Spray and Wait Based P2P Content Search Mechanism for ICMANs

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Abstract— **Mobile ad-hoc networks (MANETs) and peer-to-peer (P2P) systems are recently emerged technologies which share a common underlying decentralized networking paradigm. Deploying Peer to Peer P2P over Mobile ad hoc networks MANETs would result in efficient content distribution network. However most of the time MANETs are intermittently connected (i.e. No complete path exists from source to destination) due to scattered node densities, limited radio transmission range and power limitations. Various researches have proposed different routing/content delivery schemes under intermittent connectivity. In P2P content distribution systems searching play a major role in identifying the interested content. Existing content searching methods over intermittently connected MANETs (ICMANs) like epidemic P2P content search suffers from message delivery delays and resource wastage. This paper focuses on developing an efficient content search scheme; as a result we implemented Spray and Wait routing for content searching to find interested content in ICMANs.**

Keywords—**ICMANs, P2P, epidemic routing, spray and wait routing.**

I. Introduction

Recently, there has been much research activity in mobile, wireless, mobile ad hoc networks (MANET) [1]. Because of low cost wireless connectivity MANETs have gained huge traction. MANETs are infrastructure-less, and nodes in the networks are constantly moving. In MANETs, nodes can directly communicate with each other if they enter each other's communication range. A packet traverses an ad hoc network by being relayed from one node to another, until it reaches its destination. As nodes are moving, this becomes a difficult task, since the topology of the network is in constant change. A number of routing protocols, like Ad hoc On-demand Distance Vector (AODV) [2], Optimized Link State Routing Protocol (OLSR) and so on, have been proposed in literature for MANETs. Unfortunately, one of the key assumptions of these protocols i.e., the existence of end-to-end routing path between any two nodes becomes untenable in cases where the network experiences intermittent connections due to transmission range, node distribution, and power limitations. Often referred to as intermittently connected MANETs (ICMANs) [3], such connection discontinuity limits the routing mechanism in the network to delay-insensitive applications. In such cases, if delay can be tolerated, then the mobility of the nodes can be exploited to eventually deliver the message to the destination, i.e., the message can be temporarily saved in some intermediate nodes for the next delivery opportunity. This "store-carry-forward (SCF)" routing is quite different from the conventional routing protocols where packets are dropped by a relay node if no path exists to the destination.

ICMANs are also referred to as opportunistic networks [4].In addition, since incurred large delays primarily limit ICMANs to delay-tolerant applications. There are many real networks that fall into this paradigm. Examples include wildlife tracking and habitat monitoring sensor networks (IPN), military networks, inter-planetary networks, nomadic communities' networks etc. ICMANs belong to the family of delay tolerant networks (DTNs) [5].

Peer-to-Peer (P2P) content sharing systems, e.g., BitTorrent , KaZaA, have become increasingly popular. As the market for mobile devices has been increasing, content sharing in wireless networks cannot be ignored. Due to the common characteristics such as self-organization, decentralized architecture and self-healing features between P2P networks and MANETs, mobile ad hoc P2P (MAP2P) [6] networks have a good potential to be investigated for mobile content distribution. In a content distribution network content search or content lookup is a fundamental problem that determines the architecture and performance of the network. This is because only after discovering the information about its interested contents, a mobile user can determine which contents to be downloaded and accordingly activate the downloading process over the network. There are different types of P2P content delivery networks, different content management architectures and content search mechanisms are proposed in the literature. By considering how to organize the participating peers to build overlay network and how to place the contents, these P2P content delivery networks are classified as unstructured and structured P2P networks.

- Unstructured P2P: In the unstructured P2P content delivery networks, the placement of available contents is completely unrelated to the overlay topology.

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However, by considering how to provide efficient content search, the unstructured P2P systems can be further categorized as fully decentralized, centralized and partially centralized.

- Structured P2P: To address the scalability issues occurring in the unstructured networks, structured networks try to create network topology and place the contents based on some specific rules so that content queries can be efficiently forwarded to the node with desired contents.

In fully decentralized or unstructured P2P networks (e.g., Gnutella), all content search requests are flooded across the network to other peers to eventually find a matching content. In contrast, a centralized index server is employed by some other P2P networks such as Napster, where all content lookup requests are forwarded to the index server to get the related information. Moreover, a hybrid architecture is employed by KaZaA, where some super-nodes with higher capabilities perform as the local index servers for their neighbors. In addition, in the distributed hash table (DHT) based structured P2P networks (e.g., Pastry [7], CAN [8] and Chord [9]), the placements of the contents and even content indices are related to their identifiers generated according to a hash function so that the contents or content indices can be located based on their identifiers directly.

