Journal of Computers Vol. 28, No. 1, 2017, pp. 209-223
doi:10.3966/199115592017022801016

A Broadcast Based Random Query Gossip Algorithm for Resource Search in non-DHT Mobile Peer-to-Peer Networks

Ajay Arunachalam[1], Ohm Sornil[2]

[1, 2] Department of Computer Science, Graduate School of Applied Statistics, National Institute of Development Administration, Thailand
ajay.abhi@grads.nida.ac.th

Received 16 October 2015; Revised 29 January 2016; Accepted 11 April 2016

Abstract. This paper presents a resource discovery scheme for decentralized non-DHT Mobile Peer-to-Peer (MP2P) networks. In a mobile environment, the energy of mobile device is very critical. The aim of the proposed technique is to reduce the network overhead, lower battery power consumption and minimize query delay while improving the chance to resolve the query at every successive stage. Peer-to-Peer applications have gained a lot of attention in past years due to its decentralized nature. Resource searching algorithms are one of the major focuses of P2P network. Mobile Ad hoc Network (MANET) with its changing topology further poses additional challenges and thus increasing the search effort. Methods like flooding, random walk and probabilistic forwarding techniques are good candidates to run over such dynamic network. In this work, we study the flooding, random walk and gossip based resource discovery protocols on a P2P Mobile Ad hoc Network. We observed that the classic gossip algorithm does not work well under MANET as in the case of a wired network. We focus to improve the algorithm to suit and work better under such dynamic network scenario. The proposed system presents a light weight resource discovery design to suit the mobility requirement of ad hoc networks to optimize the search performance while at the same time minimize the extra usage of mobile and network resources. For quick and energy efficient search scheme, we explore a novel addressed jumping approach. Our algorithm is entirely distributed, and hence will scale well even to the growing size of the network. The efficiency of our proposed algorithm is validated through extensive NS-2 simulations. The results show that our proposed scheme gives better performance than the widely used techniques. We also validate through statistical hypothesis testing of simulation data.

Keywords: flooding, gossip, MANET, MP2P, peer-to-peer, resource search

1 Introduction

With widespread of technology and hardware, mobile devices have become omnipresent and centrifugal part of the communication system that strongly adheres to anywhere, anytime computing on the go. Development of mobile devices such as smart phones, laptops, mobile services and wireless internet access allow users to connect instantly to each other and building network in an ad hoc fashion. Multihop networks are widely used due to its infrastructure less characteristics and multihop routing. Mobile Ad hoc Network (MANET) being one of such network consists of mobile nodes and wireless links. Nodes in MANET communicate with each other through multihop routing whereas the nodes that are not directly connected at the link layer can communicate through the routing layer. MANETs have been a hot research topic over the past years and are widely deployed in practical applications. Resource discovery in such network is a key challenge as each node is autonomous and possess no prior knowledge about each other and their available resources, while the nodes may also join and leave arbitrarily. MANETs have several open issues including network routing [1], security threats, resource searching, maintaining network connectivity, etc. A lot of focus in recent years are given to MANET routing protocols. Due to single point of failure the client server architecture became less important and was replaced by the decentralized network architecture. P2P system is one of such architectures without any centralized coordination. The first P2P system named ARPANET was discovered in late 60s. Later this architecture was used for file sharing, data retrieval, multimedia services, storage and messaging services etc. P2P technology is popularly used in wired network. Napster and Gnutella were widely used over Internet. Such networks have shown their potential advantages over centralized approach. Inspired by the fixed domain, these networks are now penetrating the wireless and mobile domain. Incorporating P2P network characteristics in Mobile Ad hoc Network is coined as P2P MANET or Mobile Peer-to-Peer. Compared to traditional wired P2P network, MP2P has many limitations [2] which makes resource search and information sharing more difficult in such dynamic scenario. Resource searching is one of the hot topics focused by researchers in the area of P2P technology. The search mechanism in such network is broadly classified as centralized directory model, structured lookup model and flooded request model. Even as of today Gnutella P2P file sharing system uses flooding mechanism to locate the file. The communications between peers form a virtual layer independent of the underlying network. Even though P2P network and MANET have many similarities, both have one common challenge, i.e., maintaining continuous network connectivity. Further combination of both also does not jell well due to their basic differences in the operative layers and transmission mechanisms. Therefore, simply adopting P2P overlay protocol over MANET is ineffective. Due to lack of sync between these networks, the resource search protocols perform poorly. Earlier work evaluated the performance of different content searching techniques in P2P network over a wired and fixed layout like the internet. Their performance outcomes cannot be directly compared to MANETs due to the differences in the characteristics of both networks. Thus, there is a need for an improved resource searching algorithm that suits the mobile network characteristics. The Peer-to-Peer architecture is broadly classified based on the connection of the nodes and listing of the files. In P2P networks the resource discovery mechanism depends on structure, classified as unstructured and structured type. Though unstructured P2P systems are flexible and simple but if peers are looking for rare data which is available to only a section of a network, then the queries may not always be resolved. The other major concern is that popular content is likely to be available at several peers and any peer searching for it is likely to find same content from the repetitive peer node. While there is no predefined structure among the peers, the query is flooded or randomly distributed. The drawback of such searching technique is the duplicate query request which creates lots of message overhead. Further the exponential increase and duplication of query request, consumes extra processing power and network bandwidth in flooding technique. A suggestive alternate to flooding approach is gossip or epidemic protocol [3]. Here each node forwards a message to a few set of nodes randomly with some probability. One of the attractive features of the gossip protocol is its randomized nature and its redundant effort to cope up with the ever changing implicit paths. As a reason it is said that these protocols work better in mobile environment. But at the same time there are major challenges too, i.e., controlling the overhead due to randomized dissemination, using appropriate combination of probabilistic and deterministic mechanism, determining when and how to stop gossip in such mobile environment etc. In [4], their scheme describes how message is routed when a node initiates a broadcast to be sent to some set of neighbors chosen at random. In this article, we limit our work to three contributions: First, we study the neighbor discovery and connectivity techniques for existing unstructured P2P networks and suggest an alternative method for peer discovery over MANET. Our second contribution focuses towards enhancing the unstructured searching technique over MANET. Thirdly, the proposed resource discovery protocol is validated using statistical hypothesis testing and computer simulations. We present a simple query search mechanism to control flooding and overhead in unstructured Peer-to-Peer networks.

