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A DISTRIBUTED RESOURCE-MANAGEMENT APPROACH IN MANETS

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Abstract

Mobile ad hoc network (MANET) is an infrastructure less network, in where all mobile nodes are free for any movement to any side. Thus the network is going toward zero configurations that would create some problems. Ad hoc network is faced with various limitations that need to be considered among design and implementation of any protocol for it. Service Advertisement (SA) is one of the important services that are offered in each network. To have a fast service discovery in a network with minimum energy consumption, distributing of services' information and their management play important roles. In this paper for avoiding packet flooding in the MANET we used Cluster Based Routing Protocol (CBRP). For reducing amount of communication messages we moved service advertisement from application layer to routing layer. Thus we distribute the active services in the network among clustered nodes. However, the results of our experiment show that our method does not add any extra overhead to the network.

Keywords: CBRP, MANETs, Routing Protocol, Service Discovery, Service Information Accumulation Strategies

1. Introduction

The limitation of dominate to mobile ad hoc networks caused that resource advertisement/discovery and resource management become as a challenging area of research. Making proper decision is one of the definitions of management. An effective decision making entails information on the same field. Obviously, lack of enough information causes the impossibility of an efficient decision making. Therefore for a proper network management, we need to gather and store resource information. In addition, the absence of physical infrastructure facilitates in MANETs

Abbreviations

CH	Cluster Head
CBR	Constant Bit Rate
CBRP	Cluster Based Routing Protocol
DA	Directory Agent
GSDL	Generic Service Description Language
HM	Hello Message
ID	Identification
JINI	Java Intelligent Network Interface
MANET	Mobile ad hoc network
No	Number
NS2	Network Simulator 2
PDP	Pervasive Discovery Protocol
QoS	Quality of Service
SA	Service Advertisement
SAT	Service Access Table
SD	Service Discovery
SLP	Service Location Protocol
UA	User Agent
UDP	UpDate Packet
UPnP	Universal Plug and Play

are caused the time of entering the node to the network and exiting from it be unpredictable. Based on what discussed, managing such network especially network resource management in the first view seems difficult, since everything should be considered dynamically. However, it is possible to apply some efficient methods to implement better resource management. Regarding to the bandwidth of this type of networks and lack of static stability of the nodes, extra overhead should not be imposed to it for manage the network properly.

One of the main and fundamental parts of the network resource management is advertising. The following parts concern the important process

(i) Decision making process in the selection of resources' features should be saved in the network: They are crucially applicable in the second phase, based on the resources which are selected.

(ii) Information saving process: The process involves the saving process after the selection of the resources parameters, for example they are saved by employing XML method or any other methods.

(iii) The process of how and where to save information physically: It involves the place where the information resources are to be saved so that everybody can access to it easily and if a node containing information of services which is deleted from the network, it does not have more expenses imposed to the network.

We believed that the interaction of phase/part (i) and (ii) is crucially significant. Moreover, from information engineering point of view, the system throughput will not show its efficiency if the first part (advertisement) is not properly done.

After introducing SA in [1, 2] to have more investigation about information management in ad hoc network, the researcher's intention is more on the above parts of the resource management. The following key concepts are presented and defined to clarify the concept of the resource management.

A *service* in the network can be any software or hardware entity that a user might be interested to utilize.

Information is defined as any characteristics of the software and hardware resources which help to proper selection in resource management.

Resource Management is referred to a set of processes which are used in introducing the services or resources, saving their information in the network and providing availability and right selective from the point of view of QoS. It is known as management protocol.

Service Discovery (SD) is defined as one of the service management sections in the network which automatically finds a service offered by a network node on the basis of the request sent by a network node.

Service Advertisement (SA) is also defined as a part of the service management in the network which automatically distribute the service information, either software or hardware offered by a network's node to access to the information easily and fast.

In this paper, we used cluster based mechanism for routing packets to avoid packet flooding in the network. For reducing numbers of communication messages we moved service advertisement to routing layer from application layer and we distributed the active services in the network among clustered nodes.

This paper is organized as follows. Section 2 provides a brief summary of related works. In section 3 we explain proposed distributed mechanism for SA in MANETs. Section 4 discusses simulation result and analysis. We conclude this paper in Section 5.

2. Related Works

As mentioned before, many different methods are employed to save information in the network. It can be classified as:

- *Directory-less*
- *Centralized directory*
- *Distributed directory*

A *directory* is an entity that stores information about services available in the network to enable SD and invocation.

