A Service Discovery Protocol for Emergency Response Operations using Mobile Ad Hoc Networks

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Abstract—Many disaster recovery and military operations require the frequent movement of specialized personnel and equipment from one operations zone to another. Technology can play a significant role in facilitating resource organization and movements to where the need arises. In this study, we adopt the concept of service discovery in mobile ad hoc networks (MANET) and adapt it to the nature of such operations. For this purpose, we introduce a novel MANET service discovery and reservation technique that is tailored to support such environments and operations. In these situations, the network is often established hastily and the communication devices are of low computational and bandwidth capabilities. The nature of service is rather unique in the sense that a service provider is required to physically move to the location of need. A service provider is often able to service only one requestor over a period of time. The proposed technique functions as a service-oriented routing protocol that locates the resource on the basis of service levels and requirements. We evaluate the technique using a simulator that we developed specifically for this purpose. The evaluation results show the high success rate of the technique in locating and reserving services with changing operational conditions such as network density and rate of requests.

Keywords—MANET; service discovery; routing; emergency response.

I. INTRODUCTION

Mobile ad hoc networks (MANETs) have many applications where infrastructure networks are impractical or too expensive to establish and use. One of the important example applications is emergency response missions, e.g. in earthquake situations. In such missions, emergency and medical personnel move within affected areas in an effort to rescue trapped or injured victims. Makeshift camps are established in different sectors of these areas to which victims are transported in order to receive medical care and treatment. Locating and requesting the right help becomes crucial to saving lives and property in these situations. For this purpose, a MANET based service discovery arrangement can play a significant role for performing the task of the speedy and reliable locating of the right service that is closest to the location of need.

A service can generally be defined as the act of performing duties to others (e.g. clients) as an occupation or business (e.g. hospital staff that provides patients with medical care).

Our objective in this study is to provide a technique for organizing actual service deliveries from service providers who may exist in disaster areas or military operations zones. The provider in this case could be a surgeon, a nurse, a relief worker, etc. The client could be, for example, the victim who needs to receive some medical treatment. This implies that, after locating the service, the provider of this service is expected to physically move from their current location to the location of need. In addition, the service provider may in general serve one and only one client at any point of time and for a specific period of time. Once a provider is located and reserved, this specific provider may not be available for a while until the duty for which they have been called has been completed. Therefore, it is expected that every time a provider of a certain service is needed, a new service discovery is made specifically for locating and using it. It is also reasonable to assume that the communication devices that are used are of generally low computational power, storage capabilities and energy sources, e.g. hand held devices. These conditions place the following main requirements on the technique to use for this purpose:

• Since services have to be located every time they are needed, the amount of protocol-specific traffic has to be kept at lowest possible levels
• Specific service providers are available only occasionally i.e. when they are not servicing requests. Therefore, once reserved, a provider’s info may not be valid to keep track of
• The technique should have the ability to specify service-specific parameters. These parameters are needed to specify the requirements of a service request such as timing, severity, etc

In order to achieve the objective of this study, we introduce the notion of service-oriented routing. The goal of this type of routing is to locate a provider of a specific service when a need for such service arises. Although we target this technique for use with the services of the types and definition that we discussed above, it can also be extended to traditional definition of service discovery within MANET. This technique assumes that network nodes are location aware. This is necessary for the kind of operations for which the protocol is designed (e.g. disaster recovery, military, etc). The main characteristics of the proposed approach can be summarized as follows:
• It functions at the routing layer where it is most efficient to perform network searches
• Distributed operation; no reliance on specific network nodes for any of the technique’s tasks
• Provider selection, and hence route determination, is solely based on best service requirements match
• A located service provider is good only for the current request. Their information cannot be used to satisfy future requests and hence need not be kept after the assignment has been made
• The technique attempts to keep each of the zone’s providers within their original zone unless urgently needed elsewhere

The rest of this paper is organized as follows. In Section II, we discuss related MANET service discovery studies. In Section III, we introduce the detailed protocol design. In Section IV, we present protocol evaluation results. In Section V, we conclude the study.

II. RELATED STUDIES

Service discovery in mobile ad hoc networks (MANET) has been an active field of research. Many techniques of varying strategies have been proposed to address the different challenges in this area [1].

In [2], a backbone based service discovery protocol is proposed. Network nodes are assumed to have different capabilities. Stable nodes are used to form a backbone which is tasked with keeping information about currently valid services within the network. Nodes wishing to use a certain service communicate with the closest backbone node to get this information.

