

# A Location -Aided Content Searching Mechanism for Large Ad Hoc Mobile Network using Geographic Clusters

Parama Bhaumik<sup>1</sup>, Somprokash Bandyopadhyay<sup>2</sup>

<sup>1</sup> Dept. of Information Technology, Jadavpur University,  
Kolkata, India  
[parama@it.jusl.ac.in](mailto:parama@it.jusl.ac.in)

<sup>2</sup> MIS group, Indian Institute of Management.Calcutta, India  
[somprokash@iimcal.ac.in](mailto:somprokash@iimcal.ac.in).

**Abstract.** An interesting and useful application in ad hoc wireless mobile community is searching and locating information in a distributed and decentralized manner. Locating and collecting information in a highly dynamic network while minimizing the consumption of scarce resources such as bandwidth and energy is the main challenge in this domain. In this paper we present a radically new location aided content searching mechanism that can determine the location and the content as well of the information searched that incurs minimum overhead. Here we have used a stable geographically clustered network that enables us to distribute the search message in a location-aided manner. In disastrous scenarios the reachability of emergency information, services or resources is considered to be of special interest to the user groups. Mobile terminals gather information from sensors and other sources. The location-Aided content searching mechanism we discuss here is concerned with efficiently delivering this information together with the geographical location of the information content to the person in the field on an as need basis. The mobility tolerant clusters structures were used to lower the proactive traffic while minimizing the query cost. We present results from detailed simulations that demonstrate the efficiency of our mechanism and discuss the scalability of this model to larger networks.

## 1 Introduction

Ad hoc networks are multihop wireless networks consisting of 1000's or more radio equipped nodes that may be as simple as autonomous ( mobile or stationary) sensors to laptops carried by peoples. These types of networks are useful in any emergency or disastrous scenario where temporary network connectivity is needed, such as in disaster relief or in the battlefields. In this paper we have used Geographical clusters for.

locating information which were specially designed to support and manage highly dynamic mobile nodes.

In general a content-based network is a novel communication infrastructure in which the flow of message through the network is driven by the content of the message, rather than by explicit addresses assigned by the senders and attached to the message. In a content based network, receivers declare their interests to the network by means of filters, while senders simply inject messages into the network. The network is responsible for delivering to each receiver any and all messages matching the filter declared by that receiver. The content-search mechanism that we have introduced in this paper is distinct from existing content based search models in that we are not allowing the senders to inject the information in the whole network and as such there is no need of centralized servers to publish their contents. Here the users are to declare the information needed in the form of search messages, and the message itself using the location aided routing mechanism reaches to the appropriate senders. Delivering the information to the intended searchers while minimizing the message overhead and reducing battery consumption is a challenge made harder because of node mobility. Thus in our case the information is delivered back to the users using the same the location aided routing.

In order to explain the location-oriented content based searching mechanism model better, let us focus on the two obvious application areas. Imagine the effect of a severe Gas leak in Bhopal, India. It is likely that the effected area will contain a variety of threats to disaster relief personnel such as gas leaks, intense fires, toxic leaks, riots etc. Disaster relief personnel sent into these areas will need to be kept apprised of the location and types of existing threats to ensure their safety. They will also need to be kept informed of the deployment of the other relief personnel, equipment and resources (such as food, emergency medicine etc). The second application can be considered in the battlefield networks where soldiers in the field need to be constantly informed of impending threats and information such as time and distance to threat. In the same way regarding the location and movement of nearby allies also need to be presented to the soldiers.

A person in the field is typically most interested in obtaining information that will provide him with a complete picture of his surroundings. Thus in both the scenarios, information can be collected by autonomous sensors dropped into the affected area. Thus for example when people need to know about the max intensity of poisonous gas present and the exact location of the affected area it is then the task of the searching protocol to deliver this information in a timely manner to the person in the field who really need the information. This information can be searched rapidly and communicated to the user using the Location-aided content searching. *Thus the location-Aided content searching mechanism we discuss here is concerned with efficiently delivering the information together with the geographical location of the information content (from sensors and other sources) to the person in the field on an as need basis.*

In the Location-Aided Content search mechanism, we assume that nodes are interested in obtaining information about the possible threats like max Temperature, max water level and the exact location of the information zone. Sensors and other

nodes generate information about the movement, intensity and location of threats and emergency resources. They need to get this information to those nodes that need it. However, this needs to be done in a way that minimizes the network traffic overhead. The problem is, since nodes, threats and resources move, it becomes difficult to maintain the route to the receiving node, similarly the receiver have no way of knowing which sender's location information is actually correct as they themselves are moving. How then can this information be percolated? In the remainder of this section we discuss the challenges in conducting the content searching in a decentralized way that can incorporate minimum overhead.