The above section of paper discussed about MANET and the problems of deploying P2P network over MANET. The rest of the paper is organized as follows. Section II gives a brief review of the previous studies and discusses the related works. Section III describes our proposed resource discovery protocol. Section IV provides the simulation results and verifies it with hypothesis testing. And finally section V draws the conclusion.

2 Related Works

P2P (Peer-to-Peer) terminology was widely famous and mostly associated for an illegal file sharing system, where millions of peers could connect together to share or download the contents of each other without any centralized restriction imposed by either of the parties. Such P2P system falls in two broad categories mainly based on the organization of the peers and listing of the files as unstructured and structured type. For a structured P2P system the peers maintain a strict well-organized structure using complex algorithms to ensure connection between nodes making them efficient enough to resolve the lookup request instantly. While the unstructured P2P systems require no prior knowledge of the topology and peers can join and leave randomly thereby increasing uncertainty while resolving the query. In such system due to lack of strict hierarchy among the peers, the search request is flooded or distributed randomly to a set of peers. This leads to high network traffic and message duplication. The other drawback of existing search methods is that the peers being already visited are revisited at multiple instances decreasing the search efficiency in such system [5]. One of the objectives of our proposed scheme is to restrict the cyclic path in the search process and lower message duplication. Compared to structured, the unstructured system has less maintenance overhead, but then resource discovery effort increases thereby increasing the network traffic drastically. The authors in [6], propose a search technique for unstructured peer-to-peer network based on the ticket concept. In their research context, ticket specifies the number of nodes to be checked in one search round. For an object search a ticket is used. If the file is not located in one search round, then the number of tickets is increased by some random factor. When a message is received at the node for the first time, then one ticket is consumed. Accordingly it is forwarded to all neighbors as long as the message carries sufficient tickets. But here the reachability of the message wholly depends on the number of tickets and its validity. Ad hoc communication due to its leverage simplicity and special characteristics became popular over the years. Mobile Ad hoc Network being one of them is able to dynamically form a temporary network on the go which consists of mobile nodes that communicate using wireless links. While MANETs and Peer-to-Peer network build ad hoc communities instantly without any centralized control, but keeping the network connected is also a common challenge in both. Resource discovery is a key challenge in such self-organizing networks. To adapt the frequent changing topology, flooding based approaches are one of the best suitable candidates for query search. [7], provide a brief overview of various approaches to resource discovery in a wireless network. The author discusses various ways including flooding based approach, hierarchical approach and hybrid schemes. They conclude with a critical summary where the hybrid schemes along with contact based approaches tend to provide better energy efficient solution and scale best only under certain assumptions and scenarios, otherwise they conclude that the traditional flooding technique standout to be the best. Flooding and Random walk are the two widely accepted search mechanism.

Flooding technique is based on breadth first search traversal method where the resource requesting node sends query to all its neighbors which in turn is forwarded throughout the network. In contrast the random walk technique is based on depth first search traversal method where the query forwarding is probabilistic and random. The gossip based algorithm due to its simplicity and flexibility have also been applied to varied application areas including overlay maintenance, data aggregation, dissemination, object allocation and resource searching. Most of existing search techniques have a tradeoff between network traffic, query response time, peer load and probability of query hit. Like in flooding it results in a lot of traffic and do not scale well as the network size grows. While in the ring search the main problem is about how to determine the criteria for choosing a good TTL value. And that in the expanding ring search method it increases the overall network load with duplicate query messages. In contrary though random walk reduces the network load but here the query wanders in the network increasing the search latency. Our focus is to reduce the search process time and utilize the network and mobile resources effectively while at the same time provide equally good success rate. [8], proposed a gossip based search algorithm for Hybrid P2P networks. In their work, they used gossip style to collect summary about the popularity of resources thereby helping peers to make appropriate choice of search mechanism for a given query. Gossip protocol along with local knowledge of resources held by the neighbor peers can be effective solution for resource discovery in unstructured P2P network [9]. They proposed an analytical model to justify their findings. Over past years gossip style techniques were also employed for route discovery in such multihop networks. In [10] the authors modified the classic gossip algorithm by varying the gossip probability. They vary the probability with respect to the direction of path discovery along source to destination by using the forward and backward gossip conditions. The forward gossip occurs along the path, and the other in the opposite direction of the path respectively. A different approach of varying the gossip probability was discussed in [11] for broadcasting in sensor networks. Their methodology was based on the concept of hierarchy deduced by parent, child and sibling relationship using which the gossip probability is determined and chosen. The basic principle of their work is based on human gossiping ideology, i.e., to identify which of your friend's get to know gossips earlier than you, request those friends to gossip more. The friends who get to know gossips later than you will request you to gossip more. Finally you choose your probability of gossiping as the maximum value of all requests from your friends. In all the above discussed gossip based approaches, the selection of gossip probability plays a vital role in the random dissemination process. The main aim of our work is to obtain maximum gain with any gossip probability. We extend the gossip based search method under MANET and propose a way to improve the performance in such dynamic environment. P2P computing due to its special network characteristics was also extended as a file sharing application over MANET. A simple approach to resource search in Gnutella P2P file sharing application uses flooding technique. ORION [12] protocol was tailored for resource searching in P2P file sharing application over ad hoc networks. Their proposed search algorithm integrates application layer query processing and network layer route discovery. But their search technique also resembles an indirect flooding scheme. A different file sharing architecture based on super node for Mobile Peer-to-Peer network was proposed in [13]. Their method enables efficient resource sharing in mobile environment. In the past random walk and probabilistic forwarding techniques were also used but when compared to flooding it yields better results only for a wired network [14]. Efficient resource discovery in MANET is basic responsibility of MP2P system. Further in such environment effective use of battery power is very crucial for every device to participate in the system. Directly adopting P2P resource discovery protocols over MANET is also undesirable due to the rapid mobility [15]. The goal of any search mechanism is not only to successfully locate the resource but also to incur low overhead, minimize query delay and consume less energy especially with the nature of mobile nodes [16]. Therefore there is a need of simple, quick and energy efficient resource discovery scheme in P2P deployment over MANETs that abides the characteristics of wireless communication.

