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Issues of Implementing Random Walk and Gossip Based Resource Discovery Protocols in P2P MANETs & Suggestions for Improvement

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Abstract

Wireless multi-hop networks attracted much attention in recent years. Mobile Ad-hoc Network (MANET) being one of such networks has its own limitations in terms of resource discovery with unstable topology and paths through the networks. So eventually traditional searching techniques are still widely used. Peer-to-Peer (P2P) model is the major candidate for the internet traffic mainly due to its decentralized nature. This article evaluates classic flooding, random walk and gossip based resource discovery algorithms under mobile peer-to-peer (MP2P) networks and studied their performance. Further we suggest way to improve these algorithms to suit and work better under MANET. We compare the performance in terms of success rate, query response time, network overhead, battery power consumed, overall dropped packets, MAC load, network bandwidth, packet delivery ratio, network routing load and end to end delay. The experiments are validated through NS-2 simulations.

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*Keywords:*flooding; random walk; gossip; MANET; Peer-to-Peer; resource discovery;MP2P

1. Introduction

A peer-to-peer network is a compliment to the conventional client-server system. In a P2P system, the computing power relies on the edges (ends) of a connection rather than the whole network itself, and all nodes mostly referred as "peers" have equal roles. P2P computing is mostly associated with wired environments. The ad hoc infrastructure less network requires a superior resource discovery strategy, due to differences in the transmission environment as compared to the wired network. Resource searching is one of the important, demanding areas of P2P technology and becomes more difficult in such multi-hop networks. P2P networks are broadly classified as: centralized, decentralized structured and unstructured. In centralized P2P networks such as Napster, indexed servers are

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maintained wherein the files are stored in a centralized fashion. The major bottleneck in these systems is the single point of failure. For structured P2P systems such as Chord [1], CAN [2], Pastry [3] the arrangement of the peers are based on well-organized structure maintained on the basis of distributed hash functions. The unstructured P2P systems neither require a centralized index nor any strict rule for topology formation or organization of the peers. A well-known example is the Gnutella P2P file sharing system [4]. In Gnutella, each node broadcasts a query to all its neighbors thereby flooding the query as a result of which it consumes more network bandwidth and affects the scalability. The P2P network forms an overlay network at the application layer for communications between the peers wherein each link of the overlay is supported by a corresponding path in the underlying physical network. Multi-hop networks have emerged over the years with mobile ad hoc networks (MANET) and mesh networks having their practical usages respectively. MANETs operate at Level-2 which is several layers below the layer where P2P network operates. So in a MANET the peer-to-peer platform is implemented as an overlay network at the application layer of the MANET. Incorporating the P2P features in MANETs can be called as P2P MANETs or Mobile Peer-to-Peer (MP2P) networks. Compared to wired P2P, MP2P has many limitations and disadvantages [5]; Major ones include the churn of the nodes, unreliable and frequent connection loss, power of mobile nodes and decreased query success rate.

In this paper, we analyze the existing traditional search methods with objectives to

1. Study their performance under P2P Mobile Ad hoc Networks,
2. Discuss the issues related to such basic resource discovery protocols, and
3. Suggest ways to improve those methods to suit dynamic MANET networks.

The above section of paper talks about background of P2P networks, and the issues of running P2P applications over MANET are discussed in brief. The rest of the paper is organized as follows: Section 2 provides a literature survey of previous work. Section 3 provides algorithmic descriptions of the existing resource discovery protocols and their implementations under MANET. Section 4 describes simulation results. It also discusses the issues observed after implementing those methods and further suggests ways to enhance those to suit MANETs better. Finally, Section 5 summarizes the work done.