Our mechanism assumes that all devices in the network know their own location (using GPS Receivers). Since this protocol is meant to operate in an adhoc network, it is important to summarize some of the properties of the environment as they relate to the content location service.

- First, we cannot assume a static topology. Nodes may join and leave the network at any time and node mobility is an accepted occurrence. To handle this situation we will be using mobility tolerant stable cluster structures to partition the network [1] and will describe the clustering mechanism in section 3.
- Second, the cost of making sure that every one knows every thing is prohibitive. Thus to locate a specific content, a device need not be aware of all content available on the network. In this context our proposed mechanism takes the help of cluster heads which timely collects the information when needed and sends them only to the source nodes. So nodes that attempt to locate content need only to contact the cluster heads within the definite locations of cluster boundaries discussed in section 4..
- The proposed mechanism must be scalable, fault-tolerant, adaptable and accurate. Since we attempt to work in an environment where communication cost is high, we also want queries to be relatively cheap while still allowing for lower overhead cost and scalability of the mechanism. This we can show in the performance evaluation section 5.

Overview of the paper

In section 2. we describe other content based searching mechanism used for ad hoc networks and describe how our mechanism differs from them. Section 3 describes the frame work used in detail and section 4 describes our model in detail. We present results of simulations in section 5. The work reported in this paper is on going and we conclude with our current research focus in section 6.

## 2 Related Work

Recently several authors have begun developing a variety of algorithms to solve the problem of resource location in ad hoc networks. Some of the first approaches to appear followed the centralized client-server architecture. Some examples of such

approaches are presented in [3, 4, 5]. What all these models have in common is the reliance upon a centralized storage that would handle queries by users. This assumption violates the requirements of ad hoc networks where all nodes should be considered equal and no one should be given extra responsibility when compared to peers.

Decentralized approaches [6, 7] remove the reliance upon a central directory server but do not take link cost into account when computing routes. This makes them impractical for use in ad hoc networks. Some protocols have been proposed specifically for such resource poor environments [8, 9] but these still rely heavily on the use of broadcast making them too expensive to operate.

A novel approach to disseminating service information is described in [10]. The authors propose the use of location information for routing, but the protocol requires all nodes to periodically send advertisements along geometric trajectories which again congest the network with overhead traffic.

It is easy to see that the Location-Aided content searching mechanism proposed in this paper is very different from any of the above models. This is because here the searches are performed parallelly within the geographical cluster boundaries. As the location of the information changes, there is no problem in finding them within the mobility tolerant clusters. This feature of our mechanism makes it unique as well as extremely powerful in disastrous scenarios where the goal is to maximize message efficiency while ensuring minimum overhead.

### **3 The Framework used with Geographical cluster Structures**

The clustering approach proposed in this paper is based on positional concepts (individual node position), which is available via reliable position locating system (i.e. GPS). A good clustering scheme will tend to preserve its structure when a few nodes are moving and the topology is slowly changing. Otherwise, high processing and communication overheads will be paid to reconstruct the cluster.

The objective of the algorithm is to form a set of geographically stable clusters, which do not change their structures with the member mobility. We propose to define a geographic boundary for each cluster with the information of the GPS of the nodes lying at the boundary. Generally the existence of a cluster in a mobile scenario depends on the existence of its member node and so it keeps changing. In this framework once the clusters have been defined by their boundaries they remain absolutely fixed over the whole network area and only the mobile nodes move over these geo-stationary clusters. Thus there is no need to run the clustering algorithm frequently for managing the mobile nodes and to keep the cluster member information updated. In this stable network framework the initial clustering algorithm is re-

quired only when the member list of a cluster head is empty and so this algorithm is triggered with a long interval.