2.1. Directory less architecture

In the directory-less architecture, nodes do not distribute their service descriptions onto other nodes in the network. A device interested in a special service typically sends its search message to all reachable nodes. If one or more of these nodes can satisfy the request, a response is sent back to the requestor.

There are many protocols which use this type of saving information architecture. The following protocols are examples.

A) UPnP

The Universal Plug and Play (UPnP) is a simple extension of the Plug and Play peripheral model. It is designed to support zero configuration, "invisible" networking, and automatic discovery for a breadth of device categories from a wide range of vendors. With UPnP, a device can dynamically join a network, obtain an IP address, convey its capabilities, learn about the presence and capabilities of other devices, enabling zero configuration networks truly [3, 4].

B) DEAPspace

DEAPspace provides a framework to connect devices over a wireless medium. It is a push-model-based approach to fast and resource efficient SD. All of services attributes are stored on service providers. DEAPspace services are specified as a data hierarchy. The root node of this hierarchy is the DSService class. Each service description has a field to keep expire time (time-to-live). Nodes advertise their services by a broadcast mechanism to their neighbors [5].

C) PDP

Pervasive Discovery Protocol (PDP) is a fully distributed protocol that merges the characteristics of both pull and push solutions for ad hoc networks. In this protocol, each device has a cache containing a list of the services that have been heard from the network. Each service has an expire time and the service is removed from the cache when they timeout. PDP uses Generic Service Description Language (GSDL) for description services [6].

2.2. Centralized directory architecture

The centralized directory architecture relies on a central directory that stores the descriptions of all services available in the network so as to enable us to use SD and invocation. Service providers advertise their services to the central directory using a unicast message. To access a service, a client first contacts the central directory to obtain the service description, which is then used to interact with the service provider.

Centralized resource discovery is much suited to wireless infrastructure-based networks. However, this architecture makes the service SD process dependent upon the availability of the central directory, which further constitutes a bottleneck. In addition, a centralized directory limits its scope to devices within a local SD domain. The boundaries of a SD domain can be administratively defined such as an IP subnet, or they can be the result of a physical property such as the range of a wireless network. SLP and JINI use the advantages of this type of architecture:

A) JINI

Java Intelligent Network Interface (JINI) is a protocol that has an environment for creating dynamically networked components, applications and services based on Java. There is a main protocol in JINI called Lookup Service (central directory) that registers devices and services available on the network. When a device connects to network, it locates the lookup service and registers its service there

(SA), this device and its service are accessible by sending a query to lookup service [7].

B) SLP

The Service Location Protocol (SLP) provides a flexible and scalable framework for providing hosts with access to information about networked services. There are three main agents in the SLP framework: (i) User Agent (UA), issues a 'Service Request' on behalf of the client application, the User Agent will receive a Service Reply specifying the location of all services in the network which satisfy the request. (ii) Service Agent (SA) advertises the location and attribute on behalf of services. After receiving a request for a service, it unicasts a reply message containing the service's location. (iii) Directory Agent (DA), there is one or more DAs in a large network. They act as a cache and store information about the service announced in the network. SLP has two different modes of operation: (1) when a DA is present, it collects all service information advertised by SAs, and UAs unicast their requests to the DA, and (2) when there is not a DA, UAs repeatedly multicast the request, SAs listen for these multicast requests and unicast responses to the UA [8].

2.3. Distributed directory architecture

The motivation that supports the use of the distributed directory architecture for SD is the scalability which can be achieved when the network size becomes larger. This architecture is quite suited to the mobile ad hoc network scenario. Directories are dynamically selected among mobile nodes which have suitable capability (e.g. battery power, memory, processing power, node coverage, etc.) [3].

Protocols such as Sailhan use the distributed directory architecture. Sailhan in [9] proposed a SD protocol aiming at large MANETs (i.e., comprising at least about 100 nodes). Its design is based on centralized discovery architecture, as it induces less traffic. Directories are further distributed and deployed dynamically for the sake of scalability. Specifically, its discovery architecture is structured as a virtual network. A virtual network is composed of a subset of MANET's nodes acting as directories. These directories represent a backbone of nodes responsible for performing SD. They are deployed at least one directory.

2.4. Comparison of the various directory architectures

In directory-less architectures, broadcasting is generally used for SD and SA. These broadcasting mechanisms are not suited for mobile ad hoc networks due to their heavy consumption of bandwidth and energy. Therefore, the network size supported by the directory-less architecture is very limited. Nevertheless, in regions with extremely high mobility, broadcasting could be the only possible technique.

In the central directory architecture, although centralized resource discovery is much suited to wireless networks, the central server further constitutes a bottleneck. In addition, a centralized directory limits its scope to devices within a local SD domain.