3 System Model and Protocol

3.1 Problem Specification

In P2P network the communication between peers leads to formation of a virtual overlay network in the application layer on top of the underlying topology. For MANETs resource discovery is related to routing protocols, i.e., searching means to route a query to node in the network. The basic principal criterion of any P2P network is how efficiently the desired resources can be located. When a peer wants to resolve a query, the flooding approach is used. But this causes very high signaling traffic in the network and consumes more computational power. Probabilistic forwarding technique is also used for resource discovery. In [17] they suggest that gossip style approach suit best for various distributed applications. We consider an unstructured network with peers that connect each other through a pseudo-random attachment process which forms the overlay, wherein each link of overlay network is supported by a path in the underlay network that includes both, i.e., peers and ad hoc nodes. How resource discovery can be made effective in such self-organizing network while considering limitations of mobile nodes to best suit the P2P model is the focus ahead.

3.2 Design Principle

In this work, we propose a broadcast based random query gossip algorithm (iGossip) to reduce the network overhead that was observed in the classic gossip algorithm under MANETs. While doing this method, our aim is to reduce the routing overhead, minimize query response delay, lower battery power and bandwidth consumption, and improve the chance of finding the resource. Under MANET any resource searching algorithm just proceeds blindly in the network, as no external knowledge can be used to channelize and provide an effective search path direction due to the random frequent topology change. This simply means each node forwards the query received for the first time and discards it otherwise. Our proposed method is a blend of gossip algorithm and conditional broadcast with simple message delivery technique to suit such highly dynamic mobile network. The standard way of implementing gossip based P2P resource discovery protocol under MANET have some critical issues, the major ones being the complexity observed in overhead, high energy consumption and long query delay with overall low success rate. In gossip method, the message is passed to a randomly selected neighbor node using unicast message transmission which will depend on the routing layer information. While in MANET, the nodes may be in continuous movement and thereby the transmission may fail very often due to the rapid change in the network topology. And this will initiate frequent re-route discovery incurring high overhead. To overcome this problem, we suggest an addressed broadcast query gossip mechanism. The basic idea here is that the resource information will not be gossiped instead the query itself gets gossiped and moved over. Now if a node receives that gossip query, then it will make a one-hop addressed broadcast request like "Hello x, do you have the resource". If any nearby neighbor's of the node "x" have that resource then it will also respond so that gossip query will get terminated at that point, otherwise the query will get moved from that point using another gossip with the selected neighbors. Here the query gets randomly gossiped until reaching the node which has the relevant information of that gossip query. In our model, only 2 nodes will be involved in gossip at a time and in only single gossip location at a time. To understand in brief, we elaborate the query search mechanism of our proposed technique as shown in Fig. 1.

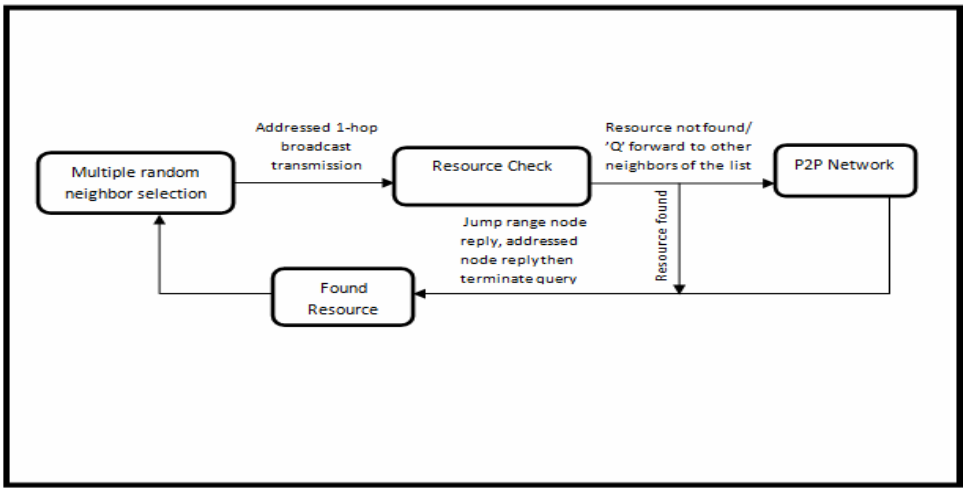

Fig. 1. Phases of iGossip search

Here resource searching is done with an addressing technique. If the resource is found within transmission range of the request forwarding node, then a reply is sent back to the initiator node. If the reply is from the addressed node itself then the query process gets terminated. But if the resource is not found or the reply was from any of the other non-addressed neighbor node then the gossip continues for certain time interval with all the selected neighbors where the addressed node will only process the query request further.

3.3 Neighbor Discovery

In our proposed scheme, the neighbors of the node are directly resolved from the AODV routing protocol. Generally the neighbor nodes are detected by doing 1-hop hello broadcast protocol. To establish a connection with the existing nodes the newly arrived node broadcast the *HELLO* message within 1-hop range. The other nodes upon receiving the *HELLO* message replies with an *HELLO RESPONSE* message. In this way the neighbor list is updated frequently in the overlay. But doing it the traditional way will again increase the broadcast overhead.