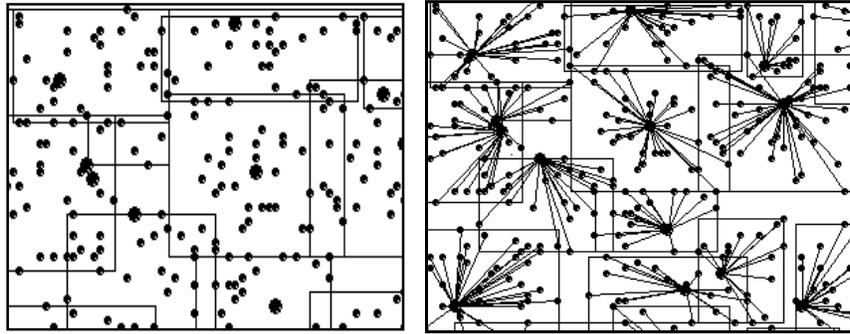


Fig 1a. The cluster Structures with their Geographical boundaries Fig 1b. The cluster Heads and their member node mappings

### 3.1 GPS Bounded Cluster Structure Algorithm

To obtain the initial set of clusters in an ad hoc environment, we referred a leader election algorithm - Max-Min D-Cluster Formation algorithm proposed by Alan D. Almis, Ravi Prakash, Vuong Duong and T. Huynh [ 2 ]. There are several advantages for using Max-Min D-Cluster Formation algorithm over other existing clustering algorithms like the nodes can asynchronously run the heuristics so no need for synchronized clocks, we can customize the number of clusters as a function of  $d$ .

In our proposed GPS based clustering algorithm we have used the initial leader election part of the Max-Min D-Cluster algorithm in the first phase. In the second phase the elected leader or the cluster head will be able to recognize its boundary by getting the GPS information from all of its member nodes and will announce this boundary location values within  $d$  hop. Thus all the member nodes get alarmed about the current cluster boundary and will utilize this value while going out of this cluster.

Thus our GPS based clustering algorithm will partition the network into a number of geographically overlapping clusters. These cluster boundaries are static, and are not required to be redefined with the mobility of the boundary nodes. This boundary value will be once notified to all the members of a cluster and will remain fixed until all the nodes move away from this region. In that case only the cluster-head will recall the initial clustering algorithm to remain connected and the cluster boundary does not exist any more. This particular technique of defining the clusters with fixed boundaries has following advantages.

1. The cluster structure becomes robust in the face of topological changes caused by node motion, node failure and node insertion /removal.
2. Conventional beacon-based cluster management algorithms require the entire network to reconfigure continuously, while in GPS based cluster management protocol the impact of node mobility has been localized within the cluster and its immediate neighboring clusters.
3. The ability of surrogating cluster headship from a mobile cluster head to any of its neighbor.
4. Independent and autonomous cluster control and maintenance by the mobile members only.
5. No performance degradation of the network due to cluster management protocol.

Here in this framework we will use the flooding mechanism to inform all the cluster heads about all other clusters formed in the network. Thus after the initial clusters were formed using our GPS Bounded Cluster structuring mechanism each CH will start flooding its boundary value within the network. In this case we cannot avoid flooding because the formed cluster structures are not known to the network. Though the network overhead is reasonably high but as the cluster boundaries are stable so this one kind of static information needs to be percolated only once in the network.

### **3.2 Cluster Management Protocol with Mobile Cluster Heads**

For periodic beacon based cluster maintenance protocols if a cluster member is moving out of the transmission range of the CH, the member node searches for the new head by detecting the new CH beacon signal. There is no other intelligent way to track the mobility of a member node. Here we have proposed a cluster maintenance protocol using GPS technology, which is able to maintain a stable cluster structure even in presence of high mobility incurring little overhead. In this protocol any node including the cluster head automatically gets alarmed while crossing the geographical boundary of a cluster using the program which continuously compares the current GPS value of the node with that of the boundary values. Thus it is quite easy for a departing node to make a timely arrangement for rebinding with a new CH and unbind with the old one. This work uses a novel optimistic cluster head-surrogating scheme for achieving efficiency in mobile cluster management process. In this scheme a cluster-head is also free to leave its cluster after delegating the leadership to any member-node of its current cluster. This member-node now will act as a surrogate cluster-head of the cluster. The process actually duplicates a copy of headship program and related member information list to the selected surrogate-head.

## 4 Location –Aided Content Searching

Based on the above discussion we can now apply the searching mechanism on the geographically clustered network. The proposed mechanism treats all the member nodes in the network as equal and only selected cluster heads are allowed to take more responsibility than others. These CHs are also responsible for delivering the information to the source clusterhead from where the query generated. Ordinary member nodes can make queries and timely forward the query to the corresponding CHs. The cluster head on behalf of a node sends the query to all other cluster heads.

