Reactive Relocation and TTL-based Search for service discovery in Wireless Sensor Networks

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Abstract

Service discovery in wireless sensor networks allows sensors to dynamically locate software/hardware without human intervention. Researchers have proposed protocols that use directories to support service discovery: servers registers offered services to directories, clients send requests for service to directories. A challenge for existing protocols occurs if a directory moves or fails, causing high communication overhead to locate services. We have proposed an algorithm that uses multiple, mobile directories to alleviate this. In this paper we propose an extension that allows neighbor nodes to select a new directory when an existing directory fails. Analysis shows that our technique can increase the number of successful requests, with just minor increase in communication overhead.

Keyword: centralized architecture, mobile directories, service discovery, wireless sensor network.

1. Introduction

Service discovery in wireless sensor networks (WSNs) allows devices to automatically find software and hardware services offered by other devices [1]. For example, the service could be a physical sensor for collecting data (e.g. light and temperature), controlling machine (e.g. robotic arms, switches, conveyor belts) or software (e.g. data processing and conversion). Typically, service discovery can be performed in either a distributed architecture, with clients broadcasting requests to servers in a network, or a centralized architecture, where servers register services to a special directory, and clients send unicast requests to the directory (see Figure 1). Using a directory can decrease response time and reduce communication overhead, but increases the reliance of selected nodes, thereby causing significant performance problems if a directory is unreachable or fails [2]. Our research addresses this issue, providing a means to use a directory to maintain satisfactory performance of service discovery in WSNs, while coping with the mobility and failure of directory nodes.

Several researchers have studied directory-based service discovery in ad hoc networks and WSNs [3-9]. There are two main approaches: using multiple directories and allowing a directory to move between nodes.

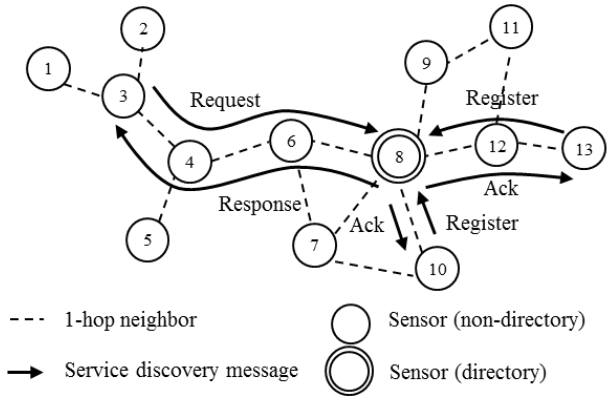

Figure 1. Directory-based service discovery

H. Artail et al. [3] presented DSDM, an algorithm for selecting which nodes should act as directories with the objective of minimising the broadcasting of packets in the network. The directory selection takes into account the capabilities of nodes – memory, expected sensor lifetime and available bandwidth. The more capable nodes should act as directories as they must handle more processing and network traffic than other nodes. In DSDM, servers register services with the closest directory and that directory forwards the registration to all other directories in the network. A node selects its nearest directory for retrieving a service. When a directory goes offline, all nodes broadcast their scores and a new candidate is chosen. The results showed that as the number of directories increases, the average traffic (load) at each directory decreases, but at increasingly smaller rate. The disadvantage of DSDM is the requirement to know the capability of each device and the potentially high overhead due to continuous network wide broadcasting.

G.V. Sergio et al. [4] proposed an algorithm to determine the optimal placement of a directory in a network to minimise communication overhead. The directory can move between nodes when needed. A semi-markov decision model is used to select the directory location, while a greedy algorithm determines whether or not the directory should relocate to another node. The results show a reduction in broadcast packets. However the algorithm is complex and needs to be run offline, limiting the deployment of this scheme.

Another paper that address directory location [5] proposed algorithm to discover services base on mobility-base clustering by clustering all nodes from their mobility, direction, velocity, duration and connectivity. It shows that this algorithm will be more efficient when nodes have a specific movement pattern.

B. Zafar et al [6] proposed a directory placement algorithm, as well as reduced power consumption by introducing a Basement Directory Agent (BDA). The BDA searches for a node which covers the most servers, and the directory is moved to that node. The

result recommends the optimal number of directories and reduces the energy consumption as well.

S.A. Chaudhry et al [7] used proxy directories which act as gateways between a WSN and Internet for service discovery by nodes on the Internet. Although the scenario differs from ours (we consider only the internal WSN, they focused on service discovery between nodes on external network and internal WSN), there are useful insights on the number of directories to be used.