So, we use the neighbor information which is available within the routing protocol and pass this information to the P2P application. Doing so, we are not increasing the overhead at application layer. We maintain neighbor list information resolved from the routing layer neighbor list. If the AODV_LINK_LAYER_DETECTION is defined, then it will use hello timer to detect the neighbors which will be overhead. Under ns2 v.2.35 this is enabled by default so that hello based detection is used directly. The algorithm 1 explains the neighbor discovery process carried out for a P2P application running over MANET given in Table 1.

Table 1. Node discovery

Algorithm1: Neighbor node discovery

```
Procedure neighborlist ( )
if (strcmp(argv[1], "neighbor_list") = = 0) then
   1. Point to the first element in neighbor cache of AODV_Neighbor
   2. For each neighbor, link to its next node.
   3. Get the neighbor address.
   4. Append AODV routing layer neighbor list information to neighbor ar-
      ray.
   5. Pass this information to P2P application.
end if
```

3.4 Random Query Gossip Search Algorithm

In this section, we present an algorithm based on the illustrated idea. The simplest form of the proposed algorithm is from the basic idea where 1 to many communication is used to suit well for a highly mobile network such as VANET. While a query is passed to neighbor, instead of sending it by a unicast transmission as done in gossip protocol under MANET we send it to that particular node with over an addressed broadcast transmission. The pseudocode of our proposed algorithm is given in Table 2. The requesting peer 'i' generate a gossip query message 'm'. The content of the gossip message 'm' are {message ID, ID-requesting peer, ID-requested resource}. The message forwarding peer gets the neighbor information from its routing agent. We resolve the neighbor list of the requesting peer from the routing layer neighbor list by modifying the routing protocol. Then select multiple random neighbors. Forward the gossip message 'm' to the first node of the selected neighbors over 1-hop addressed broadcast transmission. Here all the neighbors within the transmission range can receive the message and will be able to see that message. But only that addressed node will process the request further. Schedule the gossip to all the randomly selected neighbors until Interval I. Now in case, the resource containing node will be within the transmission range of the querying node then it may reply the query instantly. So here the query delay is minimized, while also lowering the overhead due to addressed forwarding design technique and further the probability of reaching the resource containing node is also improved. In addition, here the energy and bandwidth consumption is also lowered due to the addressed broadcast design. Our technique is different from the naïve broadcast and multicast methods where all the neighbors those are within the communication range can receive the message, but only the addressed node will resume forwarding the message.

4 Evaluation

4.1 Simulation Environment

We simulate a P2P application over MANET. We propose a resource discovery algorithm for a pure P2P network without any use of special nodes or hierarchy. We evaluate the performance of our proposed protocol with other unstructured search algorithms and verify it for 40-90 nodes respectively over a period of 120 secs. The simulator parameters are the same as in [18]. The nodes moved according to the random way point model. For each set of nodes we created "3" different scenes for every resource dis covery protocol. We calculate the performance metrics based on the average analysis of the different scenarios for every set of nodes. The query node generates a search request after a uniform interval of 5 secs. Table 3 shows the experimental parameters. The P2P application parameters are given in Table 4.

GossipDelay: If a node receives a Gossip, then how much time it should wait for sharing it with first random node.
GossipInterval: If a node receives a Gossip, after sharing it immediately with a node after GossipDelay seconds, then how much time it should wait for sharing it with another node.

Table 2. iGossip search scheme

Algorithm2: iGossip search

```
Query Q generated at node 'i'
node initiates RD(){
   1. Get neighbor list from routing layer.
   2. Randomly select 'g' number of neighbors.
   3. Forward gossip 'm' to 1st node of the
      selected neighbors over 1-hop addressed
      broadcast }

Upon receipt of gossip 'm' by node 'j'
iGossip(m)
{
  if(TTL = 0) {
     stop forwarding this message
     return
              }
     otherwise decrement TTL
     if(gossip 'm' received for first time) {
              mark processed
     append to processed list
       if(we have the resource) {
          send resource reply;
               return;
           }
      }else {
          stop gossip
     return }
Schedule gossip to remaining selected neighbors from neighbor list until
•T
Get the addressed neigbhorID from gossip 'm'
     if(this node is the addressed neighbor) {
               Start iGossip with
               GossipsPerRequestPerNode
     }else {
       on {probability p} {
                  start another iGossip
                    }  }
}
```

Table 3. Experimental environment

Parameter	Value
Simulation area	1000m x 1000m
Mobile nodes	40,50,60,70,80,90
Transmission range	250m
Pause time	20.00sec
Max speed	20.00m/s
Initial node energy	500 Joules
Routing protocol	AODV
P2P resource discovery protocol	Flooding, Random walk, Gossip, iGossip
Lookup interval	5.00 sec

Table 4. P2P application related parameters

Parameter	Value
P2P Application port	6346
P2PResourceRequestMessageSize	100 bytes
P2PResourceReplyMessageSize	100 bytes
Broadcast Delay	0.01
Transmission Probability	100% (=1)
OneHopBroadcastAddress	-1
GossipInterval	1 sec
GossipsPerRequestPerNode	2
GossipDelay	0.01

4.2 Metrics Used for Evaluation

A typical P2P network resource discovery scenario is peculiar in nature [19][20], so we need to modify the standard definitions of the commonly used metrics under MANET [21] to verify for a P2P MANET scenario. The following are the list of metrics used to measure the performance of the P2P resource discovery algorithms under consideration. 1) Query success rate 2) Resource discovery time 3) P2P Network routing load 4) P2P Network overhead 5) Overall dropped packets 6) P2P Network MAC load 7) Average consumed energy 8) P2P Agent level hop-to-hop delay 9) P2P Agent level throughput 10) P2P Agent level packet delivery ratio

The definition of each metrics is given below.

Query Success Rate (%). The success rate is an important metric for measuring the performance of P2P resource discovery algorithm. It is a ratio of total generated requests and the successfully received replies. It is measured as follows:

$$\text{Success rate} = (R_{ep} / R_{eq}) * 100 \quad \textbf{(1)}$$

where,
R_{eq} is total generated resource requests and
R_{ep} is total successfully received resource replies
The higher success rate signifies the better performance of the resource discovery algorithm.