The basic mechanism follows the scheme described in section 3.1. Once the clusters are formed with definite boundaries the boundary location information is flooded through out the network and all the cluster heads keep the record of all other cluster boundaries in the network. As these cluster boundary information are absolutely stable there is no need to send the cluster information update message periodically. The nodes inside the clusters may change their position, but using the surrogating scheme of cluster headship there is always one node to take the responsibility of head and as such the cluster structures remains absolutely stable. This significantly decreases the amount of proactive traffic as the cluster boundary information is flooded only once in the network. To make sure that all nodes on the network know the location of their corresponding clusterheads with changing positions, the cluster heads are allowed to periodically broadcast their node ID and location value (GPS) amongst it's d hop neighbors.

A user can locate content in the network by sending query message. In a dense network, the messages are guaranteed to reach all the clusters. A resulting node replies back using the same underlying geographical routing protocol that keeps their cost low while finding the closest path to the destination node in the vast majority of situations. Finding the closest path is an important benefit as it generally means fewer hops between the source and the destination [ 1,3 ] which in turn, translates into lower connection cost.

### 4.1 Detail Description of the content Discovery Mechanism

To illustrate how this strategy works suppose a source node ( shown in Fig 2 ) sends out a query message through the network. The query message is first forwarded to the cluster head. The clusterhead then searches the content among its own member by announcing the query message within d hop cluster boundary. If the searched message is found within the local cluster then there is no need to forward the search message further and the cluster head sends the current position (GPS) and the Node ID of the resultant node. But if the searched content can not be found within the cluster the search message is sent towards all the cluster locations. A cluster head can easily forward the packet to all these predefined directions as it carries these cluster boundary information from the initial stage of the clustering of network. The content searching process is exemplified in Fig 2. The next hop in the message

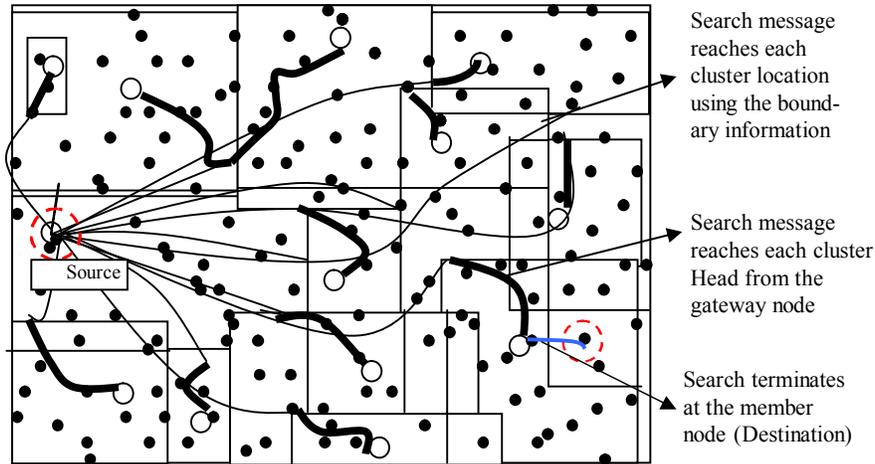


Fig 2. Location-oriented content searching using Geographical cluster boundaries.

forwarding is selected using the same regular geographic routing [ ] with each node forwarding the packet to its neighbor closest to the destination ( Here destination is the GPS value corresponding to the Boundaries described in section 3 ). The message on reaching the cluster boundaries is forwarded to the corresponding cluster heads by the gateway nodes (nodes lying at the boundaries). In this way all the cluster heads (if reachable) get the search message request packet. Each CH then advertises ( restricted flooding) this message within the  $d$  hop of its boundary, which finds the result of the search at the destined cluster. Once the result is discovered at a particular node , it immediately answers with a response message to its CH. The clusterhead is here responsible to contact the source CH from where the search request arrived. The source node may receive more than one response message to the same query . In such case it picks the response identifying the destination closest to its geographical location . Now a definite geographical route is possible to establish from source node to destination node for seamless data communication which again remains valid as long as the destination remains within the current cluster. Using our cluster management protocol [1 ] we can detect the moment a node crosses the cluster boundary and calls for de-registration. Here the CH can timely inform the source about the unavailability of the node. The source then again sets a fresh search message. This way by timely informing the source node about the unavailability of the information resource we can reduce the frequency of packet drops and can significantly reduce the searching overhead due to mobility.

Note that the idea behind choosing Location-Aided content searching comes as a result of the following observations:

1. In a large mobile network all nodes remain as a member or as a cluster head and are easily reachable using stable cluster structures.

