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Hybrid Hierarchical Approach for Addressing Service Discovery Issues in MANETs

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Abstract

Management of Mobile Ad-hoc NETworks (MANETs) is very difficult, because the movement of nodes is unpredictable, frequently changing the topology of the network. Consequently, Service Discovery (SD) in the network, a perquisite for efficient usage of network resources, is a complex problem. There are many issues in SD for MANETs. This paper aims to classify and compare existing SD protocols for MANETs by grouping them based on their SD strategies and service information accumulation strategies, and propose an efficient approach for addressing the inherent issues.

Keywords: MANETs, Service Discovery, Mobile Ad hoc Networks, Service Information Accumulation Strategies.

Introduction

A mobile ad-hoc network (MANET) is a self-configuring network of mobile nodes [2]. All of the nodes are routers connected via wireless links. The routers are free to move randomly and organize themselves arbitrarily, thus, the network topology may change rapidly and unpredictably. Such a network may operate in a standalone manner, or may be connected to the larger Internet or may be uses as a hybrid wireless network. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like natural or human-induced disasters, military conflicts, emergency medical situations, etc.

Some of the issues that affect the design, deployment and performance of ad hoc wireless system are given in Table 1. One of the important issues is ***service discovery*** [2].

Table 1. Some of issues in MANETs

Issues	Some Sub Issues
Routing	Mobility,Bandwidth,delay,Security,Overhead,...
Multicasting	QoS,Overhead,Robustness,Security,Scalability,...
Pricing Scheme	Optimal Route,Battery Charge,
Security	IDS
Scalability	Structure of network
Addressing	Routing
Medium Access Scheme	Synchronization, Access Delay, Reservation,...
Transport Layer Protocol	Flow and Congestion Control,....
Deployment Consideration	Area of Coverage, Choice suitable protocol,....
Self Organization	Neighbor Discovery, Topology Information, ...
Energy Management	Battery energy, Process and devices Power,
Quality of Service	Qos Parameters, QoS Routing, QoS Framework
Service Discovery	Routing, Agents

Although MANETs were initially mainly targeted for crisis applications (e.g., military, emergency and etc.), it appears to be valuable for civilian applications as well. Due to the absence of any centralized coordinator, service discovery in MANETs is very critical. In networks where the topology is highly dynamic, where frequent partitioning and merging of subnetworks occur, nodes should be able to locate services that other nodes provide. Hence efficient Service Advertisement (SA) mechanisms are necessary. Topological changes forces a change in the availability of service providers as well, hence fixed positioning of servers providing a particular service is hot possible. Rather, identifying the current location of the service provider is needed. The integration of service discovery with route acquisition is a suitable alternative. However, provision of certain kinds of services requires authentication, billing, and privacy that in turn, necessitates that service discovery protocols be separated from the network layer protocols [2].

Service Discovery Definition: A service in the network can be any software or hardware entity that a user might be interested to utilize. A definition of service discovery is: "Service discovery protocols are network protocols which allow automatic detection of devices and services offered by these devices on a computer network.". When the location of the requested service (typically the address of the service provider) is determined, the user may then access and use it [22].

Significant of Service Discovery: Existing approaches have been to share available resources among interested parties. In this way resources could be shared based on various criteria and hence solve the resource shortage problem. This concept is more advanced than most peer to peer resource sharing models where only one type of resource such as files are being shared. These collaborative resource sharing environments are called pervasive environments [23]. To find a suitable service or resource in MANETs is a challenging problem, because of the absence of any central intelligence in the network. Consequently service discovery is an important component for ad hoc communications and collaboration in an ubiquitous computing environment.

Manner of the Service Discovery in the network: A service is only advertised by its host machine after it has joined a network. If the service owner is willing to share the service in the network among different users, it would announce the

service availability through a *service advertisement* mechanism. Various algorithms have been proposed for the service advertisement functionality which show dissimilar performance; comparisons were based on different parameters such as the number of local and global messages passed in the advertisement process [23]. Choosing an unsuitable service advertisement procedure may cause severe network traffic congestion inside the computing environment. Selecting appropriate attributes of a service for advertisement is also vital.