Avg. Resource Discovery Time (sec). The resource discovery time is also another important metric for measuring the performance of P2P resource discovery algorithm. It is the time difference between the resource request generation time and the resource reply received time. It is calculated as follows:

$$\text{Resource discovery time} = T_{Rep} - T_{Req} \quad \textbf{(2)}$$

The lower resource discovery time signifies the better performance of the resource discovery algorithm.

P2P Network Routing Load. Generally normalized routing load is a ratio between the number of routing packets generated and the number of data packets successfully delivered. But in this P2P network scenario we measure it differently. Here routing load is measured as a ratio between the number of routing packets generated + forwarded and the number of resource discovery messages received at application layer of each node of the network during the resource discovery process. It is calculated as follows:

$$\text{Routing Load} = (R_g + R_f) / A_r \quad \textbf{(3)}$$

where,
R_g is the total generated/sent routing packets,
R_f is the total forwarded routing packets and
A_r is the total P2P agent level received packets
The lower P2P Network Routing Load signifies the better performance of the resource discovery algorithm.

P2P Network Overhead. In this work we measure overhead in terms of total number of generated and forwarded routing messages at the Network layer.

Overall Dropped Packets. Dropped packet count in a MANET scenario is an important metric to evaluate the network performance. Generally packets will be dropped due to several reasons in a wireless ad hoc network scenario. And particularly, this dropping of packets in a typical P2P network will be expected to be high since these algorithms will use lots of duplicates of the same resource discovery message during the discovery process that will increase the overhead causing network bottleneck. We count the packets dropped at the network layers of all the P2P nodes.

P2P Network MAC Load. Generally MAC load is calculated as a ratio between the number of packets sent at MAC layer and the number of data packets successfully delivered. But here we calculate the MAC load as a ratio between the number of packets sent at MAC layer and the number of resource requests received at P2P Agent level of each node. So here P2P Network MAC Load is calculated as follows:

$$\text{P2P Network MAC Load} = M_s / A_r \quad \textbf{(4)}$$

where,
M_s is the total MAC layer generated or sent packets
A_r is the total P2P agent level received packets

Avg. Consumed Energy of P2P Network. The consumed energy is calculated as the average energy consumed by all the nodes of the network for the entire duration of the simulation. It is measured in Joules. It is calculated as follows:

$$E_{Avg} = \frac{1}{N}\sum_{i=1}^{N} IE_i - FE_i \quad \textbf{(5)}$$

where,
E_{Avg} is the calculated Avg. Consumed Energy of P2P Network
N is the total number of nodes in the P2P network
IE_i is the initial battery energy of Node i
FE_i is the final battery energy of Node i

P2P Agent Level Hop to Hop Packet Delay (ms). This metric is a refined version of normal delay calculation. Here instead of calculating delay between source and destination, it is calculated for each packets generated during the flooding/random walk/gossip method, i.e., it is the time taken for a packet to reach each hop during the forwarding of query. It is calculated as follows:

$$\text{Hop to Hop Packet Delay} = T_r - T_f. \quad \textbf{(6)}$$

where,
T_r is the time at which a node receives a resource discovery request
T_f is the time at which that resource discovery request was forwarded from the previous hop.

P2P Agent Level Throughput (kbps). Normalized throughput is a measure of number of messages or data packets successfully delivered over time. It is generally measured in Kbps or Mbps. Here P2P Agent Level Throughput is calculated as follows:

$$\text{Throughput} = A_{rs} / T_d. \quad \textbf{(7)}$$

where,
A_{rs} is the sum of all the packet sizes received at the P2P Agent Level of all the nodes in the network.
T_d is the total time duration of the P2P resource discovery scenario

P2P Agent Level Packet Delivery Ratio (PDF). The significance of this metric is entirely different than the normal meaning. Here we measure PDF as a ratio of total sent messages at the P2P agent and the total messages received at the P2P agent (i.e., we are not just counting the successful resource replies only as the received packet count)

$$\text{P2P Agent Level PDF} = (A_r / A_s) \times 100 . \quad \textbf{(8)}$$

where,
A_r is the count of all the packets received at the P2P Agent Level of all the nodes in the network.
A_s is the count of all the packets sent at the P2P Agent Level of all the nodes in the network.

Usually in MANETs, a maximum PDF value of 100 will signify the top most performance. But here we may get more than that value because in the case of flooding and iGossip the received packet count will be much higher than the sent packet count because of the broadcast technique. So interpretation of PDF in this case is entirely different than the normal MANET.

4.3 Results and Discussion

In this section, we compare our method with the flooding, random walk and gossip algorithms. Compared to other search techniques our proposed algorithm obtain lower overhead, consumes less energy, query delay is minimized and the network bandwidth usage is reduced while the success rate is also marginally good as compared to flooding. The results of the experiments conducted are discussed below. Fig. 2 compares the network overhead for different resource discovery schemes. As seen in the graph, the performance of our proposed iGossip scheme is the best compared to all the other methods with less overhead. The gossip algorithm performs very poor because there was much routing overhead due to the unicast nature of message forwarding mechanism in its standard design.

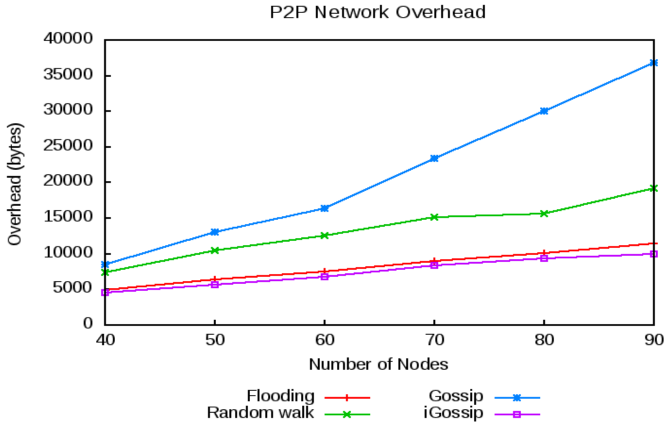

Fig. 2. Comparison of Network Overhead

Fig. 3 shows the average consumed energy for various searching techniques. The proposed protocol uses minimum battery power. If a mobile node consumes all energy and hence drains out then it will no longer be able to participate in the resource discovery process. Our iGossip algorithm consumes the least energy due to the addressed broadcast design mechanism.

