Aalborg Universitet

Cooperation of Network and Service Layer in Mobile Ad-hoc Networks

Liu, Yaoda; Olsen, Rasmus Løvenstein; Schwefel, Hans-Peter

Publication date:
2008

Document Version
Early version, also known as pre-print

Link to publication from Aalborg University

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners
and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy
If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to
the work immediately and investigate your claim.

Downloaded from vbn.aau.dk on: June 18, 2025

Cooperation of Network and service layer in Wireless Ad-hoc Networks

Yaoda Liu, Rasmus L. Olesen, Hans-Peter Schwefel

Center for Teleinfrastruktur, Aalborg University, Denmark

{yl, rlo, hps}@kom.auc.dk

Abstract— **In this paper, we investigate how service discovery protocols can be improved in Mobile Ad-Hoc Networks by utilizing routing information from the network layer. We consider in this paper proactive routing protocols as the underlying routing protocols and optimize proactive service discovery protocols. We first propose a general framework for the cooperation of service protocols and routing protocols, and then propose the optimization scheme.**

I. INTRODUCTION

Service discovery in Mobile Ad-Hoc Networks (MANET) has gained much attention [2], [8], [9], [10], [11]. At a system architecture level, a system designer has to address two issues: 1) whether directory-less approach (all nodes are equal) or directory based approach (a central node maintains the service table and others consult to it to locate the desired service) should be taken; 2) who proactive or reactive service discovery (advertisement by service providers or query by the service customers) should be utilized? For 1), by intuition the directory-less architecture seems to be more suitable for service discovery in mobile-ad hoc networks because of the infrastructure-less nature of mobile ad-hoc networks and the requirement of directory based architecture on infrastructure[1]. Kozat and Tassiulas [2] however showed that by using a virtual backbone, a directory based architecture outperforms pull (query/reply) based directory-less architecture in the considered system. However, in this work, only pull based service discovery schemes are considered as reference scheme; and only reactive routing protocols (ODMRP [3], DSR[4] and AODV[5]) are considered as the underlying routing ptotocols; moreover, the routing protocols and service discovery protocols are assumed to work independently. Issue 2) depends on the network scenario: user activity, network dynamics and so on.

Recently, the cooperation of network layer and service layer has been studied intensively [8], [9], [10], [11]. As far as the authors are aware of, the main idea behind all the existing work so far is to piggyback the service discovery message onto routing related messages in reactive ad hoc routing protocols. In this paper, we also address the cooperation of service layer and network layer. But, our work differs from previous work in the following way: First, we focus on proactive service discovery protocols instead of the reactive service discovery. One could argue that reactive approaches may be more efficient as the service discovery procedure is executed only when it is desired. However, based on what we have observed in field of routing within mobile ad-hoc networks, we believe that proactive service discovery needs to be studied properly as well. At

the early stage of developing routing protocols for MANET, reactive routing protocols such as DSR [4] and AODV [5] was proven to be more efficient than proactive routing protocols like DSDV[6]. However, proactive routing protocols proposed later like OLSR [7] have been proven to be as efficient as DSR and AODV. Second, instead of the cooperation of service discovery and reactive routing protocols by piggybacking the service message on routing message, we suggest another way of cooperation, i.e., service discovery protocols utilize the routing table to optimize the service advertising procedure.

The rest of the paper is organized as follows. In Section II, a framework for the cooperation of service protocols and proactive routing protocols in a distributed directory-less architecture for service discovery is described. The proposed cooperation scheme is then discussed in Section III, and evaluated in Section IV. Section V concludes the paper.

II. DISTRIBUTED DIRECTORY-LESS SYSTEM ARCHITECTURE ENABLING THE COOPERATION OF SERVICE DISCOVERY AND PROACTIVE ROUTING PROTOCOLS

The proposed system architecture for the cooperation of service and network layer consists of the following functionalities as shown in Fig. 1.

The following components comprise of the service discovery protocol:

- *Service advertisement at the service layer of service provider*: The service advertisement protocol is responsible to announce the existence and properties of services provided by the service provider. With the help of routing information, it may also select the means for service advertisement, i.e., broadcast, unicast or others.
- *Service table maintenance at the service layer of each node*: Service maintenance module is responsible for adding/removing service and also editing the service properties. This functionality works in a purely passive manner. The events to trigger service maintenance can be a notification message from the network layer or the reception of service advertisement.
- *Service search at the service layer of each node*: The service searching protocol is responsible to find a desired but unknown service by flooding service requests to the network. This is only optional for proactive service discovery approach where discovering an unknown service is of less interest.