On the other hand, a task being submitted to the environment for execution must identify its service needs. In this step the service management system should search for suitable services conforming to the constraints introduced by the task and allocate the matching services immediately to the task, or reserve the service if it is currently occupied using *service discovery*. Various service discovery models based on information store strategies have been implemented [23]. If all service information in an environment is gathered into a single service information store, service discovery can simply be done through querying this database; however the information and status of the available services is usually scattered throughout the environment in different repositories in a decentralized manner. Although a decentralized service information store complicates the functionality of the service discovery algorithm, it serves to avoid network bottlenecks.

In this paper we classify and compare existing service discovery protocols for MANETs based on SD strategies and service information accumulation strategies and survey the features of the discovery architecture. The SD taxonomy defines mechanism based on:

- Service Discovery Strategies
  - Service Discovery based on Supporting Layer
    - Network Layer
    - Application Layer
  - Service Discovery based on Multicast DNS
- Service Information Accumulation Strategies
  - Without Directory
  - Central Directory
  - Distributed Directory

Service Discovery Strategies

Depending on which layer network that protocols work in, the service discovery architectures can be divided into two categories: network layer based and service caching strategy based.

These protocols were designed for Ad hoc network to store general attributes of services. Among the protocols, only ODMRP was designed to be scalable to different applications.
Network Layer SD Strategies

In these protocols, service discovery is coupling with routing layer. Service query and response messages are often piggybacked on to ad hoc routing protocols. In this way, a node requesting a service in addition to discovering the service also be informed of the route to the service provider at the same time. Examples are: AODV, ODMRP, M-ZRP, LSD and DSD [3].

Table 2 gives an overview of network layer protocols for service discovery in MANETs.

Table 2. Comparison of network layer SD protocols

Protocol	Network Architecture	Storage Service Information	Search Method
AODV [4]	Central and Distributed Directory	Central and Distributed Directory	route request/reply
ODMRP [1],[5],[15]	Central and Distributed Directory	Cache of nodes	Push and Pull
MZRP [6]	Use cluster	Central Directory + every node in cluster	Push and Pull
DSDP [15]	Use cluster	Distributed Directory	multicast trees rooted
LSDP [14]	Central and Distributed Directory	Central and Distributed Directory	Push and Pull

Application Layer SD Strategies

In these protocols, service discovery functionality is implemented above the routing layer, typically in the application level. Examples include DEAPspace, Konark, GSD, SSD and SANDMAN.

Table 3 gives an overview of Application layer protocols for service discovery in MANETs.

Table 3. Comparison of application layer SD protocols

Protocol	Network Architecture	Storage of Services Information	Search Method	Service Description
Konark [8,9,16]	Point 2 point	All nodes	Push& Pull	XML
GSD [9,17]	Point 2 point	All nodes	Push& Pull	DAML +OIL
SANDMAN [10]	Clustered	Cluster head	Pull	Wakeup time+general

Service Discovery based on Multicast DNS

Multicast DNS has been devised for the resolution of domain names to IP addresses in the link-local scoped network. multicast DNS comprises a Responder and a Sender. The Sender is the resolver that sends a query in link-local multicast and the Responder is the name server that sends the response to the Sender using unicast. When the Sender receives the response, it verifies if the response is valid the Sender stores it in its cache and passes the response to the application that initiated the DNS query. Otherwise, the Sender ignores the response and continues to wait for other responses [12]. It is possible to extended the response with the name of services by changing the DNS entries. using this method, we can implement service discovery through multicast DNS.

In [12], a proposed architecture for name service called ANS (Ad-hoc Name Service for IPV6 MANET) implement SD in **IPV6** MANET. ANS allows mobile nodes to perform the service discovery as well as the name-to-address resolution. ANS supports the discovery of unicast and multicast service. In addition, ANS provides auto configuration technology for zero configurations related to name service, such as generation of unique domain names for mobile node and zone files for the name service. In this manner ANS will be a suitable DNS service and service discovery for MANETs and all networks where there are no network managers especially home and small office networks.