2. Related Work

Resource discovery in MANET is a key challenge as the topology is unstable, and paths are discovered dynamically. Traditional search methods are mostly considered irrespective of increase in query message cost or network traffic during the resource discovery process. One of the simple search techniques is flooding. Each request is flooded throughout the network. Simple flooding causes every node to forward the request packet until every other node in the network receives it. In a wireless network, flooding causes a 'broadcast storm' wherein many packets are sent in a relatively short period, leading to congestion and collision. Several variants of flooding were proposed, such as scoped-flooding, reduced broadcast, controlled flooding etc. Scoped flooding performs a search in expanding rings and stops when resource is found while the reduced broadcast approach uses heuristics for searching [6]. The controlled flooding is a variation of flooding which uses a ratio of neighbors to forward the query. The ratio of neighbors to whom message is forwarded is selected randomly. The other traditional search technique used is random walk (RW) or drunkard's walk in which the path is constructed by taking successive steps in random directions. The idea of RW is that instead of forwarding a request to all neighbors as in flooding, the request is sent to random neighbors. This search mechanism doesn't generate huge query traffic as compared to flooding, but there is a trade-off as the search response time is significantly longer. Many variants of random walk have also been proposed in the past. Further several on demand ad hoc routing protocols were built upon the flooding search mechanism. Random walk techniques have also been exploited in wireless networks where the nodes offer ad hoc connectivity. Various issues of applying such methods in dynamic networks have their own merits and demerits [7]. Gossip protocols also termed as epidemic protocols are good candidates to be used in such dynamic networks as it requires less or no hierarchy to operate. These protocols very well fit for such self-organizing networks [8]. Gossip-based probabilistic forwarding methods are used for resource discovery and also in routing protocols. In [9] they use a gossip-style of forwarding approach where each node forwards a message with some probability to lower the overhead in the routing protocol. P2P computing has received a lot of attentions in past years as major P2P applications are for file sharing or information retrieval which can handle large number of peer's being connected together instantly. Those applications cannot be directly applied to Mobile Adhoc Networks due to the limited features of ad-hoc networks [10] , and hence there is a definite need for Overlay/P2P networking over MANET. A simple traditional approach to resource search is offered by Gnutella [11] that uses the flooding technique. ORION [12] which is a P2P file sharing application for MANET also uses a Gnutella-like technique for file search in the network. File searching in peer-to-peer networks have also used a random walk technique, but when compared to flooding it yields better results only for wired environment [13].

3. Resource Discovery Algorithm Descriptions

To describe the algorithms, let us consider a simple network scenario shown in Figure 1.

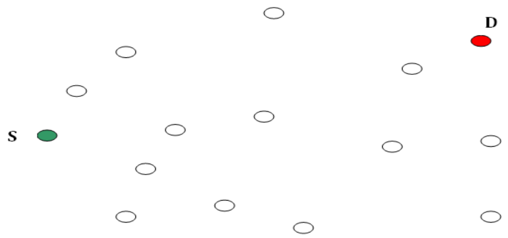

Figure 1. A Sample P2P Network

The green node 'S' initializes the resource query, and the red node 'D' actually has that resource. In our simulation and the algorithms, the basic meaning of resource discovery is nothing but discovering the address of the node in the network which actually has that resource. The implementation is based on the resource reply which will be sent by a resource containing node, the requesting node will resolve the address of the resource provider.

3.1. Standard Flooding Based Resource Discovery Method

The following steps outline a standard flooding based resource discovery method which is to be implemented in MANET.

1. The resource request starts from node 'S'
2. First the node 'S' will send a one-hop broadcast with message "*S needs resource X*".
3. All the one-hop neighbours receiving that message will store the sequence ID of the message in the processed message list so that it will not forward the same message again in case it will be received over another path.
4. If a neighbour is the owner of the resource 'X' (node 'D' in this case), then it will send an exclusive multi-hop reply to source 'S' based on the path resolved by AODV/any other routing protocol. Now even after node 'D' sends the resource reply, all other nodes which receive the request may meaninglessly resume forwarding the message until reaching all the nodes in the network.
5. Otherwise all the one-hop neighbours receiving that message will continue forwarding the message until reaching the node 'D'. (since node 'D' already processed that request it will silently drop the duplicate requests that are received over other paths)

Here the message is flooded to all nodes in the network.