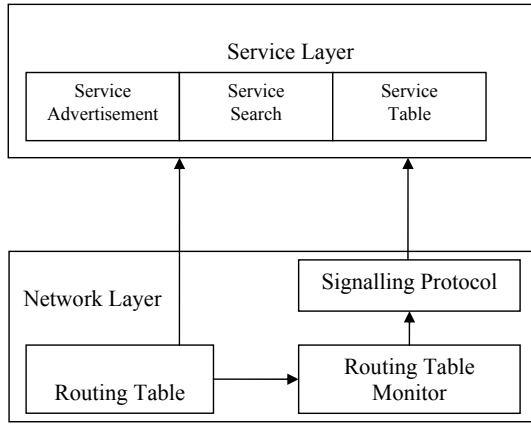At the network layer, the following components are needed to accommodates the cooperation:

Fig. 1. system architecture for a single node (service providers / customers) that enables the cooperation of service management and network layers

- *Routing table*: Routing table provides the relevant information, i.e., reachability and topology to the service layer.
- *Routing table monitor at the network layer of each node*: This monitor is responsible to find the relevant changes such as new-coming/disappearing nodes. If such changes occur, the signalling protocol is use to inform the service layer.
- *Signalling protocol at the network layer of each node*: The signalling protocol at the network layer of each node is an internal signalling protocol used to inform the service layer about the relevant changes in the routing table.

III. THE PROPOSED COOPERATION SCHEME

A. principle of the cooperation scheme

As mentioned in Section I, at the service layer, we consider the directory and proactive based service discovery approaches, i.e., service providers advertise their services and customers maintain a list of services that are available in the network. At the network layer, we consider proactive routing protocols.

If proactive routing protocols are deployed at the network layer, Both customers and service provider can obtain the reachability of each other. More specifically, customers can reply on the network layer to get the information about whether the service provider is still reachable or not. And the service provider can get the information about new-coming nodes (potential customers who do not know the services). As described in Section II, routing table monitor keeps track of the changes in routing table and report relevant changes to service layer through the signalling protocol so that the service layer can take the corresponding actions.

To optimize the service advertisement functionality, the service provider would like to advertise the service in a most efficient way, i.e., making all the potential customer to be aware of the service with lest amount of service advertisement. Depending on the business model, the service provider may need to pay intermediate nodes for forwarding the service advertisement to other nodes not in the transmission range of the service provider. Hence the service provider want to reduce the number of packet transmissions induced by the service advertisement.
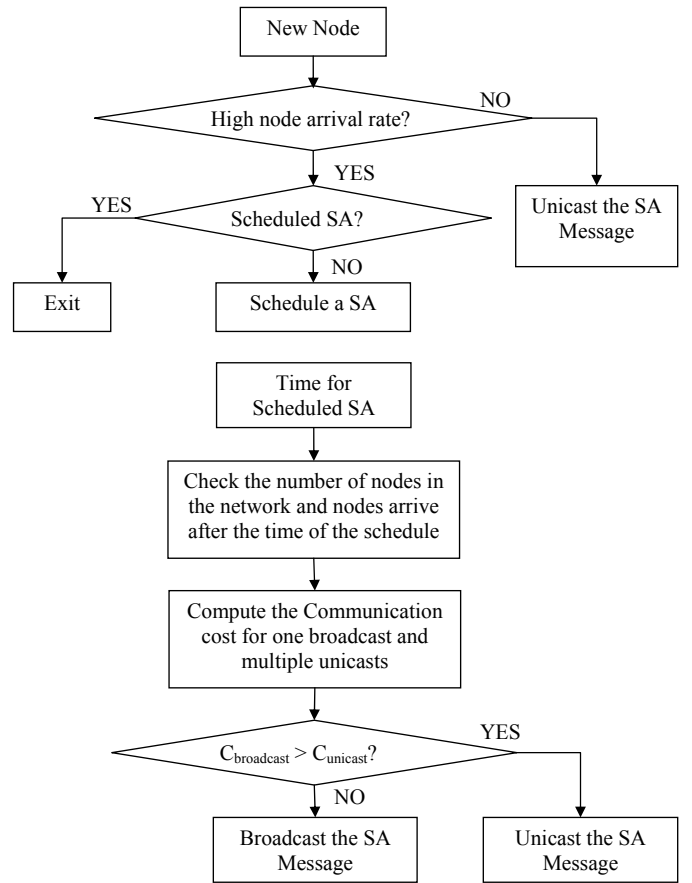