Comparison of the various SD strategies

Protocols that implements service discovery at the routing layer instead of the application layer significantly reduces the communication and energy consumption overheads. By implementing service discovery in the routing layer through piggybacking the service information into the routing protocol control messages, devices are able to acquire both service and routing information simultaneously. This approach decrease communication overheads and saves battery power.

Services Information Accumulation Strategies

A directory is an entity that stores information about services available in the network so as to enable service discovery and invocation.

Services Information Accumulation (SIA) methods can be classified as:

- *SD without using directory(directory-less)*
- *SD using centralized directory*
- *SD using distributed directory*

Table 4 gives an overview of Directory Architecture protocols for service discovery of mobile ad hoc networks.

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. Examples include UPnP, DEAPspace, PDP and SSD.

The centralized directory architecture rely on a central directory that stores the descriptions of all services available in the network so as to enable service discovery and invocation. Discovery of the directory by clients and service providers is in general based on multicasting. Then, service providers advertise their services to the central directory using a unicast message. And, 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 well suited to infrastructure-based wireless networks. However, this architecture makes the service discovery 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 service discovery domain. The boundaries of a service discovery 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. Examples include JINI and SLP.

The motivation that support the use of the distributed directory architecture for service discovery is that scalability can be achieved when the network size becomes larger. This architecture is very well 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). It does not require any pre-defined infrastructure. Mobile ad hoc networks are characterized by their highly dynamic, multi-hop, and infrastructure-less nature [8]. Examples include Sailhan.

In table 4, Sailhan search method is Centralize and other protocols search method is pull and push. Security in JINI define based on Java security.

Comparison of the Various Directory Architectures

In directory-less architectures, broadcasting is generally used for service discovery and advertisement. These broadcasting mechanisms are not suited for mobile ad hoc networks due to their heavy consumption of bandwidth and energy, which are limited in mobile devices. 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 but the central server further constitutes a bottleneck. In addition, a centralized directory limits its scope to devices within a local service discovery 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.

Comparison of Service Directory Strategies

Table 5 gives a comparison of Service Directory Strategies for service discovery in mobile ad hoc networks.

In order to have an efficient service discovery and service advertisement architecture, it is better to combine the distributed directory architecture and central directory architecture approaches to achieve the benefits of both.

Proposed Enhancement to SD Mechanisms for MANETs

Service discovery on a fairly large mobile ad hoc network must employ Zero Configuration network technologies, to minimize flooding, energy consumption and communication overheads. This would be achieved in proposed enhanced Hierarchical SD protocol via:

Table 4. Comparison of Directory Architecture protocols

Protocol	Network Type	Network Architecture	Storage Information	Service Description	Scalability
UPnP[8,11]	Enterprise	Point 2 point	Any devices	XML	N/A
PDP[18]	Ad hoc	Fully distributed	Any devices	GSDL	N/A
DEAPspace[19]	Ad hoc	Point 2 point	Any devices	General	N/A
JINI[20]	Enterprise	Centralize	Central Directory	Java objects	Service Grouping
SLP[21]	Small Scale Ad-hoc & enterprise	Point 2 point & centralize	Central Directory	General	service scope
Sailhan[22]	Ad hoc	Hybrid (infrastructure based+less)	Distributed	XML(WSDL)	Scalable SD

Table 5. Comparison of Directory strategies

Architecture ▶ Parameters ▼	**Directory-less**	**Centralized Directory**	**Distributed Directory**
Store Information	Stores the descriptions of services on their own device	Stores the descriptions of all services available in a directory	Directories are dynamically selected among mobile nodes
Network size	network size is very limited	Network size is limited	Network size is not limited
Search Method	Use reactive service trading	Use proactive service trading	Use proactive service trading
Problem	Heavy consumption of bandwidth and energy,	Which further constitutes a bottleneck.	Complexity of management of network
Scalability	N/A	Service discovery is scalability when the network size becomes larger	Service discovery is scalability when the network size becomes larger
Service Request	Normally Use Broadcast	Normally Use Unicast	Normally Use multicast
Advantage	In regions with extremely high dynamics, broadcasting could be the only possible technique	Response time for locating services reduces, Scalability is achieve, Server are not flooding with service requests,Can use load balancing algorithm.	Response time for locating services reduces, Scalability is achieve, Servers are not flooding with service requests Can use load balancing algorithm,improved efficiency

(i) Clustering mechanism to combine distributed architectures for maintaining service information with centralized stores for each cluster to decrease delay for finding a service in the network.