3.2. Standard Random Walk Based Resource Discovery Method

The following steps outline a standard random walk based resource discovery method which is to be implemented in MANET.

1. The resource request starts from node ‘S’ (here the current node C = S). The request will contain a message like "*S needs resource X*".
2. Get the neighbour list {N} of the current node ‘C’ from the routing layer and maintain the neighbour list and its corresponding neighbour count information.
3. Randomly select one neighbour ‘n’ from the list {N}
4. The request is then passed to only one randomly selected neighbour node ‘n’ over a unicast transmission. Even though it is a one-hop communication, the unicast transmission mechanism of MANET will find the next hop information of ‘n’ from the routing table and forward the packet to that hop.
5. On receiving the message, if that randomly selected neighbour node ‘n’ is the owner of the resource ‘X’ (the node ‘D’ in this case), it will send an exclusive multihop reply to the source ‘S’ based on the path resolved by the routing protocol, the query gets terminated at that point since the address ‘S’ will be available in the received message itself, and the process is terminated.
6. Otherwise, the neighbour node ‘n’ becomes the current node ‘C’. The same process is repeated from step 2 until "randomly finds" the destination ‘D’ which has the resource.

Here the message is not flooded to all the nodes in the network, but the probability of reaching ‘D’ is low because a request packet may be lost in between the process. The random process may take much time to find that resource, however, overhead expected will be low since the message is not broadcasted to all the neighbours, and the message is only moved to one node at a time.

3.3. Standard Gossip Based Resource Discovery Method

The following steps outline a standard gossip based resource discovery method which is to be implemented in MANET.

1. The resource request starts from node ‘S’ (the current node C=S). The request will contain a message like "*S needs resource X*"
2. Get the neighbour list {N} of the current node ‘C’ from the routing layer.
3. Randomly select ‘g’ number of neighbors from the list {N} and forward the gossip message to the first node of the selected neighbors ‘g’.
4. Schedule the gossip message for the remaining selected neighbours in ‘g’ for an interval I. It means a node may gossip with more than one node in a periodic manner (in steps 3 and 4 the request is then passed/gossiped to ‘g’ randomly selected neighbour nodes over a unicast transmission). Here even though it is a one-hop communication, the unicast transmission mechanism of MANET will find the next hop information from the routing table and forward the packet to that hop.
5. On receiving the message, if any one of those randomly gossiped neighbour nodes is the owner of the resource ‘X’ (node ‘D’ in this case), it will send an exclusive multi-hop reply to the source ‘S’ based on the path resolved by routing protocol, and the query gets terminated at that point. The process is terminated at that node, but without knowing about that reply the remaining randomly gossiped nodes resume the gossip even if any other node already sent a reply for that request.
6. Each gossiped neighbour ‘g’ becomes the current node ‘C’, and the same process is repeated from step 2. The process continues until "randomly finding" the destination ‘D’ which has that resource. The gossip will spread in more than one direction at a time.

The gossip protocol involves periodic message exchanges between a pair of nodes. Disadvantages of a gossip protocol are message duplication, high latency of message delivery, low speed, and being unstable, however, the probability of reaching 'D' can be higher.

4. Experiments and Results

To study the performance of traditional search methods under an MP2P network, we simulated a P2P application over a MANET using ns-2 [14]. We simulated a typical P2P network resource discovery scenario as follows: a portion of the nodes are resource providing nodes, and some are resource requesting nodes. We generated random resource discovery requests from nodes at uniform intervals. We used AODV as the underlying routing protocol. AODV [15] which is a reactive protocol is strictly on-demand, i.e., nodes don't keep a routing table unless they are a part of the route. We modified the AODV routing protocol to get the neighbour list and maintained a neighbour count for each current node. For each number of nodes, we created at least 3 different scenario files and calculated averaged performance metrics from the entire set of nodes.