Fig. 2. The flow diagram of the proposed service advertising method at the service provider

To achieve this goal, we propose here an event driven service advertisement method, which is illustrated by the flow chart in Fig. 2. Using this method, the services are advertised only when certain events make the advertisement necessary instead of periodic service advertisement in conventional proactive approaches. There are several events that could trigger a schedule of service advertisements, e.g., service properties change at the service provider and the appearance of new-coming nodes. When a new service becomes available or the property of an existing service changes, the only way by which the change can be announced to the whole network is to 'flood' the network with a service advertisement. However, when a new-coming node is observed, the service provider can either uni-casts the advertisement specifically to this node or flood the network with a service advertisement. The choice depends on the dynamics and the topology of the network. If new nodes occur frequently in a certain period (for example in the case of network merge), a single flooding may perform better than multiple uni-casts.

B. Heuristics

We present a heuristic of the proposed cooperation scheme, focusing on two aspects: when to conduct service advertisement and whether broadcast or unicast should be used in order to achieve better performance in efficiency.

In this heuristics, we assume that the service layer record the times of nodes arrived in the past. Based on this knowledge,
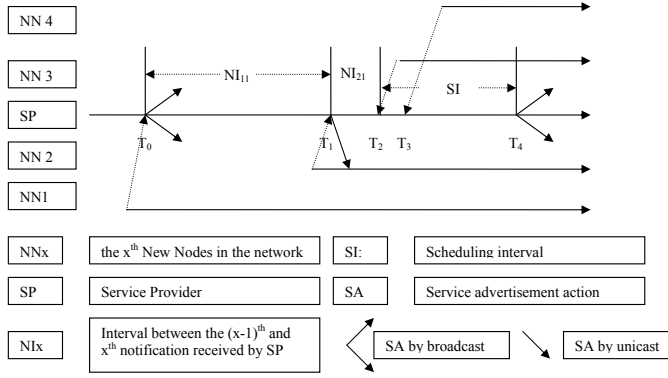
Fig. 3. An example showing the heuristic of the adaptive approach

the service provider decide whether it should conduct service advertisement immediately or wait for a certain period, called scheduling interval in the rest of the paper. On one hand, if nodes are arriving very often (In this heuristics, this is reflected by a smaller interval between the last two arrivals than a threshold, called scheduling interval from now on), advertising services after waiting for a period of scheduling interval may be better to avoid overloading the network with service advertisements. On the other hand, if nodes are arriving not so often, a service advertisement is conducted immediately after a new-coming node is noticed. The reason for this is not so many new-coming nodes are expected in the near future such that the waiting period may not bring any extra information and benefit at all, but does lead to longer delay for the new-coming node to be notified about the available services.

Up to this point, we know when to conduct service advertisement, the next issue is whether broadcast or unicast should be used. For this issue, we simply calculate the communication overhead in number of transmissions for both operations, and then choose the operation with least cost. For broadcast operation, we assume flooding as the underlying protocol for simplicity. Hence the communication overhead is equal to the number of nodes in the network as in flooding each node is supposed to forward the broadcast message once. For unicast operation, we assume that the routing table can provide the number of hops to the new-coming nodes, hence the communication overhead is just the sum of hops to all new-coming nodes.

The procedure above is illustrated in Fig. 3. At time $T1$, The service provider become aware of a new node (e.g., the new node sends a notification by broadcast), $NN1$. As the interval between this notification and the last notification ($T0$), $NI1$ is longer than the scheduling interval, the service provider sends a service advertisement (SA) immediately by unicast. At time $T2$, another new node, $NN3$ is noticed. As the interval from $T2$ to $T3$ is smaller is shorter than the scheduling interval, the service provider schedules a SA in a scheduling interval instead of sending a SA immediately. At time $T3$, although another new node is noticed, no action is needed as there is a SA scheduled. At time $T4$, the service provider choose broadcast based on communication overhead of a single broadcast and multiple unicasts.