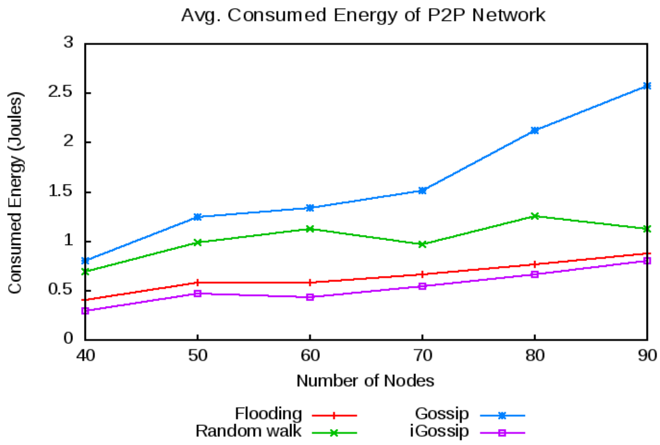

Fig. 3. Comparison of energy consumed

Fig. 4 displays the average query response time for different set of nodes for each compared protocols. Our proposed method resolves the query at the earliest as compared to the existing methods. The flooding method also has the least resource discovery time because lots of duplicate requests are received over multiple paths so there is always a chance that atleast one request will reach the resource containing node thereby resolving the query quickly.

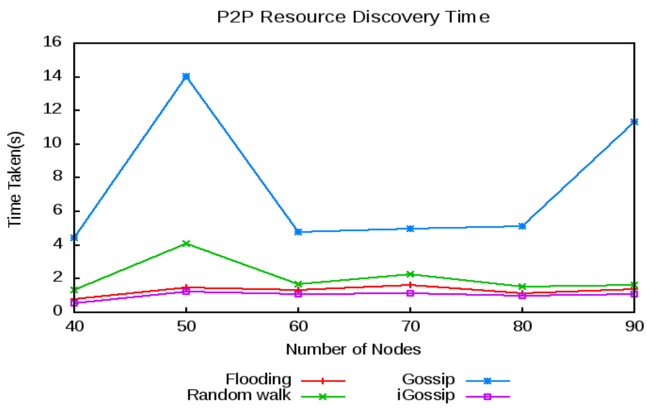

Fig. 4. Comparison of Resource Discovery Time

Fig. 5 presents the network bandwidth consumed by various resource discovery protocols. An algorithm is best if it consumes less bandwidth (i.e., minimum throughput) and provides the best success rate. Our proposed algorithm consumes less bandwidth than the flooding technique, while it also provides a good success rate.

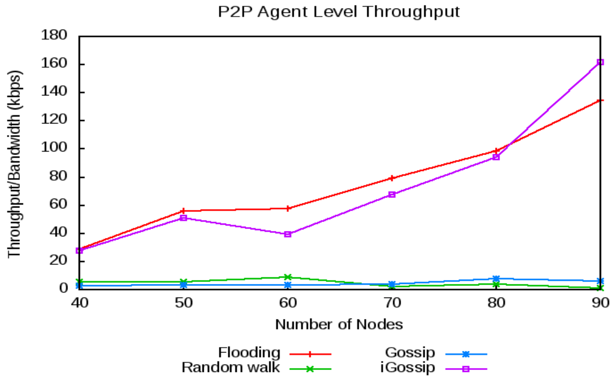

Fig. 5. Comparison of Throughput

Fig. 6 projects the query success rate of the resource discovery algorithm verified for different network size. The flooding technique provides the best results because even though the moving request at one node fails, the same copy will be forwarded from another node and so it will have much possibility of reaching the destination. Instead the mobility will not affect the resource discovery process under flooding. Our proposed algorithm performs better than random walk and gossip schemes because even the intermediate neighbors can send reply if they have the resources, the success rates as compared to flooding are low.

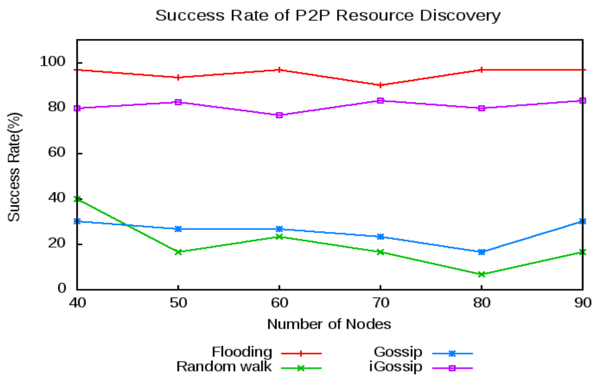

Fig. 6. Comparison of Success Rate

Fig. 7 shows the comparative performance of the resource discovery protocols in terms of routing load. As seen in the graph, the performance of our proposed scheme and the flooding technique are almost equal so the lines are overlapped which is better than random walk and gossip protocols.