Distributed directory architectures are quite well suited to the mobile ad hoc network scenario, but when we have many nodes in the network, the overhead will increase exponentially.

In order to have an efficient SD and SA architecture, it is better to use the hierarchical distributed directory architecture.

2.5. Cluster based routing protocol

CBRP is a routing protocol designed to be used in mobile ad hoc networks. The protocol divides the nodes of the ad hoc network into a number of overlapping or disjoint 2-hop- diameter clusters in a distributed manner. Each cluster chooses a head to retain cluster membership information. Based on cluster membership information kept at each cluster head, inter-cluster routes are dynamically discovered. The protocol efficiently minimizes the flooding traffic during route discovery and speeds up this process by clustering nodes into groups. Moreover, the existence of uni-directional links and the use of these links for both intra-cluster and inter-cluster routing are extremely considered by the protocol. An example of an ad hoc network is shown in Fig. 1. Nodes are organized to five clusters and each of them has a cluster head.

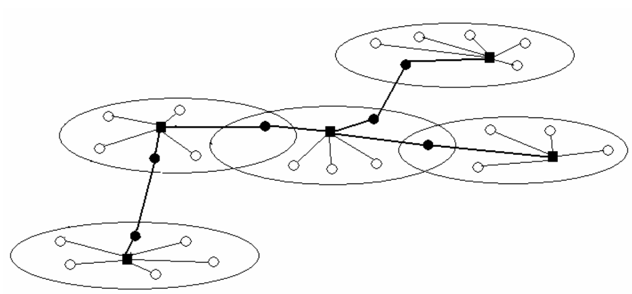


Fig. 1. A Cluster Based ad hoc Network.

Unlike the other on-demand routing protocols, in CBRP the nodes are organized in a hierarchy. Cluster-head coordinates the data transmission within the cluster to other clusters. The advantage of CBRP is that only cluster heads exchange routing information, therefore the number of control overhead transmitted through the network is less than the traditional flooding methods. However, as in any other hierarchical routing protocol, there are overheads associated with cluster formation and maintenance [10].

The information about link states (uni-directional or bi-directional) and its neighbors' states (retained by every node in CBRP) are presented in a neighbor table. A cluster head keeps information of its neighboring clusters, in addition to the information of all members in its cluster. The information includes the cluster heads of neighboring clusters and gateway nodes connecting it to neighboring clusters [11].

CBRP proposes the shortening route for performance optimization. Since CBRP uses a source routing scheme, a node gets all information about the route when receiving a packet. Nodes exploit route shortening to choose the most distant neighboring node in a route as next hop to minimize the hop number and adapt to network topology changes.

CBRP has the following features [11]:

- Fully distributed operation.
- Less flooding traffic during the dynamic route discovery process.
- Explicit exploitation of uni-directional links that would otherwise be unused.
- Broken routes could be repaired locally without rediscovery.
- Sub-optimal routes could be shortened as they are used.

In these protocols clusters are introduced to minimize updating overhead during topology change. However, the overhead for maintaining up-to-date information about the whole network's cluster membership and inter-cluster routing information at each and every node in order to route a packet is considerable.

3. Distributed Mechanism for SA in MANETs

As mentioned before, one of the important issues in ad hoc networks is SA. SA has more side effects on traffic and SD in the networks. Therefore we must advertise services' information using an efficient method, with the minimum number of packets in a very short time. However every node is capable to find its requested services properly. Generally, once a service provider wants to advertise its services' information through the application layer; it needs to employ two messages, firstly to perform a communication between application layers, secondly to conduct a communication between routing layers of two parties (service requester/service provider).

As our first assumption is degradation of overhead and energy consumption by minimizing the number of control messages and also duration of finding services through a network. Therefore, moving the SA from application layer to routing layer facilitate to use only one message for delivering the information related to a requested service and also a suitable path from service requester to service provider. In contrast, instead of using two separate messages for conducting service advertisement and establishing suitable rout; by using only one message (that consists of all this information), we proposed an efficient SA for MANET. Moreover, to provide an easy access to the services' information for all the mobile nodes, we stored the detailed services' information including static service attributes, service access models and the service physical location in all clustermate nodes. Consequently the nodes in the same cluster are aware of the service details. In summary, we proposed an efficient SA with low overhead for MANET by (i) Moving SA from application layer to routing layer and (ii) Storing detailed services' information in a suitable places.