IV. PERFORMANCE EVALUATION

In this section, we evaluate the proposed service discovery protocols by simulation.

A. Simulation model

We developed an abstracted network model as described as follows:
- the network consists of a service provider and multiple nodes as potential customer;
- a star topology is used to model the network;
- the number of hops from each node to the service provider is uniformly assigned and remain constant during the simulation;
- The dynamics of the network is modeled by each node going on and off randomly with the period following a poisson process
- The uplink (from client to service provider) and downlink (from service provider to client) delay are modeled by a poisson distribution, the mean of which is proportional to the number of hops between the communication pair;

The communication cost and the service awareness delay for a new-coming node to be aware of the service in the network are the performance metrics. The communication cost is the sum of transmissions used for service advertisements, and the advertisement delay is the period from the moment a node joins the network until it receives a service advertisement. And this delay is modeled by a poisson distribution with mean proportional to the number of hops between the communication pair.

Following this simulation model, we implemented four protocols:
- Event-driven Unicast (Unicast): the service provider unicasts a service advertisement to all new-coming nodes immediately after it is notified about the presence of a new-coming node;
- Adaptive Broadcast (Broadcast): the service provider schedules a service advertisement upon the reception of new node notification if there is no service advertisement scheduled, the service advertisement is broadcasted to all active nodes in the network;
- Adaptive Broadcast/Unicast (Adaptive): this is similar to the 'broadcast' approach except that the service provider compares the communication cost of unicast and broadcast before a scheduled service advertisement is sent, and chooses the approach with less communication cost.
- Periodic Broadcast (Periodic): with this approach, the service provider broadcasts a service advertisement periodically.

B. Simulation results and discussions

In the first set of simulation, the impact of scheduling interval is investigated. Figure 4 and 5 present the delay and communication cost of all protocols with varying hold-off time in networks of 30 nodes. As expected the 'Unicast' approach achieves constant performance. With all other three approaches, a node experiences increasing service awareness delay with the increase of scheduling interval. However, the
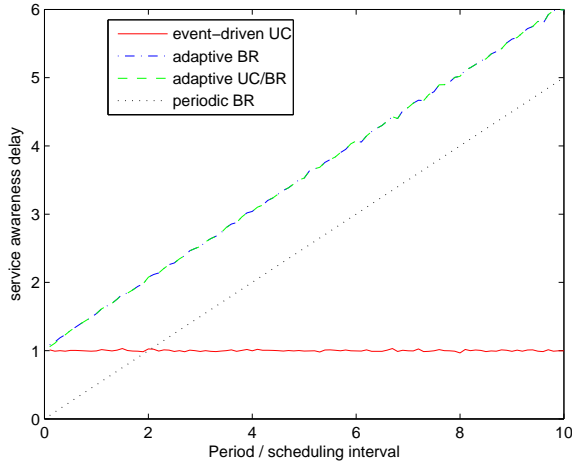
Fig. 4. service awareness delay in the following scenario: maximum 30 nodes in the network, average delay per hop is 1 second; hold-off time varying from 0 to 10 seconds, average on/off period is 10 seconds
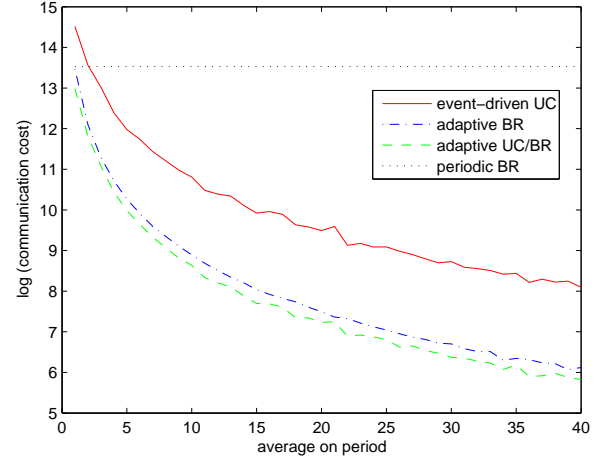