In [3], a decentralized service discovery mechanism for MANET is proposed. The authors proposed distributing information about available services to the network neighborhood. Service is discovered on the basis of the client distances and the capacity of the services. The approach allows for differentiation of service instances based on their capacity.

In [4], a service discovery protocol that is based on the peer-to-peer caching of the service advertisements is proposed. It uses the DARPA Agent Markup language (DAML), which is based on XML, for service description and requests. Each node that is hosting one or more services advertises these services periodically to its one-hop neighbors. These neighbors then propagate the service information periodically on the basis of the mobility-dependent parameter that is configured for this purpose. Nodes store remote service information in a finite cache that is maintained for this reason.

In [5], a routing layer service discovery protocol is proposed. It is a simple extension of a MANET routing protocol (ZRP) where the ID of the service is piggybacked on the hello messages of the routing protocol instead of using specific messages for service discovery. The service information is then included in tables at the receiving nodes. In [6], a service discovery protocol that is based on the GRID routing protocol [8] is proposed. It uses mobile agents for service discovery and XML to advertise services to the service directories.

In [7], a comparison is made between distributed architecture, where there is no service coordinators, and hybrid service discovery techniques that function by piggybacking on a reactive routing protocol. In the hybrid strategy, service coordinators as well as flooding are used to discover and request services. The study finds the distributed strategy, where only flooding is used (i.e. no service coordinators are used), to perform better in terms of cost and overhead. The marginal improvement of service availability is found to be negligible compared to the overhead incurred.

The authors in [9] proposed some modifications to accelerate the service discovery strategy of the IETF Zeroconf technique [10]. These modifications ensure that nodes discover new services in a real-time fashion via launching service discovery upon detecting any topology changes. The technique assumes the use of IEEE 802.11 as the underlying MAC protocol.

Our proposed technique is a service-oriented routing protocol that is concerned about locating and reserving services in the context of emergency or military operations. Unlike other service discovery techniques that function at the routing layer, our technique does follow an address-centric operation, as the address of a node is irrelevant to the discovery operation. In addition, it is a light-weight technique that suits that nature of the devices that are usually used in such operations. Therefore, the control packets are simple and yet self-contained. This avoids the rather heavy bandwidth, computational and energy cost incurred when structured languages such as XML are used. It also avoids the complexity involved in using techniques such as those based on agents.

III. PROTOCOL DESCRIPTION

The service discovery protocol that we introduce in this study aims at connecting service requestors to service providers. This protocol is therefore not confined to managing data exchanges but is used for the management of providing physical services which have specific attributes.

A. An Illustrative Example Scenario

We consider a disaster stricken area where the need for medical and emergency staff is severe. It is usually quite hard to reach such areas due to the difficulties imposed by, for example, a war situation or an earthquake, due to destroyed supply roads. Therefore, available emergency and medical crew members are considered scarce resources in such situations. In order to manage the work of these team members, each of them may be provided with a simple communications device such as a PDA. We also determine service categories and levels of severity of need. Examples of service categories include a surgeon, a nurse, an ambulance worker, equipment of different types, etc. Severity of need includes severe, medium and low. We
divide the disaster area into zones, each of which is denoted by a certain code. When a new casualty is discovered, it gets transferred to one of these zones for treatment. As time goes, the different personnel and equipment are expected to move between zones as the need arises. Figure 1 gives an illustration of this arrangement.

It is clear in such scenario that there is no available networking infrastructure. The deployment depends on the mobile networking devices i.e. the PDAs. The expected nature of the service requests is simple and involves few parameters.

When a new case that requires help is found, a search for the appropriate help, or service, is launched across the network, with the properties of the required service specified in the search message. The processing of these requests and the determination of the provider of the service is detailed in the remainder of this section where we give a description of the proposed protocol.

B. Protocol Overview

We base our discussion on a network layout such as the one shown in Figure 1. The protocol depends on dividing the network into different geographical zones. Each zone has service providers of different service categories. These providers are generally mobile. They move within their zones and can also move from one zone to another depending on the need. Service requestors could generally be mobile as well. However, practically speaking, they would normally be stationary, e.g. a patient requiring treatment, and confined to a certain zone. This is due to the fact that a certain emergency case that was discovered in an area is usually moved to the closest zone where it can be taken care of. The help could then be requested from within the same zone if available, or from any other zone, when the available resources within the zone of the requestor are no longer sufficient to satisfy its requests.