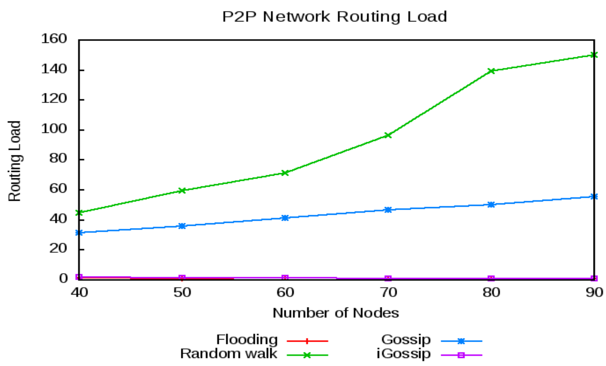

Fig. 7. Comparison of network routing load

Fig. 8 shows the performance of the proposed and existing search schemes in terms of MAC Load. From the graph it is observed that our proposed scheme and the flooding method are almost equal and better than the other compared algorithms. The gossip and random walk algorithms perform poorly because there were much routing overhead due to the unicast nature of message forwarding mechanism in their standard design.

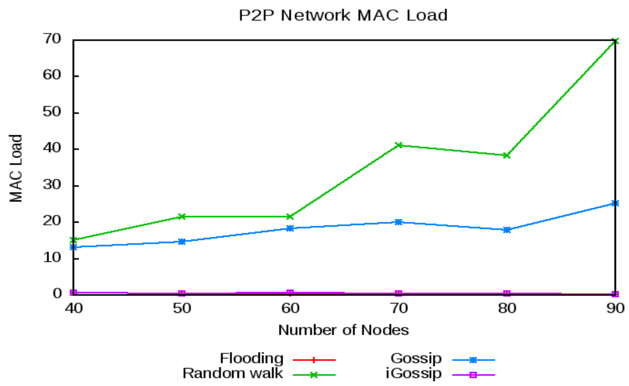

Fig. 8. Comparison of MAC load

In Fig. 9 we compare the performance of the resource discovery protocols in terms of dropped packets. As seen in the graph, the random walk and gossip algorithms perform very poor due to unicast transmission which causes network bottleneck and worst network condition that trigger excess packet loss. The performance of our proposed technique is the best while the flooding scheme also shows good results.

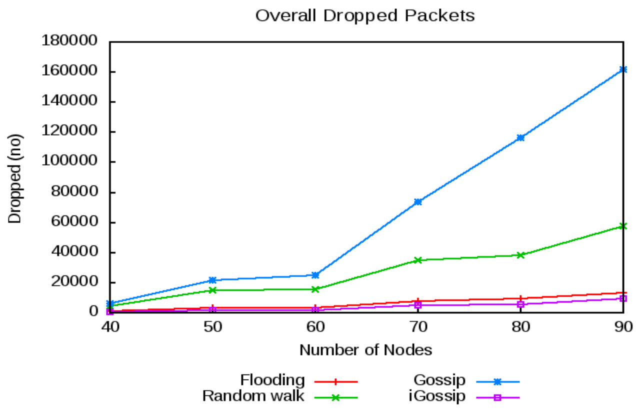

Fig. 9. Comparison of overall dropped packets

The following Fig. 10 shows the comparative performance of the various resource discovery algorithms in terms of hop to hop delay. Our proposed algorithm performs better than the existing techniques.

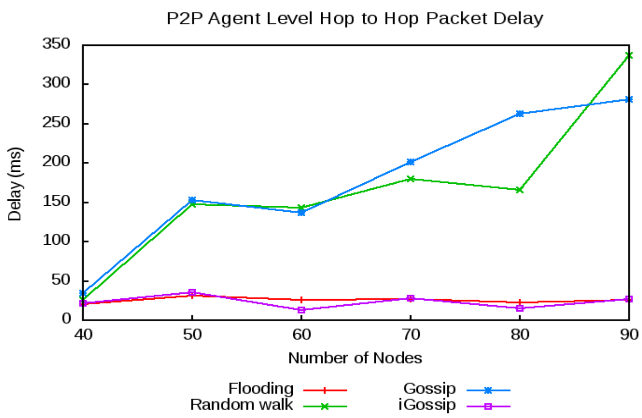

Fig. 10. Comparison of end-to-end delay

Fig. 11 presents the comparative performance of the various resource discovery schemes in terms of PDF. Here we have to interpret this graph in a different manner where we have to compare the broadcast based techniques and the unicast techniques separately. So, among the broadcast based methods our proposed protocol shows better results than the flooding protocol.

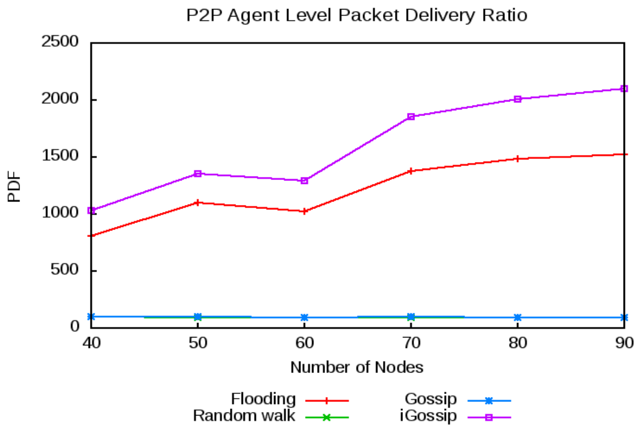

Fig. 11. Comparison of packet delivery ratio

4.4 Model Validation

In this section, we verify the validity of our model proposed in section 3.4. The algorithms are compared using paired t-test on the performance metrics which include query success rate, resource discovery time, P2P network routing load, P2P network overhead, overall dropped packets, P2P network MAC load, average consumed energy, P2P agent level hop-to-hop delay, P2P agent level throughput and P2P agent level packet delivery ratio. The higher values of query success rate and packet delivery ratio signifies the better performance of resource discovery protocol while the lower values for the other metrics signifies the better performance of the protocol. We focus on the comparison between the flooding and our proposed techniques since from the results, our method clearly outperforms the other compared ones, i.e., the classic gossip protocol and random walk protocol in every analyzed metrics.