Table 1. The Experimental Environment

Parameter	Value
Number of nodes	30,40,50,60
Resource providing nodes	10
Simulation Area	1000 m x 1000 m
Transmission range	250 m
Pause time	20.00 sec
Node speed	20.00 m/s
Initial Energy of node	500 Joules
Resource discovery requests	1-10

Table 2. P2P Application Parameters

Parameter	Value
P2P application port	6346
P2PResourceRequestMessageSize	100 bytes
P2PResourceReplyMessageSize	100 bytes
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)	1sec
NoGossipsPerRequestPerNode	2
GossipDelay (If a node receives a Gossip, then how much time it should wait for sharing it with first random node)	0.01

4.1. Results

We used a set of standard metrics to evaluate the performance of each algorithm in a MANET. Due to the peculiar nature of P2P network and its resource discovery scenario, we need to modify few standard definitions of the commonly used metrics. We measured the query success rate, resource discovery time, P2P network overhead, avg consumed energy of P2P network, overall dropped packets, P2P network MAC load, P2P network routing load, P2P agent level hop to hop delay, P2P agent level throughput and P2P agent level packet delivery ratio.

The following bar chart shows the comparative performance of the three resource discovery algorithms in terms of the success rate of query request. As shown in this graph, the performance of the simple flooding is better than all other compared algorithms. The standard random walk and standard gossip methods perform poorly

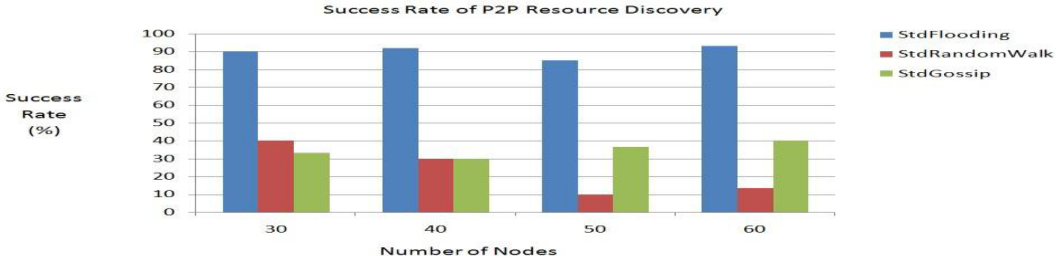

Fig. 2. Success Rates of the Algorithms

The following bar chart shows the comparative performance of the three resource discovery algorithms in terms of query response time. As shown in this graph, the performance of the simple flooding is better than all other compared algorithms. The standard gossip method performs very poorly.

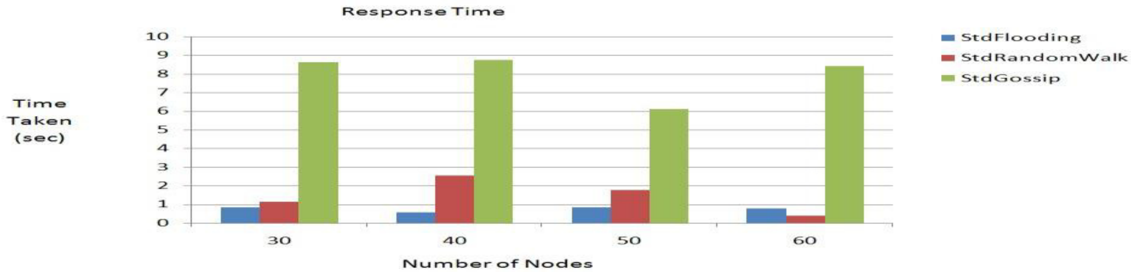

Fig. 3. Resource Discovery Time of the Algorithms

The following bar chart shows the performance of three resource discovery algorithms in terms of overhead measured in terms of generated routing packets. As shown in this graph, the performance of flooding is the best. The standard random walk and standard gossip algorithms perform poorer than the flooding because, there was much routing overhead in their design due to the unicast nature of message forwarding mechanism in their standard design.