The protocol can be viewed as comprising of two main components, namely, service discovery and service reservation. As we stated above, service discovery is launched when a node needs a service of a certain category and attributes. Upon receiving replies with information about a possible provider that could fulfill the request, the requesting node starts the service reservation phase.

C. Service Discovery Phase

The service providers that we deal with in this study are of volatile nature in terms of their availability and location. Therefore, every time a service is needed, a service discovery has to be initiated. This is done by broadcasting a service request (SREQ) message and specifying the distance, in terms of the number of hops over which it should be propagated. This propagation distance depends on the urgency of the request. For urgent cases, the service is required to be in close proximity to the requesting party.

If a service is requested and no suitable provider is available to respond, the requesting node can increase the search area by increasing the number of hops and re-launching the request. All responses that get received within a certain timeout period get included in a service table, which we describe later. The phase is considered complete when the requesting node has located one or more providers which match its request. Figure 2 gives a description of the pseudo code of the algorithm that is used in this phase.

D. Service Reservation Phase

Once the service discovery phase is completed successfully, the requesting node assesses all the responses that it obtained in order to make its selection based on the provider response that best matches the need. Once it makes its selection, it issues a service reservation (SRESV) message directly to the best matching provider. If the provider is still available to provide the service with the required parameters, it responds back with a “service acknowledgement” (SACK) message, which would conclude this phase. If this provider is no longer available by the time it gets the reservation message, it responds with...
a “service NACK” (SNACK) message. If the requesting node gets an SNACK message, it tries the next best provider on its list and so on. If it does not find any of them available anymore, it will have to restart the service discovery scheme. After the provider reservation is complete, the requesting node deletes the other providers’ information for this request from its service table to free up some resources. Figure 3 shows the service reservation pseudo code.

```c
service_reservation {
  // Requesting node
  process(service_table) {
    sort(provider_offers)
    reservation_done = false
    while (offer_list != NULL and reservation_done =false)
      send SRESRV(next_best_offer_provider)
      wait (RSERV_timeout)
      if (received(SACK)) {
        cleanup(service_table)
        reservation_done = true
      }
    Call service_discovery{}
  // Provider node
  receive(SRSRV) {
    if (service available) {
      send(SACK);
    else
      send(SNACK);
    }
  }
}
```

Figure 3. Service Reservation algorithm

E. Service Table

The service table is used to keep information about available service providers for a certain request and how to reach them, while the processing of a certain request is in progress. This table exists at each network node. Table 1 shows the structure of the table. The table is updated when a requesting node gets a new service reply (SREP) packet as a response to an SREQ that it sent previously. The service reservation for a certain provider is completed, the table entries that pertain to this SREQ are deleted. Also, when the timeout for these entries occurs, the entries for the request are considered stale and are therefore deleted from the table. The latter situation occurs at nodes that are intermediate between a requestor and a provider.

| S. Provider | The provider of the service (ID of the node) |
| S_CAT | Service category |
| S.Zone | Zone of the provider |
| S.Avail | Service availability |
| Next_Hop | Direction of the provider |
| S.Distance | Requestor-to-provider distance |

Table 1. Structure of the Service Table

F. Packet Structure

We have to ensure that all nodes use a standard way to advertise their services. Service description is to be understood by all nodes requesting these services. The following are the main attributes of a discovery packet structure.

- **S_CAT**: Service Category
- **REQ_ID**: Request ID
- **S_Requestor**: ID of requestor
- **S_Provider**: ID of provider
- **SN**: Service Name.
- **SSN**: Service Severity of Need
- **SA**: Service Attributes
- **R_LOC**: Location of service requestor (x, y)
- **P_LOC**: Location of service provider (x, y)

The protocol supports the following packet types:

- **Service Request (SREQ)**: The main structure of the packet is as follows:
  ```plaintext
  SREQ (S_Requestor, REQ_ID, S_CAT, SN, R_LOC, SSN, SA)
  ```
- **Service Reply (SREP)**: The main structure of this packet is as follows:
  ```plaintext
  SREP (S_Provider, REQ_ID, SN, S_CAT, P_LOC, SA)
  ```
- **Service Reservation (SRESV)**: The main structure of this packet is as follows:
  ```plaintext
  SRESV (S_Requestor, REQ_ID, SN, SSN)
  ```
- **Service provider Acknowledgement (SACK)**: The main structure of this packet is as follows:
  ```plaintext
  SACK (S_Provider, REQ_ID, SN, SA)
  ```
- **Service provider not available (SNACK)**: The main structure of this packet is as follows:
  ```plaintext
  SNACK (S_Provider, REQ_ID, SN)
  ```