Content search will eventually require routing algorithm which routes search requests in the network. As mentioned earlier routing in ICMANs involve SCF method. Initially Epidemic Routing [10] was proposed for ICMANs, where message diffuses over the network until it reaches the destination. Although optimal results can be achieved with unlimited resources, in most realistic cases with constrained resources such as buffer space, bandwidth and power, its performance is significantly degraded. With all this we propose a novel P2P content search mechanism for intermittently connected mobile content distribution network. Proposed mechanism include Spray and Wait [11] as routing protocol instead of epidemic routing. Due to intermittent connectivity, a fully decentralized architecture is employed, in order to avoid high maintenance overhead for DHT-based and centralized index-server based content search. Each node indexes its own stored contents based on their related keywords, while any peer can accordingly search its interested contents over the network just based on several related keywords. Note that such keyword-based search requests are flooded over ICMANs to allow other peers (as many as possible) check whether they contain the matching contents or not. As epidemic routing is resource intensive, Spray and Wait routing protocol is considered to diffuse content search requests over ICMANs.

The remainder of this paper is organized as follows. Spray and Wait P2P content search mechanism is proposed in Section II. The simulation and evaluation are presented in Section III, followed by some concluding remarks.

II. Spray and Wait P2P Content Search over ICMANS

Unlike others, routing protocols for intermittently connected networks should possess some properties, they include performing significantly fewer transmissions, generate low contention, especially under high traffic loads, achieve a delivery delay that is better than existing single and multi-copy schemes, and close to the optimal, should be highly scalable. With all this in mind we choose Spray and Wait routing protocol.

A. Spray and Wait definition

Spray and Wait routing protocol include the following two phases:

- Spray phase: for every message originating at a source node, L message copies are initially spread–forwarded by the source and possibly other nodes receiving a copy –to L distinct “relays”.

- Wait phase: if the destination is not found in the spraying phase, each of the L nodes carrying a message copy performs direct transmission.

Spray and Wait utilizes the advantages of epidemic and direct transmission mechanism by combining the speed of epidemic routing with the simplicity and thriftiness of direct transmission. It rapidly spreads message copies initially as in epidemic routing. When enough copies have been spread to guarantee that at least one of them will find the destination quickly, it stops and lets each node carrying a copy perform direct transmission.

The above definition of Spray and Wait leaves open the issue of how the L copies are to be spread initially. A number of different “spraying” heuristics can be envisioned. For example, the simplest way is to have the source node forward all L copies to the first L distinct nodes it encounters also called Source Spray and Wait.

B. Procedure of Spray and Wait P2P content search

In the proposed mechanism, every content is assumed to contain a unique content identifier and a meta-data file with corresponding keywords. Every mobile node indexes all of its own stored contents (published and downloaded contents) based on their corresponding keywords. As a result, whenever a node wants to download some interested contents without any information about the corresponding content identifiers, it can facilitate a content query based on the related keywords across the network. On receiving such a content query message, each intermediate node performs a keyword-based search through its stored indices, while if any matching content exists, a response message is accordingly generated and forwarded back. The response message includes the content identifiers and the meta-data files of the matching contents. On receiving this information, the node can eventually determine which contents it would like to download and accordingly requests them over the network based on the received content identifiers.

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Since the contents are indexed locally in the fully decentralized architecture, to allow other nodes (as many as possible) check whether they contain the matching contents or not, the content queries are spread across the network using source spray and wait routing, i.e. content requesting node generates L search request copies and forwards then to first L encountering peers one by one. To perform spray and wait P2P content search, every issued search request includes peer ID, request ID, keywords, timestamp and expiry time. Peer ID and request ID together represent each unique request, while expiry time is given to eliminate regular maintenance in the ICMANs context. Note that for a given request, if the expiry time is passed, it should be removed by all possible intermediate peers from the storage.

Interaction between peers is purely opportunistic because of intermittent connectivity i.e. request forwarding and content search only happen whenever two mobile peers encounter each other. After connection is established between two encountering peers, the entire procedure can be summarized as follows.

Initially, each peer checks its buffer space and removes all expired content search requests. Then the source peer sprays the L copies of the search request to L different peers. On receiving a request, each of the L peers executes the keyword-based search through its locale index server. If any matching contents are discovered, a response message as mentioned earlier is generated and delivered back to the querying peer based on the peer ID as well as the request ID. As P2P content search can contain more than one destination, the L peers containing a copy search request enters the wait phase by saving the request into its local buffer or storage to direct transmit the search request to the destination if possible

C. Choosing L to Achieve a Required Expected Delay

In this sub-section we specify two different methods for choosing L (i.e. the number of copies used) in order for Spray and Wait to achieve a specific expected delay.