Our research aims to improve the service discovery approach of Chauhdary [7] by applying the mobile directory mechanisms developed by Sergio [4] allowing mobile directories relocated in WSNs. Our previous work has analysed the impact of the number of directories on performance [8] and proposed Service Discovery Relocation Algorithm (SDRA) [9], a system for selecting locations of multiple directories. In this paper we evaluate an improvement on SDRA, specifically focusing on how to increase the success rate for requests in the presence of directories leaving the network.

2. System Design

2.1 System Model

We design SDRA for a moderate sized WSN with 50 to 300 nodes. Service discovery in a small network (10 to 30 nodes) is generally achievable without the complexity of directory nodes. However as the number nodes grow, this additional complexity can be outweighed by saving in performance. We have not yet considered very large networks (1000's of nodes) as they will be less likely to occur in practice and will probably require different mechanisms for service discovery (e.g. distributed hash tables). We assume that nodes in a WSN may be mobile (e.g. people, robot and objects in factories) and are aware of their location (e.g. via GPS or other location technology). The scenario under consideration is a WSN for service discovery in a building factory or outdoor area. According to the resource limited and decentralized network such as a WSN, relying on centralized directories can create problem (e.g. directory node fail or leaves the network) and performance bottleneck; however multiple directories can improve the performance of service discovery. Therefore two designs criteria must be considered: how many directory nodes are necessary and which node should be directories?

H. Artail et al. [3] considers and recommends less than 10% of all nodes to be directories. We follow this approach by setting an upper limit to 10% of all nodes. Selecting an undesirable node to be a directory can cause several problems (e.g. high communication overhead from transfer the information, highly cost deployment, high

processing and energy consumption). Therefore selecting appropriate node to act as directories is important for service discovery performance.

Wireless sensor devices in WSN are normally low capability; however some nodes have more capability than other nodes. For example, some nodes may be fixed and use an external power source, allowing for higher processing/storage capabilities and different wireless technologies (e.g. IEEE 802.11). It is possibly beneficial to locate directories on them as directories typically require more processing, storage and communication than client and servers. Therefore, SDRA algorithm considers this information when selecting directories. As the optimal placement of directories on node may vary over time, it is also important to allow directories to move between nodes, i.e. mobile directories. On the other hand, to improve the performance of service discovery only more capabilities may not be enough. Our proposed Service Discovery Relocation Algorithm (SDRA) addresses the challenge to find appropriate node to be directories and improves the service discovery performance. Figure 2 illustrates the components of SDRA, which are described in the following sections.

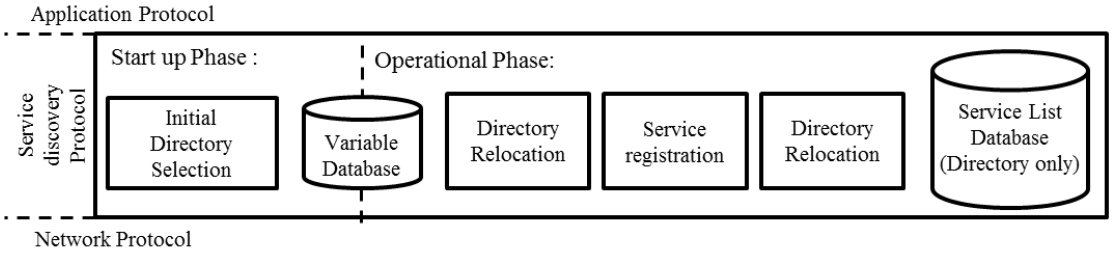

Figure 2. System Components of SDRA

2.2 Method of selecting directory nodes

Using more directories can degrade the communication overhead and response time [3,7-9]. Our previous work [8] showed that selecting a node with the most neighbors to be a directory can increase performance, but has problems when node capabilities vary. Therefore we developed SDRA [9] which consider node capabilities (memory, battery, wireless communications) in selecting directories, and also avoids selecting directories too close to each other. Details of SDRA are in [9].

2.3 Method of searching service

To improve the efficiency of a client searching for a server, SDRA uses a time to live method (TTL) in requests. The default behavior in service discovery (and DSDM) is that if a client sends a request to its closest directory and the requested service is not available, the directory responds with a failure message. In SDRA, if the request service is not available at the closest directory, that directory forwards the request to a neighbor directory. The number of directories that the request traverses is limited by TTL set by the client. The TTL is decremented by each directory upon reception;

a failure message is sent if TTL reaches 0. The value of TTL is set by the client and should be less than the maximum number of directories in the network.