In order to add SA capability to CBRP, it needs to accomplish services attributes on the network. For this purpose a new table by the name of Service

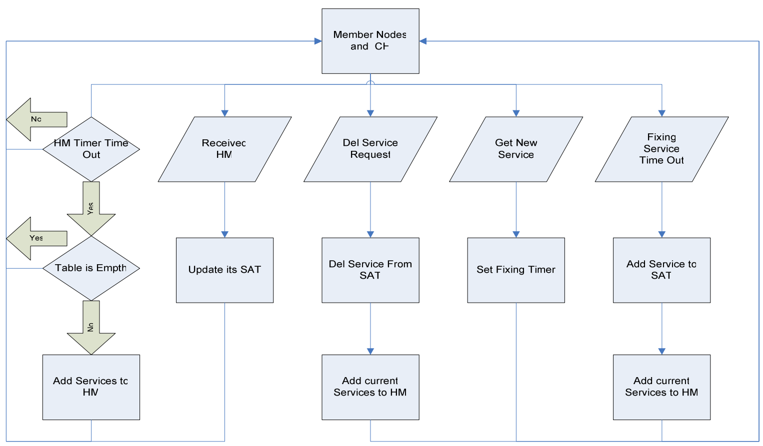
Access Table (SAT) has been created. Each node has a SAT to store all the available services. The SAT structure is shown in Table 1.

Table 1. SAT Structure.

Service ID	Service Type	Service Attributes	Service Owner
ID_1	$Type_1$	$Attributes_1$	Owner Address
…	…	…	…
ID_n	$Type_n$	$Attributes_n$	Owner Address

SA is started when a service is added to a node located within the ad hoc network environment and the owner of that service/decides to share its service based on some criteria.

Since the information of services kept in member node's SAT as well as cluster head's SAT, the state transition diagram for each of them is shown separately in Fig. 2.



HM: Hello Message, SAT: Service Access Table

Fig. 2. State Transition Diagrams for SA.

In clustered SA approach, service attribute information including static service attributes, service access models and the service physical location is sent to all clustermate nodes.

When a node shares a service, the node stores its service in its SAT and then sends the service to all cluster mates via making a packet which contains the SAT and sends it with a unicast service. Any change in this table causes the service packet to be sent to cluster head in addition to periodical hello message if difference of next periodical HM and current time greater than Change_Time. For example, when we delete a service from SAT in member node we have to update the SAT, thus, based on Fig. 3 we proposed an UpDate Packet (UDP) and send it to CH directly to distribute.

Status	**No Service$_{(k)}$**	
Service ID $_{(1)}$	Service Type $_{(1)}$	Service Attributes $_{(1)}$
…	…	…

Service ID $_{(k)}$	Service Type $_{(k)}$	Service Attributes $_{(k)}$

Fig. 3. Structure of UDP.

A new Hello message packet has been organized for CBRP to advertise the services (see Fig. 4). In fact, we use the CBRP hello message with adding some fields for services. When the cluster head receives a packet containing one or more services, it should update its SAT without any overhead in this updating.

Status	Type of packet	No Neighbor Node (n)	No Neighbor Cluster (m)	No Service (k)
Neighbor (1)			Neighbor status (1)	
…			…	
Neighbor (n)			Neighbor status (n)	
Neighbor Cluster (1)				
…				
Neighbor Cluster (m)				
Service ID (1)	Service Type (1)		Service Attributes (1)	
…	…		…	
Service ID (k)	Service Type (k)		Service Attributes (k)	

Status: 0 = undecided, 1 = Member, 2 = Cluster Head
Type of packet: 8 = Reply to member
9 = Service Advertisement
10 = Service Discovery
11 = Request to Head in its cluster
12 = request to all cluster heads

Fig. 4. Structure of New Hello Message.

Upon a node in the network receiving a hello message packet or any packet containing one or more services; the node modifies its own service table on the basis of the following algorithm (see Fig. 5 also):

1. It checks whether services in the hello message is already in the Services Table or not? If not, it adds some entry for them.
2. If there is a service in Services Table which has already been received, and it is not included in the Hello Message the service has to be deleted from Services Table in CH.

The pseudo code of the algorithm is as follows:

```
For (all services in hello message) {

    Extract service parameters from packet;
     If (the service is in SAT)
         Update the timeout event;
    Else {add it as a new record;
 }
If (there is a service from B in SAT but there isn't in hello message)
   Delete service from SAT;
```

Fig. 5. The Pseudo Code of the Algorithm.

4. Simulations, Results and Analysis

Our simulations were conducted in the Network Simulator 2 (NS2) [12].To facilitate the analysis of the results, we assumed that there are 15 services in the network. The services are first distributed randomly to nodes so that each node cannot own more than one service to offer to other nodes. The scenario files are created by the SetDest tool of the NS2 and the traffic files are created by 'cbrgen.tcl' program. The simulation settings and parameters are shown in Table 2.