(ii) Hybrid mechanisms for Service Discovery using network and application layers approaches to decrease connection overhead and power consumption. The Network Layer is used to find Services based upon requests and The Application Layer is used to select the most suitable Service heuristically.

Hierarchical service discovery and advertisement is based on the concept of clusters. Each cluster consists of one cluster head (CH) and an arbitrary number of clustered nodes (CNs). Both CH and CNs can offer and use services. In each cluster, the CH acts as a representative for its CNs in terms of service discovery and the CH has a public view of the entire network but each of the CNs has a complete view only of its own cluster. Each CN can send packets to another cluster only via CHs.

Hierarchical Service advertisement is started when a service is added to a machine located within the ad hoc network environment and the owner decides to share the service based on some criteria.

In contrast to existing clustered SA approach, service attribute is divided into 2 categories, static and detailed attribute, detailed information including static service attributes, service access models and the service physical location is sent to every machine in the same cluster. In this way, all machines in the cluster are aware of the exact details of the service.

Advertisements of the service to machines in other clusters involve sending only the static attributes of the service. Only one message is sent to the destination cluster's cluster head for distributing the Service advertisement. The cluster head, having received the message, would then broadcast the message to all of its neighboring machines within the cluster. The flowchart of service advertisement is presented in Fig 1. In this Figure, based on size of network propagation of service information according to above mention is started. This approach is expected to improve to the accessibility of services information and decreases communication overhead.

Hierarchical Service Discovery means that, a client first search for the required service within the same cluster. If the queried service is shown to be suitable for the waiting task it is selected and the discovery process is terminated. But if a suitable service could not be found, search of the other clusters using Hierarchical Service Discovery will be performed. The flowchart of service discovery is presented in Figs, 2&3. Discovery in this flowchart is started when there is a request for service and it attempts to find a suitable service based on requested parameters. This approach also is expected to

decrease communication overhead and improved service finding.

Conclusion

SD and SA are very important issues in MANETs. Choosing a suboptimal SD and SA protocol will increase overheads network communications and power consumption. As a result this will also increase delay for finding a suitable service in the MANET. The proposal algorithms will be tested using simulation approaches to verify its suitability for improving SA & SD performance.