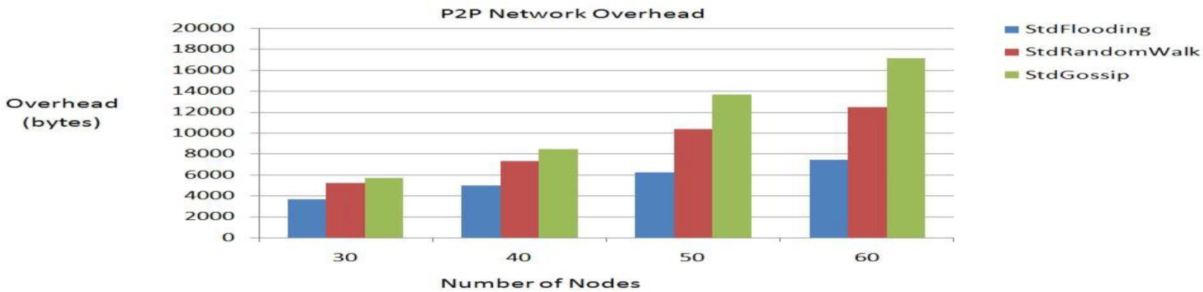

Fig. 4. Network Overhead of the Algorithms

The following bar chart shows the comparative performance of the resource discovery algorithms in terms of battery power consumed. As shown in this graph, the performance of flooding is better than all the other techniques. The standard random walk and standard gossip algorithms consume more battery energy because, there was much routing overhead in their standard design due to the unicast nature of message forwarding mechanism which causes frequent re-route discoveries because of the rapid mobility of nodes. Flooding algorithm consume less energy because of the use of broadcast in the message forwarding design.

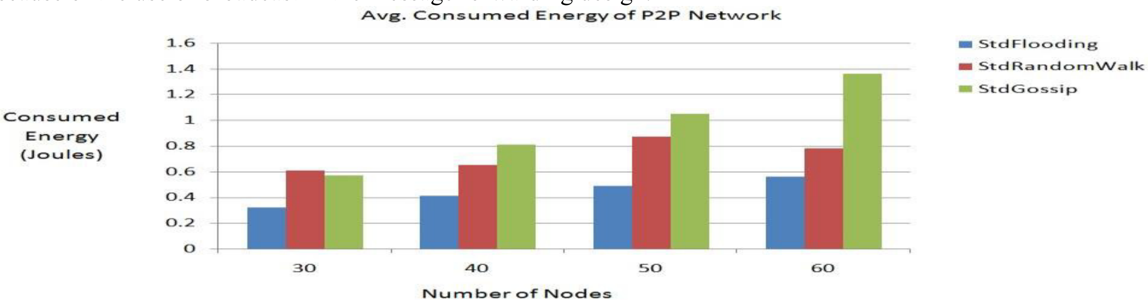

Fig. 5. Energy Consumed by the Algorithms

The following bar chart shows the performance of the resource discovery algorithms in terms of overall dropped packets. As shown in this graph, the performance of the flooding is good. The packet loss in flooding is comparatively less than the others. The standard random walk and standard gossip algorithms perform very poor because there was much routing overhead due to unicast transmission which causes network bottleneck, and worst network condition triggers excess packet losses.

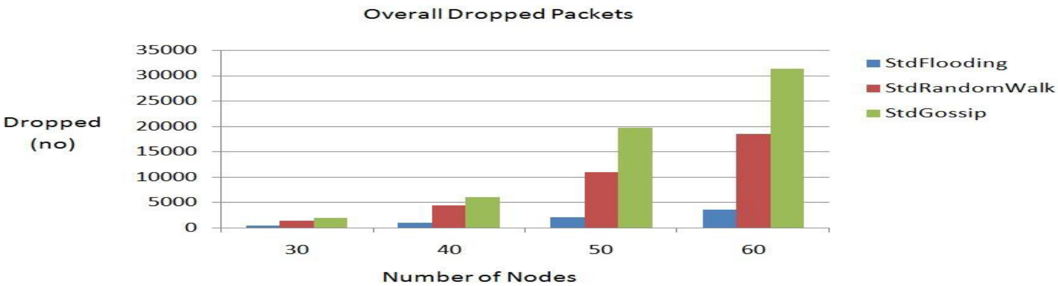

Fig. 6. Packets Dropped by the Algorithms

The following bar chart shows the comparative performance of the traditional resource discovery algorithms in terms of MAC load. As shown in this graph the performance of the standard flooding is better than all other compared algorithms.