In this test, we set the probability of making a Type I error to be 0.05. To validate the significance level, we conduct two tests. The first test is for measures in which a greater value is better, where the null and alternative hypothesis is formulated as:

$$H_0 : u_{igossip} - u_{flooding} \leq 0$$
$$H_1 : u_{igossip} - u_{flooding} > 0 \qquad \textbf{(9)}$$

The second test is for measures in which a lower value is better, where the null and alternative hypothesis is formulated as:

$$H_0 : u_{igossip} - u_{flooding} \geq 0$$
$$H_1 : u_{igossip} - u_{flooding} < 0 \qquad \textbf{(10)}$$

The null hypothesis is rejected when p-value ≤ 0.05 and accepted otherwise. The rejection of a hypothesis signifies that our proposed method performs better for that measure.

For the metrics query success rate and packet delivery ratio the p-value are 0.9996 and 0.0008568 respectively. While for other metrics like the overhead, energy consumed, bandwidth consumption, query response time, dropped packet count, end-to-end delay, MAC load and NRL load the p-values are 0.001017, 0.00003103, 0.03759, 0.001534, 0.005489, 0.2384, 0.9451 and 0.9432 respectively. We can conclude that our results are significant.

5 Conclusion

In this work, we suggest a simple scheme to replace the naive broadcast by flooding technique for resource discovery in unstructured Peer-to-Peer over Mobile Ad hoc Network. Probabilistic methods under MANET incur high routing overhead due to network dynamics thereby decreasing the overall search efficiency. Further these techniques consume tremendous battery power and network bandwidth. Our proposed method addresses these concerns by lowering the network overhead, minimizing the query response time, consuming less processing power and use minimum bandwidth while providing good hit rate. The experimental results show that our method can be an alternative to existing protocols as it improves almost all the important performance metrics. The proposed protocol is also validated using the sample tests of statistical hypothesis. Further to improve the overall performance of our protocol, we plan to do modification in the wireless physical layer to increase the transmission range dynamically on receipt of a P2P message.

References

[1] G. Ding, B. Bhargava, Peer-to-peer file-sharing over mobile ad hoc networks, in: Proc. of Second IEEE Annual Conference on Pervasive Computing and Communications Workshops, 2004.

[2] T. Repantis, V. Kalogeraki, Data dissemination in mobile peer-to-peer networks, in: Proc. of MDM ’05 Proceedings of the 6th international conference on Mobile data management, 2005.

[3] R. Friedman, D. Gavidia, Gossiping on MANETs: the beauty and the beast, ACM SIGOPS Operating Systems Review - Gossip-based computer networking 41(5)(2007) 67-74.

[4] M. Portmann, A. Seneviratne, Cost-effective broadcast for fully decentralized peer-to-peer networks, Comput. Communication 26(11)(2003) 1159-1167.

[5] Z.F. Mengkun Yang, A novel approach to improving search efficiency in unstructured peer-to-peer, J. Parallel Distrib. Computer 69(11)(2009) 877-884.

[6] S. Chen, Z. Zhang, S. Chen, B. Shi, Efficient file search in non-DHT P2P networks, Computer Communication 31(2)(2008) 304-317.

[7] A. Helmy, Efficient resource discovery in wireless AdHoc networks: Contacts do help, in: Proc. of Resource Management in Wireless Networking Series: Network Theory and Applications, 2005.

[8] M. Zaharia, S. Keshav, Gossip-based search selection in hybrid peer-to-peer networks, Concurrency and Computation: Practice and Experience 20(2)(2008) 139-153.

[9] S. Ferretti, Searching in unstructured overlays using local knowledge and gossip, in: Proc. of Complex networks V, studies in computational intelligence, vol. Volume 549, no. Complex Networks V Studies in Computational Intelligence, 2014.

[10] R. Beraldi, A directional gossip protocol for path discovery in MANETs, in Proc. of Distributed Computing Systems Workshops, 2006.

[11] P. Kyasanur, R.R. Choudhury, I. Gupta, Smart gossip: an adaptive gossip-based broadcasting service for sensor networks, in: Proc. of Mobile Adhoc and Sensor Systems (MASS), 2006.

[12] C.W. Klemm, A. Lindemann, A special-purpose peer-to-peer file sharing system for mobile ad hoc networks, in Proc. of Vehicular Technology Conference, 2003.

[13] K. Elgazzar, W. Ibrahim, S. Oteafy, H.S. Hassanein, RobP2P: a robust architecture for resource sharing in mobile peer-to-peer networks, Procedia Comput. Sci. 19(2013) 356-363.

[14] C. Gkantsidis, M. Mihail, A. Saberi, Random walks in peer-to-peer networks: algorithms and evaluation, Perform. Eval.

63(3)(2006) 241-263.

[15] A. Mawji, H. Hassanein, P2P overlay topology control in MANETs, in: Proc. of World of Wireless Mobile and Multimedia Networks (WoWMoM), 2010.

[16] A. Arunachalam, O. Sornil, Issues of implementing random walk and gossip based resource discovery protocols in P2P MANETs & suggestions for improvement, Procedia Comput. Sci. 57(2015) 509-518.

[17] A. Kermarrec, Gossiping in distributed systems, ACM SIGOPS Oper. Syst. Rev.-Gossip-based Comput. Netw. 41(5)(2007) 2-7.

[18] A. Arunachalam, O. Sornil, An analysis of the overhead and energy consumption in flooding, random walk and gossip based resource discovery protocols in MP2P networks, in: Proc. of 2015 Fifth International Conference on Advanced Computing & Communication Technologies, 2015.

[19] Q. Lv, P. Cao, E. Cohen, K. Li, S. Shenker, Search and replication in unstructured peer-to-peer networks, in: Proc. of the 16th International Conference on Supercomputing ICS ’02, 2002.

[20] L. Oliveira, I. Siqueira, Evaluation of peer-to-peer network content discovery techniques over mobile ad hoc networks, in: Proc. of Sixth IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks, 2005.

[21] A. Jacobson, Metrics in Ad Hoc Networks, Luleå Universityy of Technology, Swedish, 2000.