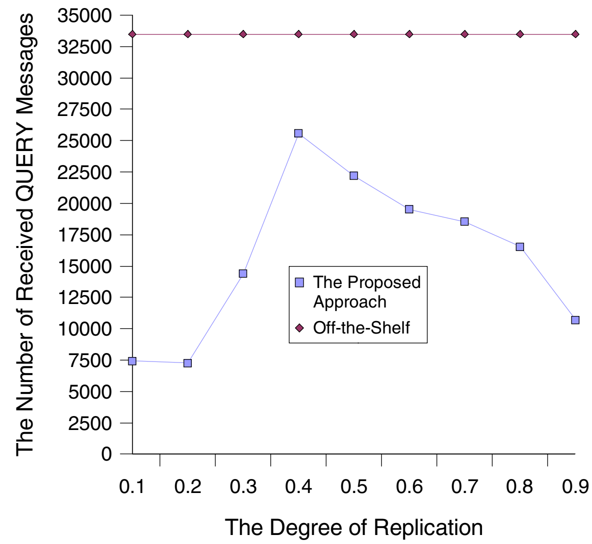

Fig. 8. The number of messages received during QUERY message broadcasting vs. the degree of replication where $s_{max} = 5m/s$.

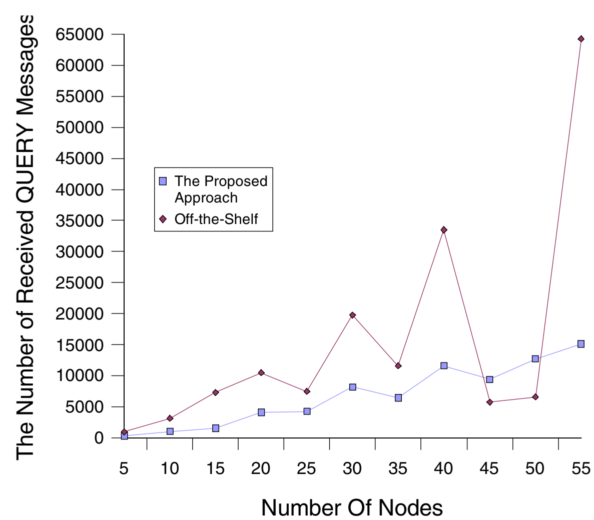

Fig. 9. The number of messages received during QUERY message broadcasting vs. nodes

the querying node broadcasts random query in every 4 seconds. For each point in the performance curves, we performed 254 queries having at most 3 random file identifiers.

In Figure 7, as s_{max} increases, the number of received files becomes almost stable and around 10,000 for the proposed approach. The number of received files for the Gnutella-like filterless approach becomes approximately 2.7 times of that of the proposed approach for higher s_{max} values. This demonstrates that the filtering scheme is very effective for the cases where the mobility and the degree of replication are high. The proposed approach exploits mobility for high maximum speed s_{max} values. The degree of replication is 0.9 for this experiment.

Figure 8 shows that the proposed approach uses less messages for all degree of replications. There is a peak when the degree of replication is around 0.4, because there are more partial filtering. After 0.4 the number of received QUERY messages decreases as the degree of replication increases, for the proposed approach, because there exists more full filtering. On the other hand, for fixed s_{max}, the number of received QUERY messages becomes stable for the Gnutella-like filterless approach.

Figure 9 shows that the proposed approach uses less QUERY messages and the increase of the number of messages received is almost linear and stable as the number of nodes increases. The overall gain of the proposed approach is approximately twice as many as during QUERY message broadcasting, because the filtering affects the number of RESPONSE messages, as well.

VI. Conclusion and Future Work

In this apper, we propose two efficient search schemes for peer-to-peer file sharing systems over mobile ad hoc networks. The proposed first approach, filtering QUERY messages and applying protocol $GOSSIP1(p,k)$, provides a good solution for implementing efficient network-wide flooding of messages. This is useful for the file update of P2P file sharing over mobile ad hoc networks. The second approach, adaptive hop-limited search, exploits the degree of replication and becomes useful especially for heterogeneous mobile ad hoc networks.

In future work, we plan to simulate the operations of file update. Moreover, a hybrid reactive and proactive version of the proposed approaches will be investigated. Intermediate nodes can use their File Routing Tables and the corresponding connectivity for similar queries coming from different nodes around the same time, instead of QUERY flooding. An optimal period value can be determined by considering s_{max} value and T_{hold}. Furthermore, we plan to increase the search accuracy of ORION.

In addition, we propose to use location services instead of QUERY flooding, and compare their advantages and disadvantages. We will investigate how a reactive location service such as Reactive Location Service (RLS) [13] could be incorporated into MAP file sharing systems where location information is queried on an as needed basis. These approaches will be tested for higher speed and different rest time T_{hold} values.

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Abstract

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We propose two efficient search schemes that use query messages filtering/gossiping and adaptive hop-limited search, respectively, for peer-to-peer (P2P) file sharing over mobile ad hoc networks. While the former does network-wide flooding of query messages and is suitable for the applications requiring file update, the latter uses local broadcast transmission and exploits the degree of replication. We compare the first scheme with a Gnutella-like P2P file sharing system in a MANET environment via simulation, and show that the proposed schemes offers less transmission overhead and better scalability. We also qualitatively compare both proposed schemes with ORION.

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