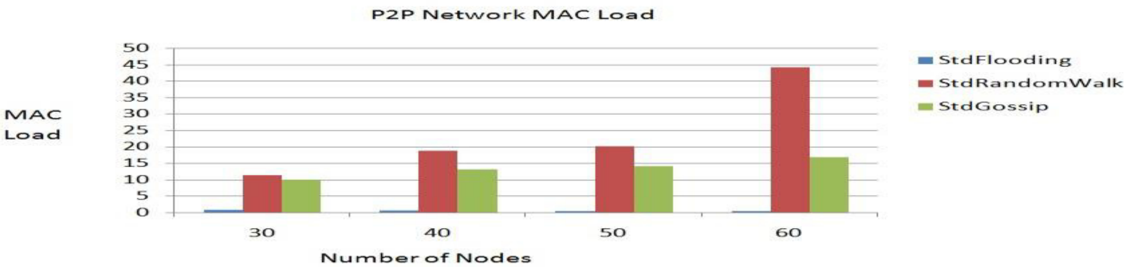

Fig. 7. MAC Loads of the Algorithms

The following bar chart shows the comparative performance of the classic flooding, the random walk and the gossip based resource discovery protocols in terms of network routing load. As shown in this graph, the performance of the standard flooding is the best.

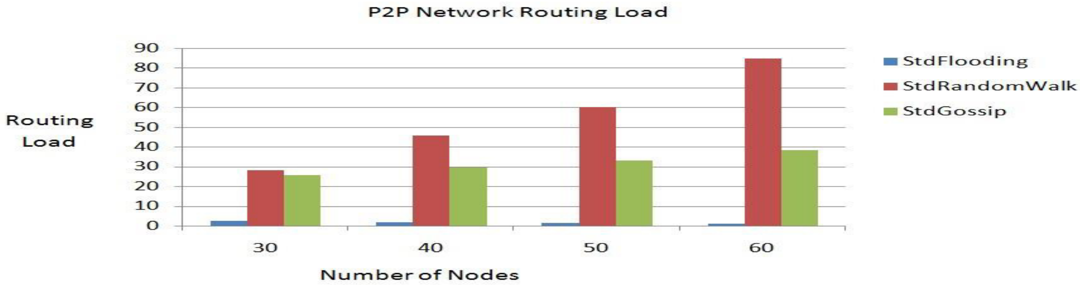

Fig. 8. Routing Loads of the Algorithms

The following bar chart shows the comparative performance of the three resource discovery algorithms in terms hop to hop delay. This metric is a refined version of the 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 process. The flooding method is found to be the best performer. The standard random walk and the standard gossip perform poorly.