2.4 Method of relocation directory

A problem occurs when using centralized architecture for service discovery when directory leaves the network on its own accord or fails. To address this problem, we propose a method to relocate a directory from one node to another where possible. Proactive relocation is used when a node knows it will leave the network. According the environment and the connectivity of movable nodes, there could be more appropriate nodes to act as directory than current directory; however another challenge is directory node may leave without notice. We proposed reactive relocation to periodically relocate more appropriate node to be a directory by using selection approach for selecting new directory; however to broadcast the whole network can cause high communication overhead. Hence, we design a scheme that broadcasts to just local area (1-4 hops) to find appropriate directories. The protocol is shown in Figure 3.

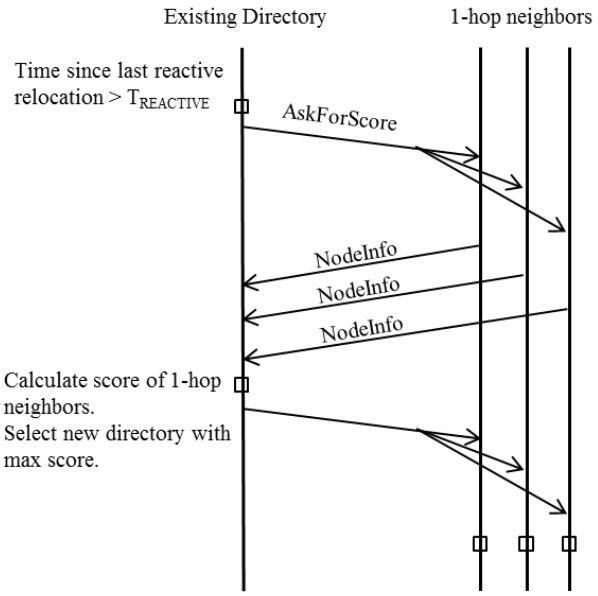

Figure 3. Reactive Relocation

3. Simulation Model

We developed a simulation model in MATLAB to compare the performance of our proposed SDRA to DSDM [7]. The simulator models the network as a graph, where edges are created between vertices (nodes) when within range. Wireless link delay is constant (1ms) and packets are sent along the shortest part between source and destination. Simulation will select directory at the first time and reselect directory (reactive relocation) every 30 seconds and time to wait after all nodes broadcast is 1

second. We vary the number of directories, mobility (speed and pause time) and the number of services offered in the network. The parameters are listed in Table1.

Table 1. System parameter

Number of nodes		**Scenario**	
Total	100	Area	100x100 m
Client	60	Transmission range	15 m
Server	40	Initial position	Uniform distributed
Directory	1-10	Weight of Battery	2
Extra Memory	10	Weight of Memory	2
Extra Battery	10	Weight of Wireless link	4
Extra Wireless	5	Number of directories for searching	1-5 TTL
Mobility		Broadcast hop in Reactive	1-4 hops
Model	Random way point	**Simulator**	
Speed	0.5 m/s	Simulation duration	10 minutes
Pause time	30 s	Seeds	10
Service and request			
Service type	10	Request rate	0.1 req/s
Max service/node	3	Packet size	81 byte

The weights of capabilities were selected to give nodes with an extra wireless interface higher importance than other nodes. The ideal values of the weights will depend on the network scenario and node capabilities, and are subject to future study.

The compare our SDRA against DSDM service discovery performance, we used successful request rate, response time and communication overhead as performance metrics.

4. Analysis Result

Key results are presented in Figures 4(a-f). The data points are the average across 10 simulations, each with different random seeds. The 95% confidence interval is also shown as error bars (in those plot with no error bars, the confidence interval was very small). We have analyzed the performance of all features in SDRA to compare with DSDM but in this paper due to space limitations we show results with significant difference in performance. The result of the TTL search approach can be seen in Figure 4(a-c). The expected trend is that the more directories there are, the better the result is (lower response time and communication overhead). Even the success rate is lower when increase the number of directories because to have more directories, server will have more choice to register service with the closest directory, therefore each directory did not have the same service. However, to increase the successful request rate SDRA proposed a searching approach to search more directories. The result shows that SDRA obtains a higher success rate but with slightly higher overhead due to traversing more directories. In case of search only one directory SDRA perform better than DSDM. In DSDM directory selection approach used only capabilities of node, not connectivity as in SDRA. Therefore directory might not be located near with the most nodes; some nodes still take longer time to communicate

with directory as can be seen in Figure 4(d) the average number of hops between directory and node. Another important approach is reactive relocation of the directory which will improve the performance of service discovery as can be seen in Figure 4(e-f). The graph varies the number of hops for broadcasting to reselect directories and also compare reactive relocation approach with non-reactive. The result shows that reactive relocation can improve the successful request rate but a little bit higher overhead according to broadcast every 30 seconds to reselect directories.