Figure 4 illustrates an example of a service request packet related to the scenario we have described above: Emergency Response System illustrated in figure 1.

```plaintext
SREQ (S_Requestor, REQ_ID, S_CAT, SN, R_LOC, SSN, SA)
S_CAT = Medical
SN = Surgery (Surgical Intervention)
SSN = Urgent
SA = head injuries, a bypass heart surgery, etc
R_LOC = (134,23)
```

Figure 4. Example of Service request

IV. SIMULATION AND RESULTS

In this section, we evaluate the performance of the new technique using the DisSERV simulator which we developed for this purpose. The DisSERV simulator provides an integration of two main aspects; namely, the service discovery protocol that we propose, and the node mobility model. The simulator generates mobility patterns using the random waypoint mobility model with specified distance distribution function [12].

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In this study, we adapted the MANET service discovery concept to the needs of constrained environments. In these environments, where nodes are often mobile and communication links are limited, service discovery mechanisms need to be designed to efficiently find available service providers. The MANET service discovery concept is well-suited for these environments, as it allows nodes to discover and reserve services in a distributed manner, which is crucial given the limited resources available in such settings.

To achieve this, we designed an algorithm that enables service requestors to efficiently find service providers. The algorithm involves several key steps: discovering service providers, reserving services, and managing the service requests. To evaluate the performance of this algorithm, we conducted experiments under various conditions.

### Experiments

#### Varying the Number of Service Providers

We changed the number of available service providers to observe how the system performs under different provider densities. The number of available providers significantly affects the success rate of service discovery. As the number of available providers increases, the probability of successfully locating a provider also increases. Conversely, if the number of available providers is low, the system may struggle to locate a suitable service provider.

#### Varying the Number of Service Requestors

The number of service requestors also influences the system's performance. As the number of requestors increases, the demand for services grows, which can lead to a higher success rate. However, if the number of requestors exceeds the number of available providers, the success rate may decrease since the providers may already be engaged in service reservations.

#### Varying the Mobility of Service Providers

Service providers, being nodes themselves, may move or change locations. This mobility can affect the system's ability to discover and reserve services. When service providers are highly mobile, it becomes more challenging to discover them. Conversely, providers that are stationary for longer periods are easier to locate and reserve services.

### Results

#### Discovery Success Rate

- **Fixed Number of Providers:** As we increase the number of available service providers, the discovery success rate increases. This is because with more providers, the probability of finding a suitable provider grows.
- **Fixed Number of Requestors:** Increasing the number of service requestors also increases the discovery success rate. However, this increase is more pronounced when the number of requestors is low relative to the number of available providers.

#### Service Reservation Success Rate

- **Fixed Number of Requestors:** The service reservation success rate is also influenced by the number of available providers. With more providers, the success rate is higher, as there is a greater chance of finding a provider that can meet the service request.
- **Fixed Number of Providers:** As we increase the number of service requestors, the reservation success rate improves, indicating that providers can more efficiently allocate their resources.

### Conclusion

The experiments demonstrated that the MANET service discovery and reservation system is effective in constrained environments. By adjusting parameters such as the number of providers, requestors, and mobility, the system can adapt to various conditions, maintaining high success rates for both discovery and reservation. This system has potential applications in various domains, including emergency response and mobile computing, where reliable and efficient service discovery and reservation are critical.

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*Figure 5: Service reservation success vs. number of available providers.*

*Figure 6: Discovery success vs. number of available providers.*

*Figure 7: Provider reservation success vs. number of available providers.*
operations. We introduced a service-oriented routing protocol with the sole purpose of locating and reserving disaster relief service providers for the different needs that may arise in such situations. We ensured that service discovery in this case responds to the nature of these environments such as the ability of the provider to serve only one case at a time at the requestor’s physical location, which results in the need to launch a new discovery every time a service is needed. The proposed technique enables locating services based on the client’s requirements. These requirements may include elements such as service provider proximity and service severity of need.

We performed several experiments to evaluate the new technique using a simulator that we developed for this purpose. These experiments showed that discovery and reservation success rates generally increase with the increase of network density. They also show the ability of our algorithm to discover available service providers with high success rates. With mobile service providers, the discovery rate increases as the level of mobility of the service provider decreases, in general.

![Figure 6. Service Discovery vs. node density and number of discovery hops](image)

![Figure 7. Service Discovery delay vs. clients and provider density](image)

**REFERENCES**