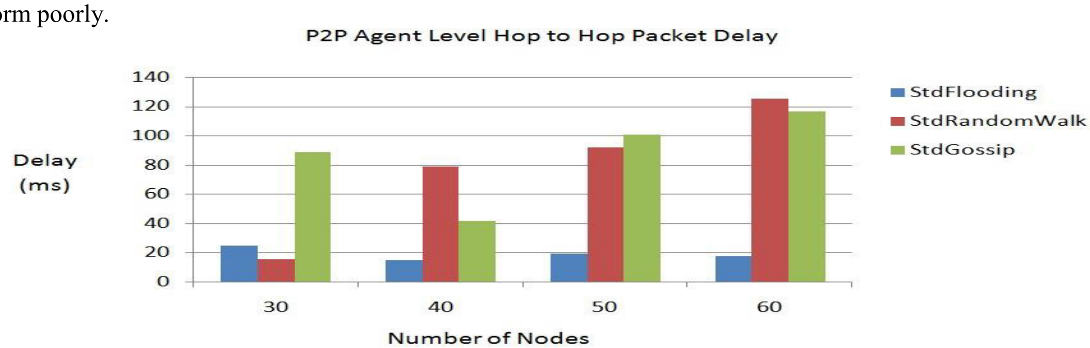

Fig. 9. Hop to Hop Packet Delays of the Algorithms

The following bar chart shows the comparative performance of the traditional search methods in terms of network bandwidth/throughput. Here the throughput signifies the consumed throughput of the algorithms. So if an algorithm consumes higher throughput and provides less success rate, then it will be a poor algorithm. The standard random walk and the standard gossip consume less bandwidth so that the throughput is minimum. The throughput of the flooding is higher compared to all others. A good algorithm should consume less bandwidth (so less throughput) and provide good success rate.

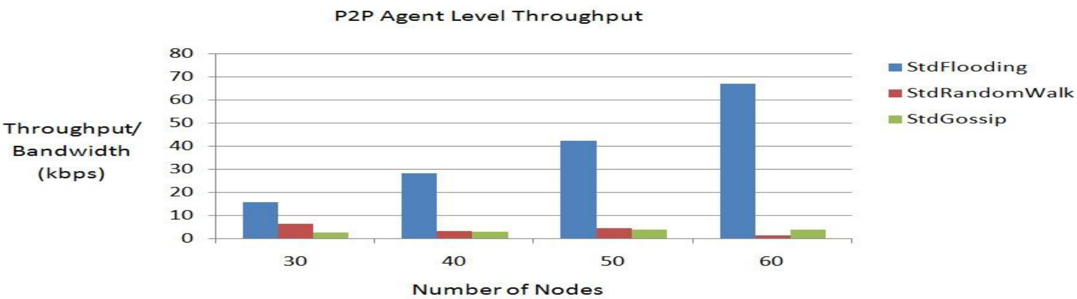

Fig. 10. Throughputs of the Algorithms

The following bar chart shows the comparative performance of three resource discovery algorithms in terms of packet delivery ratio (PDF). We have to interpret this graph in an odd way because one algorithm is a broadcast based while the other two are unicast based. We should not compare the standard random walk and the standard gossip algorithms which only use unicast transmission for forwarding message with the classic flooding which uses broadcast transmission for forwarding message because they are different kinds of algorithms. So in the broadcast based method, the flooding is the best performer in term of PDF. And in the unicast based methods the Standard random walk and the standard gossip algorithms perform equally in terms PDF.

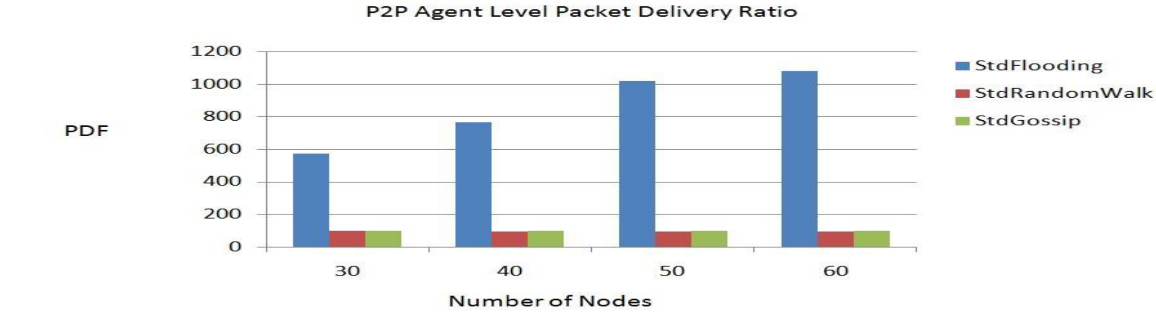

Fig. 11. Hop to Hop Packet Delivery Ratio of the Algorithms

4.2. Issues Related to Implementing the Random Walk and the Gossip Based Resource Discovery Methods in MANETs

The random walk and the gossip based algorithms performed poor in terms of network overhead than the flooding in Mobile Ad hoc Networks. Most of the previous work talks about random walk and gossip are for wired networks or the Internet which has a wired infrastructure, and that is why those algorithms performed poorly under MANETs, and even poorer than the simple flooding. Further the success rate, avg. energy consumed and response time for the simple flooding method were observed to be far better than the random walk and the gossip based techniques. Overall, the flooding mechanism outperformed the other existing resource discovery protocols in almost all the evaluated performance metrics.