Fig. 7. Communication cost in the following scenario: maximum 30 nodes in the network, average delay per hop is 1 second; hold-off time is 2 seconds, average on/off period varies from 1 to 20 seconds
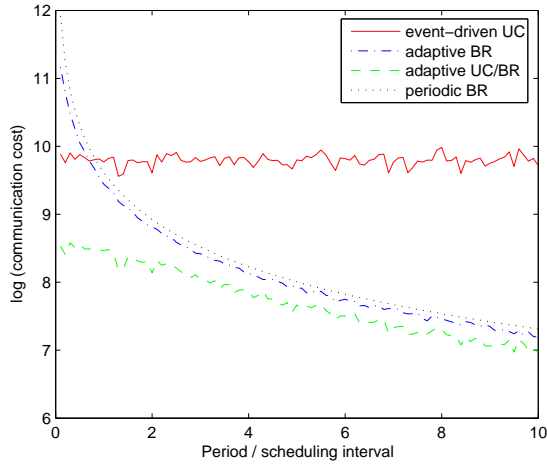

Fig. 5. Communication cost in the following scenario: maximum 30 nodes in the network, average delay per hop is 1 second; hold-off time varying from 0 to 10 seconds, average on/off period is 10 seconds
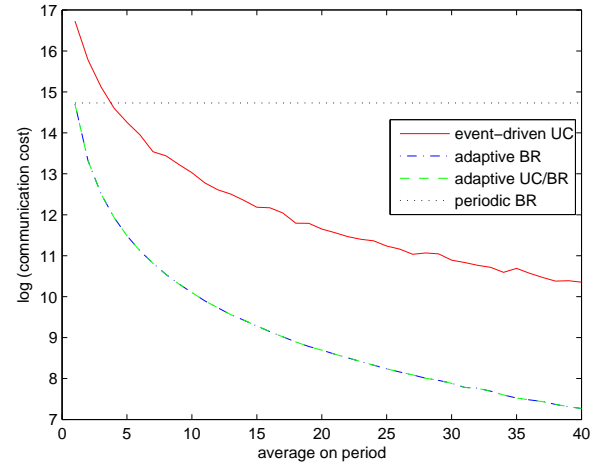

Fig. 8. Communication cost in the following scenario: maximum 100 nodes in the network, average delay per hop is 1 second; hold-off time is 2 seconds, average on/off period varies from 1 to 20 seconds
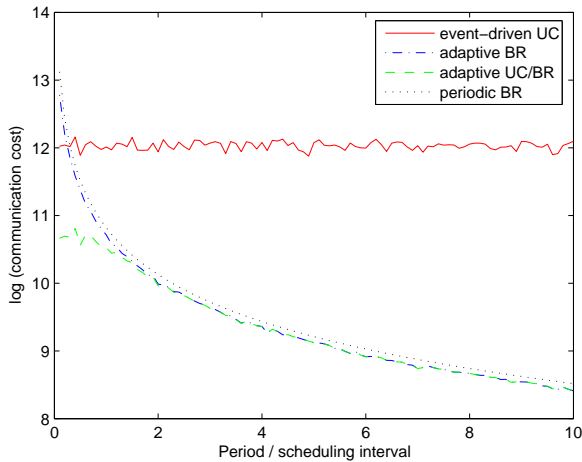

Fig. 6. Communication cost in the following scenario: maximum 100 nodes in the network, average delay per hop is 1 second; hold-off time varying from 0 to 10 seconds, average on/off period is 10 seconds

'Periodic' approach achieves shorter delay due to event-driven nature of the 'Broadcast' and 'Adaptive'. As the service awareness delay performance are straightforward due to our rather simple delay model, in the discussion follows, we focus on the communication cost. As for the communication cost, the 'Unicast' approach generates constant amount of service advertisement traffic; the 'Adaptive' approach generates the smallest amount of traffic compared to any of the others; the 'Broadcast' approach generates marginally smaller amount of communication cost than the 'Periodic' approach.

Figure 6 present the simulation results with varying scheduling interval in networks of 100 nodes. Compared to the case of 30 nodes, the gain achieved by the 'Adaptive' approach over the 'Broadcast' and 'Periodic' becomes smaller.