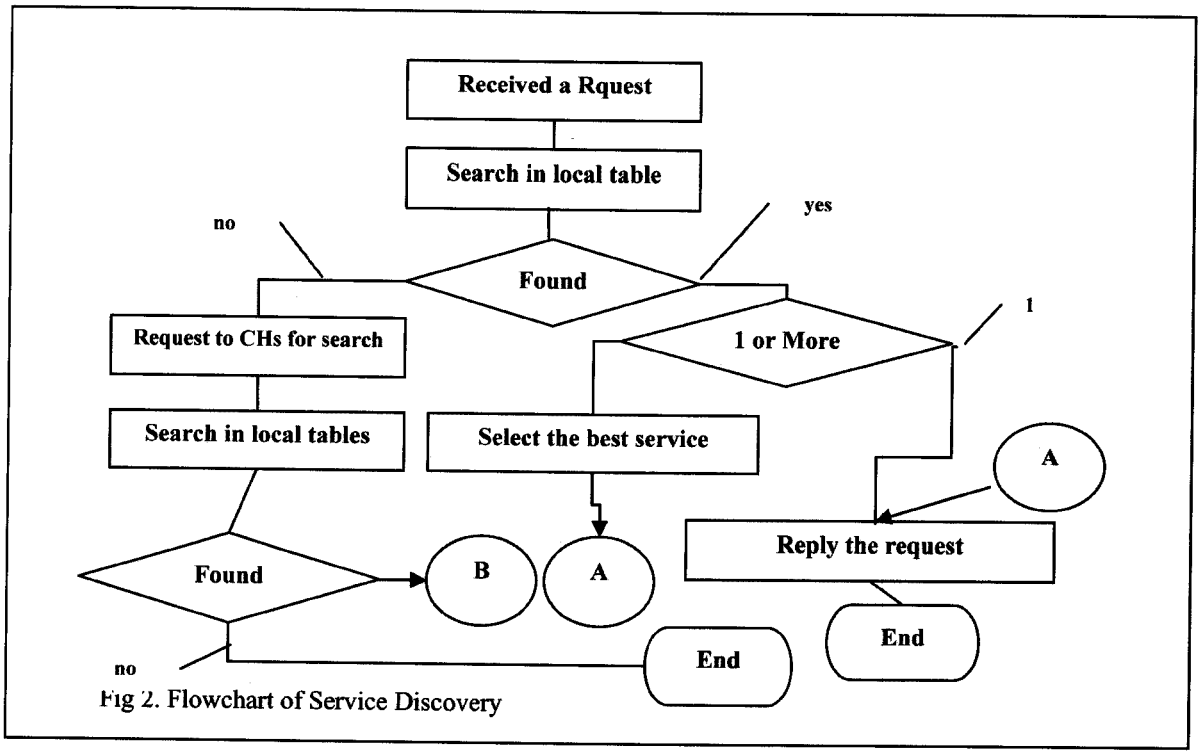

Fig 2. Flowchart of Service Discovery

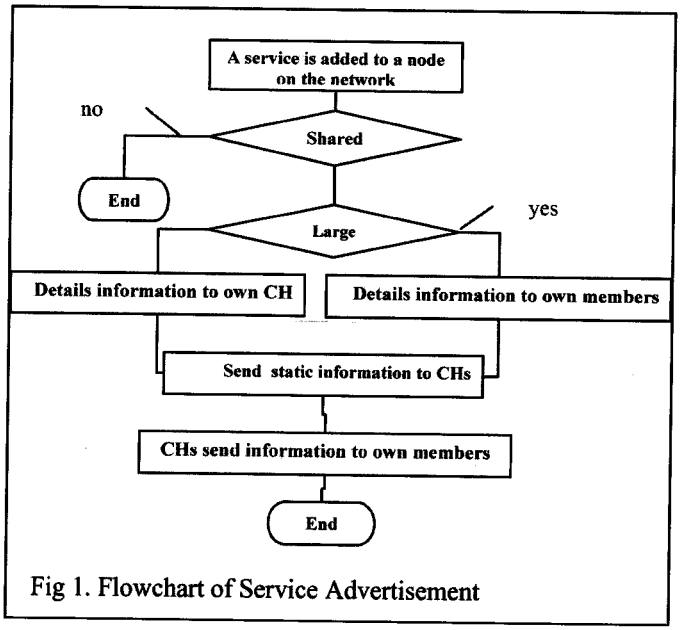

Fig 1. Flowchart of Service Advertisement

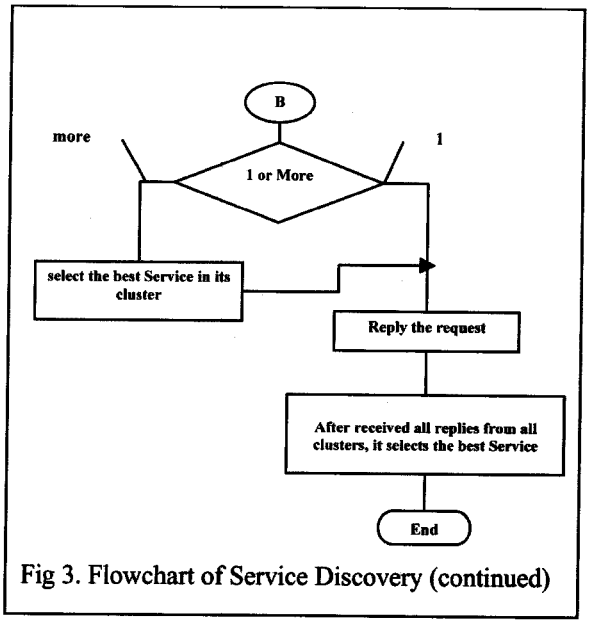

Fig 3. Flowchart of Service Discovery (continued)

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