2. The end-to-end delay during data transmission and probability of packet failures may decrease due to timely informing the source about the absence of the destination node.

3. In a large dense network, using large cluster structures may significantly reduce searching overhead as a much lesser number of search messages need to be sent to lesser number of clusters.

## 4.2 Algorithm for Location -Aided Content Searching

**Step I:** The Source node sends Search Message (**SM**) to its cluster head (**CH**);

**Step II:** If the **SM** is not found in the current Cluster  
The **CH** forwards the **SM** towards predefined cluster boundaries;

**Step III:** A gateway node finding the **SM**  
Forwards the **SM** to the **CH** of that boundary

**Step IV:** Each **CH** broadcasts the **SM** within **d** hops  
If the result is found  
Forward the Resultant message together with the location of the cluster and the **node ID** (the node which contains the information) to the Source **CH** node using geographical shortest distance calculation;

**Step V:** On receiving the search result and the location the source **CH** forwards the message to the original source node which can now continue further communication using geographical routing.

## 5 Simulation Results

In this section we evaluate the performance of our protocol in a simulated environment. A java simulation was developed to simulate a variety of network conditions. The area over which the simulated network was situated was 1000 by 1000 meters. A variety of network densities were simulated. For each case, 20 simulations were run and the results were averaged to produce the presented data. To study the effects of mobility a moderate density network of 100 nodes was evaluated with varying

node speeds. Transmission range of the wireless nodes used for simulations was 100 meters.

Several measures were considered when evaluating the search mechanism. The proactive traffic used to make the cluster knowledgeable about other clusters were used only once in the network and need not be updated frequently. Here we have considered only the on demand overhead traffic generated during the message searching.

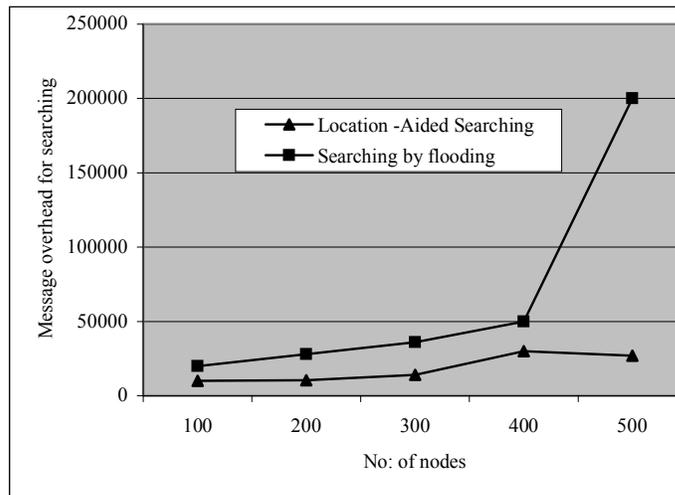


Fig 3. Searching over head with varying node density

### 5.1 Effects of network Density

This section studies the effects of node density in the network on the performance of Location-aided content searching as measured by the factors specified in the discussion. To simulate a low to high-density network we have placed 100 to 500 nodes on the same area of 100 by 1000 meters. As seen in Figure 3, in case of searching by simple flooding the amount of search message increases rapidly in the network with the addition of nodes. The lowering curve for location aided searching shows that with the increase of network density the number of search messages generated in the network is not increased at all. As in this case the search messages are forwarded towards the cluster boundaries using the same regular geographic routing [ 1,3 ] with each node forwarding the packet to its neighbor closest to the destination. This is only possible due to the construction of stable geographic cluster structures. The above mentioned figures clearly demonstrate the scalability of the mechanism.