Choosing L value plays a crucial role because if L is too low it will result in larger end-to-end delays and As L grows larger, the more the network is congested and the sophistication of the spraying heuristic has an increasing impact on the delivery delay of the spray and wait scheme. So L value must be chosen not too low nor too high.

This is the basic method to choose L value. With all the above in mind we proposed this method. It state that L value should be in between half the number of nodes and number of nodes. The minimum number of copies L_{min} needed for Spray and Wait to achieve an expected delay is independent of the size of the network N and transmission range K, and only depends on the number of nodes M.

$$M/2 \leq L_{min} < M \quad (1)$$

D. Utility-based cache management policy

Store and carrying opportunity cannot be provided to every content search request from other peers due to the cache constraints, therefore in this subsection, we evaluate each available request and accordingly determine which request to discard when the cache space of a peer is full. We first discuss about the essential information that a peer needs to know when it wants to make any reasonable evaluation for each request. Then, we make some assumptions regarding the content search service itself and the mobility characteristics of the mobile peers in ICMANs context, and accordingly derive a utility function to evaluate each request based on such essential information. After that, we explain how such essential information can be collected by every peer.

As can be seen in Fig. 1, if any peer can build up such relationship map among keywords, content identifiers and peer identifiers, it can accordingly know how many matching contents exist over the network and where to find them when it receives any content search request. Moreover, the peer can further estimate its discovering probability for any possible matching content with several known locations, if it also has the related historical encountering statistics. Accordingly, the peer can eventually get an expected serving ratio, an expected value indicating what percentage of the matching contents that can be discovered in the future, if it offers storing opportunity to such content search request. Thus, to improve the overall searching performance, such expected serving ratio can be exploited by the dropping policy to determine which requests should be dropped.

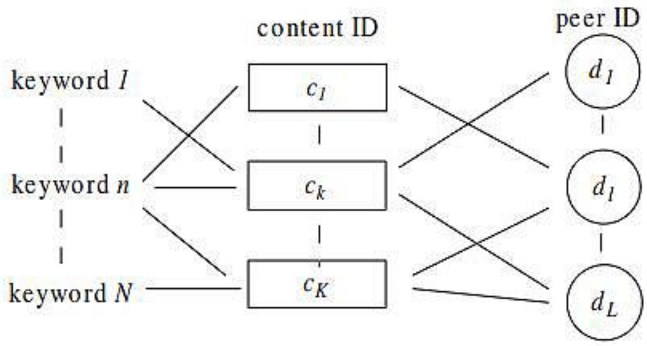

Fig. 1. Relationship map among keyword, content ID and peer ID

To derive a utility function to carry out the expected serving ratio for request evaluation, instead of making any assumption about a particular mobility model involved, we only assume the inter-encountering time between each pair of mobile peers follows the exponential distribution or at least has an exponential tail. Similar mobility assumptions are employed in [12][13], since most popular mobility models such as Random Waypoint, Random Direction [14] and even other community based mobility model [15] have been proved to have such a property.

III. SIMULATION RESULTS

Performance of spray and wait P2P content search mechanism is evaluated by using Network Simulator NS2 discrete event simulator. During the simulation maximum of total 50 mobile peers are considered. ICMANs were implemented as DTN network. Over ICMANs P2P overlay network is implemented in which routing is performed using Spray and Wait routing protocol.

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The simulation considers a total of 50 unique contents with 10 related keywords. Note that in the simulation, we just focus on how search requests can be diffused over ICMANs by epidemic P2P content search scheme and how its utility-based buffer management policy can affect the overall searching performances (rather than the keyword-based content search itself). Therefore, to simplify the simulation, each content only selects one related keyword randomly. Moreover, in most realistic cases, people collect and store contents based on their interests and a certain interest may just attract a group of users.

A. Performance Attributes

Performance attributes that are to be compared between epidemic and spray and wait P2P content search are

- End-to-end delay: Time taken by the search requests to travers from source to destination.
- Throughput: Ratio of No. of search requests handled successfully to total number of search requests.

IV. CONCLUSION

This paper proposed an efficient content search mechanism over P2P ICMANs, which uses spray and wait routing protocol for search request forwarding. Thus reducing the overall end-to-end delay and network resource usage than epidemic P2P content search.

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