Table 2. Simulation Setting.

Simulation time	900 s
Broadcast interval	2 s
Pause time	2 s
Maximum speed of the node	10 m/s
Data stream	CBR
CBR Maxpkts	1100
Max. connection	8
Sending rate	0.25
Seed	1.0
Number of nodes	15, 20, 30, 40, 50, 60, 70, 80, 90
Area	Max x = 500 m Max y = 500 m

One of the performance metrics is the total mean of control message's overhead of SA mechanism. This metric measures the load of the algorithms on network resources in terms of the number of packets.

In the first experiments, we intend to capture the effect of adding SA to the CBRP on control message overhead when we increase the number of nodes. We have captured the mean of control message overhead for various states in terms of the number of nodes in the network. Figure 6 shows the overheads versus number of nodes for SA and it illustrates that adding SA to the CBRP does not impose more overhead to the network.

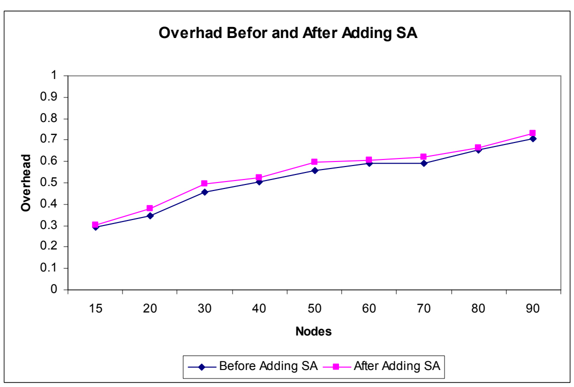


Fig. 6. Overhead before and after Adding SA to CBRP.

In order to facilitate the analysis of the results we have done another experiment on chain topology. A chain topology, where nodes are connected in a row (each one having one neighbour to the left and one to the right), was selected. Based on this topology we calculate the amount of service penetration on the network, which has been shown in Fig. 7. As can be clearly seen, in our proposed SA the amount of a service penetration on the network is exactly 32.34% of nodes.

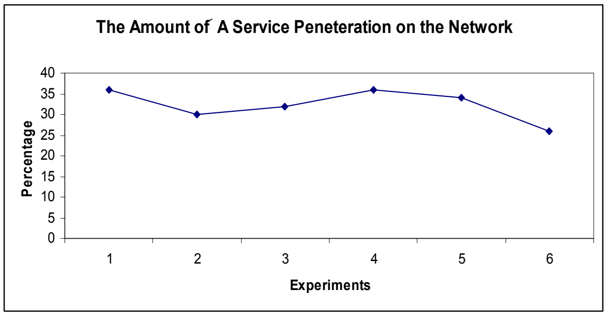


Fig. 7. Service Penetration on the Network.

In another experiment we analyze the message passing among a SA, which has been shown in Fig. 8. Eventually, in our SA more than 0.86 (86%) of the messages have been sent locally (messages broadcasted inside each cluster) which shows very low network traffic (inter clusters) creation and therefore low network resource consumption.

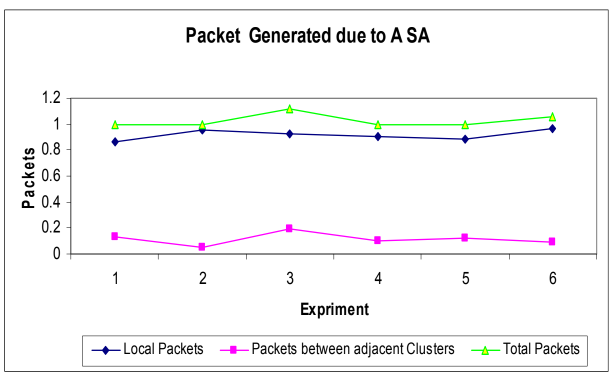


Fig. 8. Message Passing among SA.

5. Conclusion

Based on our experiment, adding SA to CBRP does not insert more overhead in various states. On the other hand the amount of a service penetration on the network is more than 30% of the nodes and more than 86% of the messages have been sent locally (messages broadcasted inside each cluster) which shows very low network traffic (inter clusters) creation and therefore low network resource consumption. Every node inside the cluster knows all of service in its cluster and no need to search inside. Since increasing number of nodes does not have more effect on overhead, we have an acceptable and scalable Hierarchical Service Advertisement. (New phrase that we did not talk about that in the paper before)

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