The impact of average scheduling interval is investigated in the second set of simulation. Figure 7 and 8 present the communication cost with varying average on/off period for a network with 30 and 100 nodes. In the case of 30 nodes, the

communication cost by the 'Adaptive', 'Unicast', and 'Broadcast' approach decreases with the increase of average on/off period, while the 'Periodic' approach generates constant communication cost. The 'Unicast' approach generates much higher communication cost while the 'Adaptive' approach achieves the lowest traffic load. When the number of nodes increases to 100, the communication cost gain introduced by the 'Adaptive' approach over the 'Broadcast' approach becomes very small, which is not even visible in the log-scale. This can be explained by the fact that with the increase of number of nodes, the number of new-coming nodes during a scheduling interval becomes larger, and consequently the chance that broadcast is preferable compared to unicast becomes larger, which leads to the similar communication cost generated by these two approaches.

To summarize, the 'Unicast' approach achieves short delay, but much higher service advertisement traffic; the 'Broadcast' approach achieves marginally lower communication and longer service awareness delay than the 'Periodic' approach; the 'Adaptive' approach always performs better than the 'Broadcast' approach (similar delay and less service advertisement traffic); with the increase of network size, the gain introduced by the 'Adaptive' approach becomes smaller. From the service provider poitn of view, the 'Adaptive' approach should be chosen if the allowed delay is higher than roughly two times of the delay experienced by a packet from the service provider to the customer; the scheduling interval should be then chosen to satisfy the allowed delay. While, if the requirement on the delay is very tight in the current network situation, the 'Unicast' approach should be chosen to satisfy the delay requirement better.

V. CONCLUSION

In this paper, we propose a system architecture and protocols for cooperation of proactive service discovery protocols and proactive routing protocols. The proposed approach utilize the routing information provided by the proactive routing protocol to optimize the service advertising procedure. The simulation results show the superiority of the proposed protocol. However, the simulation model is rather simple in this paper. A more detailed simulation model, i.e., introducing a real dynamic network model, a real unicast and broadcast protocol could bring more accurate performance evaluation.

ACKNOWLEDGEMENT

REFERENCES

[1] MICHEL BARBEAU, "Service Discovery Protocols for Ad Hoc Networking," *CASCON 2000 Workshop on ad hoc communications, 2000*
[2] ULAS C. KOZAT, LEANDROS TASSIULAS, "Network Layer Support for Service Dsicovery in Mobile Ad Hoc Networks," *IEEE INFOCOM 2003*
[3] S-J. Lee, W. Su, and M. Gerla, On-Demand Multicast Routing Protocol (ODMRP) for Ad Hoc Networks, Internet Draft, draft-ietf-manetodmrp-02.txt, Jan. 2000.
[4] David B. Johnson et al., The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks, Internet Draft, draft-ietf-manet-dsr-05.txt, March 2001.
[5] C.E. Perkins, E.M. Royer, and S.R. Das, Ad Hoc On-Demand Distance Vector (AODV) Routing, Internet Draft, draft-ietf-manet-aodv-05.txt, 2000.
[6] CHARLES E. PERKINS AND PRAVIN BHAGWAT. Highly dynamic Destination- Sequenced Distance-Vector routing (DSDV) for mobile computers. SIGCOMM 94 Conference on Communications Architectures, Protocols and Applications.
[7] T. Clausen, P. Jacquet, Optimized Link State Routing Protocol (OLSR). *RFC 3626*.
[8] Chang-Seok Oh, Young-Bae Ko, Yong-Sung Roh,"An integrated approach for efficient routing and service discovery in mobile ad hoc networks," CCNC. 2005, 3-6 Jan. 2005 Page(s):184 - 189
[9] Paal E. Engelstad et al, Name Resolution in on-demand MANETS and over external IP Networks IETF Internet Draft, draft-engelstad-manet-name-resolution-01.txt, Jan 2004
[10] Rajeev Koodli and Charles Perkins, Service Discovery in On-Demand Ad Hoc Networks, draft-koodli-manet-servicediscovery- 00.txt, IETF Internet Draft, 2003
[11] Liang Cheng, Service Advertisement and Discovery in Mobile Ad Hoc Networks, Workshop on Ad hoc Communications and Collaboration in Ubiquitous Computing Environments, in conjunction with the ACM 2002 Conference on Computer Supported Cooperative Work, New Orleans, Louisiana, USA, November 16-20, 2002.