4.3. Rationale

The standard way of implementing the random walk and the gossip for P2P resource discovery under MANET has a number of critical issues. In both the random walk and the gossip approaches, the message is passed to a randomly selected neighbour node using a unicast message transmission. But such unicast transmissions will depend on the routing layer information. But in MANET the nodes may be in continuous movements. So the neighbours of all the nodes will rapidly change over time. The unicast message transmission may fail very often due to the rapid change in network topology, and this will initiate frequent re-route discovery which increases the routing overhead even for finding the route to the nearest neighbour. The random walk and the gossip based methods try to discover route at each and every hop while passing messages to another node; and due to mobility and link failures, a frequent re-route discovery is induced thereby increasing overhead. The flooding based technique does not use routing at all.

4.4. Suggestions for Improvement

We can modify the standard algorithms to suit P2P Mobile Adhoc Network communication scenarios using "addressed one-hop broadcast". Let us consider a simple network scenario to understand addressed broadcast in brief (the green node is sending the request, and the blue node has the requested resource).

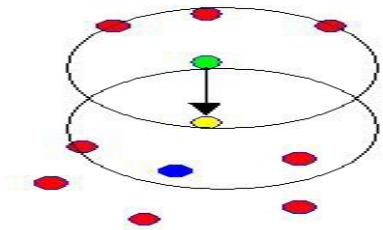

Fig. 12. An Example Wireless Network

If the node raises a resource request, it will reach all the nodes (within its one-hop range), but if it is addressed to the node which is shown in yellow, then it will only forward when no other red nodes at the top does anything since being non-addressed. If the yellow node is sending a message addressed to the blue node then the query will get terminated. But if the message is actually addressed to any one of the other two red nodes in that range, then the blue node also overhears it and will send a reply, hence the delay can be minimized along with a brighter chance of resolving the query at every successive stage. Now one of the other red nodes which actually received the addressed message then will again try to forward the request to the blue node. The blue node may again send a reply or decide to drop it since it already replied to that message. A maximum of 2 replies for the same requests that may reach the blue node from different paths and after that if the blue node sees the same request id then it will just ignore the message. Here the message is not actually flooded all the nodes in the network while the probability of reaching the resource providing node is higher because the overhearing neighbours can send a reply if they have the resource. The routing overhead can be reduced because the one-hop message forwarding will not use the routing protocol, and the message is just broadcasted one hop. With a good mixture of a conditional transmission technique and a broadcast address based message delivery, the routing overhead can be lowered, further minimizing the query response time delay and thereby improving the query success rate in such networks.

5. Conclusion

With limitation of Mobile environment if the resource discovery techniques consume extra processing power and high network bandwidth then it can produce relatively low search efficiency. Further duplication of query message or multiple copies also increase the resource discovery effort. We study existing traditional search methods and describe the issues related to implementing these basic resource discovery protocols in MP2P networks. The results of the simulations show that the efficiency of classic flooding is better than the other existing methods especially in terms of network overhead, success rate, query response time and the battery power consumed. Conditional broadcast technique can be used to address the observed issue to suit such highly dynamic mobile network. Most popular P2P file sharing application GNUTELLA still uses the flooding based search technique. It may be the practical reason for using flooding mechanism. Our future task is to implement the suggested technique with a mixture of gossip protocols and verify the same under different network scenario to extensively validate the performance and compare with the existing ones. Further as of now we haven't focused on the peer discovery issues and membership management of the peers at Overlay network. We will also consider this aspect in due course to boost the overall performance.

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