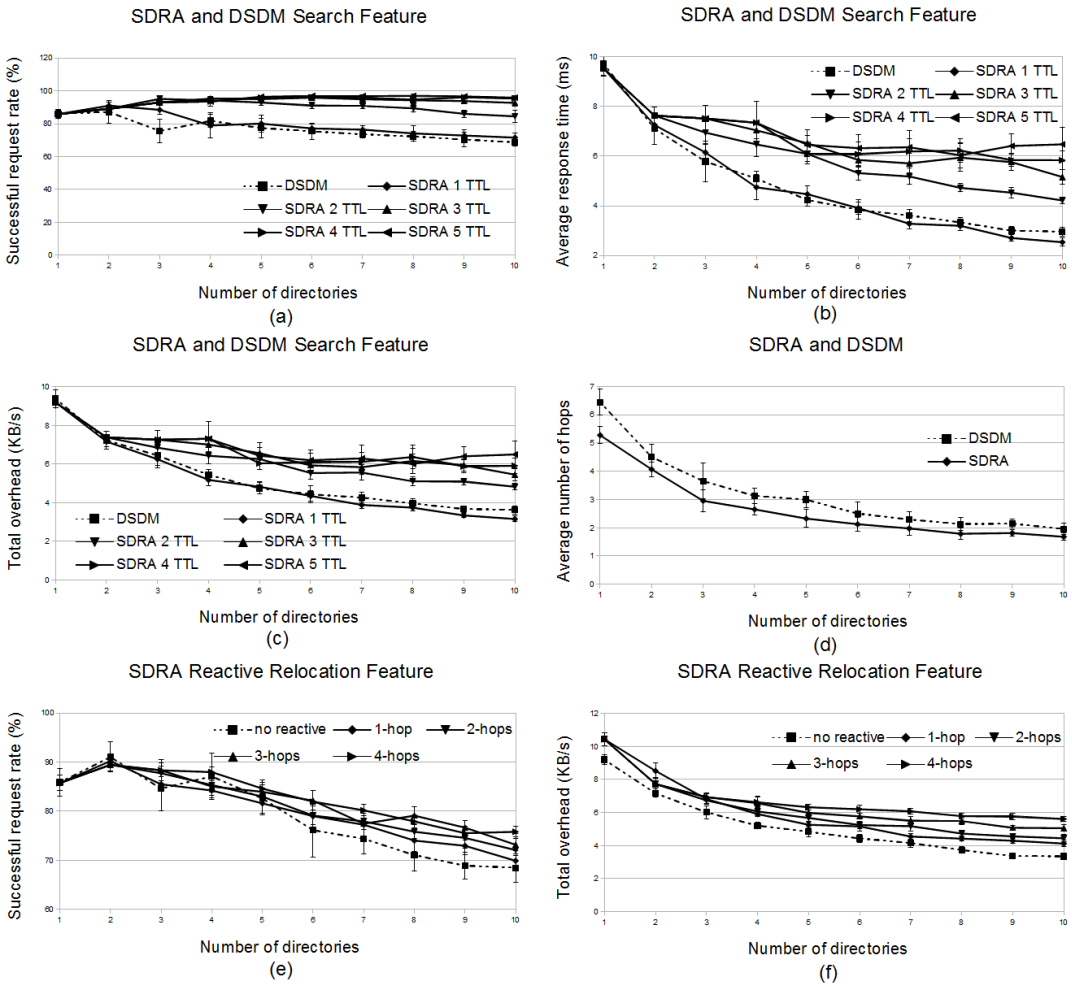

Figure 4. The result of simulation: (a) successful request of search Feature; (b) average response time of search feature; (c) total overhead of search feature (d) average number of hop; (e) successful request rate of reactive; (f) total overhead of reactive

5. Conclusion

We have proposed SDRA [9], the algorithm for selecting and relocating multiple, mobile directories, to improve service discovery performance in WSNs. SDRA consists of three main approaches which are composed of selecting directory by its capability and connectivity; searching for multiple directories and relocating directory when it leaves or fails. In this paper, we aim to evaluate an SDRA algorithm specifically focusing on how to increase the success rate for requests even if

directories have left the network, and compare the results with DSDM [3]. Our analysis shows that SDRA can increase the successful request rate by using TTL for search and reactive relocation of directories. Future work is needed to consider larger networks and the presence of highly mobile sensor nodes.

6. Acknowledgement

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