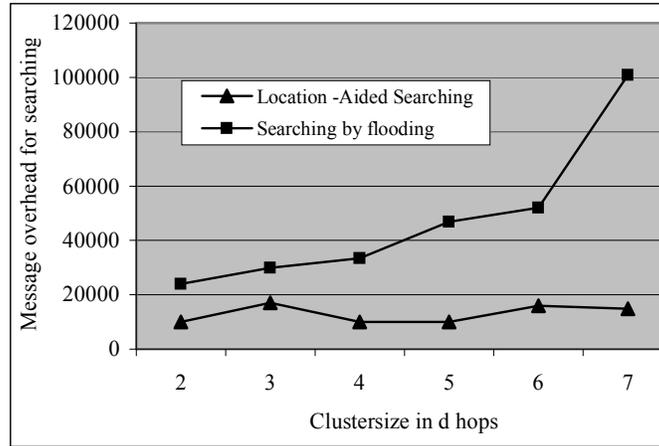


Fig 4. Searching over head with varying Cluster size in

### 5.1 Effects of Cluster Size

Here we have allowed our  $d$  (the input which determines the cluster size) to vary from 2 to 7 i.e from 2 hops cluster size to large 7 hops clusters. We can find from figure 4 that the searching overhead involved with flooding does not vary with the cluster size as simple routing protocol does not utilize any advantage of clustering in the network. Here maximum overhead has been used for tracking the mobile nodes. But the searching overhead for location aided content searching has a general tendency to get reduced as in this case with increase in  $d$  the larger clusters are forming in the network forcing the total number of clusters formed in the network to be less. As such the number of search messages required to forward toward the cluster boundaries are also becoming less which shows that with the use of large clusters for larger networks the searching over head can be significantly reduced using our mechanism.

## 6 Conclusion and Future Work

Discovering any resource in mobile ad hoc networks while minimizing the searching overhead and reducing network maintenance cost is a challenge made harder because of node mobility. In this context we have developed a radically new mechanism to search information in mobile ad hoc networks using fixed geographical cluster boundaries.

Proposed Location-Aided content searching mechanism aims to support geographical position based searching in large mobile ad hoc networks. It achieves its goal with the introduction of stable cluster structures and proposes low overhead methods

for discovering resourceful nodes. A special scheme of mobility management and cluster maintenance solves the problem of constant location updating of the nodes. We have presented simulation results which shows that with the use of large clusters for larger networks the searching overhead can be significantly reduced using our mechanism.

There are a number of possible optimizations to this searching mechanism. These optimizations are subject of future work and have not been studied extensively from the point of view of performance in real world conditions. Such optimizations may be used to improve the reliability and efficiency of the mechanism. One optimization is in a highly mobile scenario the cluster heads can temporarily store the found information on behalf of the resource node. This possibly aims at reducing the re-searching calls in the network in case of a departing destination node.

## References

- [1] Parama Bhaumik, Somprakash Bandhopadhyay, A Mobility Tolerant Cluster Management Protocol with Dynamic Surrogate Cluster-heads for A Large Ad Hoc Network, published in proceedings of 8th International Conference on Distributed Computing and Networking ICDCN 2006, IIT Guwahati 29-31 December.
- [2] Alan D. Amis Ravi Prakash Thai H.P. Vuong Dung T. Huynh. Max-Min D-Cluster Formation in Wireless Ad Hoc Networks. IEEE INFOCOM, March, 2000.
- [3] [BCSW] S. Basagni, I. Chlamtac, V.R. Syrotiuk, B.A. Woodward, A distance routing effect algorithm for mobility (DREAM), Proc. MOBICOM, 1998, 76-84.
- [4] H.Chen, A.Joshi, and T.W.Finin Dynamic service discovery for mobile computing: intelligent agents meet jinni in the ether, Cluster Computing, vol. 4, no.4, pp. 343-354, 2001.
- [5] S.D.Gribble, M.Welsh, J.R.von Behren, E. A. Brewer, D. E. Culler, N. Borisov, S. E. Czerwinski, R. Gummadi, J. R.Hill, A. D. Joseph, R. H. Katz, Z. M. Mao, S. Ross and B. W. Zhao, The ninja architecture for robust internet- scale systems and services, Computer Networks, vol. 35, no.4, pp.473-497, 2001.
- [6] A. Rowstron and P. Druschel, Pastry : Scalable, decentralized object location, and routing for large scale peer-to-peer systems, Lecture Notes in Computer Science, vol. 2218, 2001.
- [7] K. Hildrum, J.D. Kubiatowicz, S, rao, and B.Y. Zhao, Distributed object location in a dynamic network, Tech. Rep. UCB? CSD-02-1178, Apr. 2002.
- [8] D.Doval and D.O'Mahony, Nom: Resource location and discovery for ad hoc mobile networks, in Med-hoc-Net 2002 (Sardegna, Italy), Sept 2002.
- [9] Q.Z.B.L Jiang Chuan Liu, Kazem Sohraby and W. Jhu, Resource discovery in mobile ad-hoc networks, in Handbook on Ad Hoc Wireless Networks, CRC Press, 2002.
- [10] I.Ayden and C. C. Shen, Facillitating match-making service in ad hoc and sensor networks using pseudo quorum, in 11<sup>th</sup> IEEE International Conference on Computer Communications and Networks (ICCCN), Miami October 2002.