Minema Thematic Workshop on Service Description and Discovery in MANETs

September 19th – 21st, 2006
Infolab21, Lancaster University

-- Scientific Report --

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1. Introduction

Service discovery is a fundamental aspect of dynamic, distributed systems. Software services advertise their capabilities using service descriptions, in order for them to be automatically found and interacted with. Furthermore, service discovery is vital for mobile applications, where users frequently move to locations where they have no pre-existing knowledge of the available services. Currently, well-established discovery protocols are available for use in fixed, infrastructure networks e.g. Universal Plug and Play (UPnP), Service Location Protocol (SLP), Jini, and UDDI. However, the increasing deployment of wireless hotspots and utilisation of wireless ad-hoc networks have increased the need for new service discovery protocols technologies. Mobile Ad-hoc Networks (MANETs) are typically characterised by: i) no network infrastructure, ii) dynamic and unpredictable behaviour of network nodes, iii) devices with constrained resources, and iv) limited network bandwidth; therefore new protocols that can overcome these limitations are required.

A number of research groups across Europe are investigating service discovery technologies for MANETs. This is a broad area of research and the specific topics include: network-level routing protocols, middleware architectures, and semantic description and reasoning technologies. However, these topics are inherently related, and we believe this work can be strengthened by ensuring researchers can gain knowledge about other aspects of service discovery, and can collaborate directly with other researchers in this field. Therefore, the key aim of this Minema-funded workshop was to bring together PhD students, and researchers to foster increased collaboration on the topic of service discovery and description in mobile, ad-hoc networks.

The workshop itself was hosted in Infolab21 at Lancaster University from the 19th to 21st September 2006. Nine participants attended from Lancaster University, ETH Zurich,

University of Neuchatel, INRIA Paris, University of Rome, Trinity College Dublin, and University College London. The workshop consisted of 7 research presentations each followed by lively discussions, and a full day was then committed to open discussions about service discovery research and the potential collaborations that could be made between the participants. The key themes that emerged from the workshop were:

- *Discovery protocols at the network layer*. Network–level routing specifically targeted at supporting discovery can increase the efficiency of resource usage by hosts in a MANET.
- *Overlay networks for application specific discovery protocols*. Overlay networks can be layered on top of existing MANETs to add services that are not currently available e.g. resource discovery routing, semantic lookup, etc.
- *Semantic service discovery*. Standard service type lookup is limited; semantic service discovery technologies can better match services that previous technologies do not consider a match.
- *Dynamic Adaptation*. MANETs are dynamic environments therefore systems and protocols must typically adapt to deal with fluctuating operating conditions.
- *Trust*. Trust must be built between users and services in ad-hoc networks; service discovery protocols can then use this trust information to find the best service to fulfil the application's requirements.

These key themes were prominent throughout the workshop, and were notably used for identifying connection points between researchers that fuelled further plans for collaboration. This scientific report documents the outcome of these discussions. On a final note, the organisers of the workshop are confident the results will continue to benefit the community. Initial research collaborations have been planned, and a special interest group into the field of service discovery for MANETs has been initiated.

2. Participants

This section briefly describes the nine participants to the workshop, and describes the content of the seven research presentations:

2.1 Gordon Blair, Lancaster University (Local Host)

Gordon Blair currently holds a chair in distributed systems at Lancaster University. He is also an Adjunct Professor at Tromsø University and a Visiting Researcher at the Simula Research Laboratory (both in Norway). He is Chair of the Steering Committee for the ACM/ IFIP/ Usenix Middleware conference and has been on the programme committes of many conferences in his field. He has published over 200 papers over a 20 year period. His current research interests include distributed systems architectures, reflective and adaptive middleware, middleware for embedded systems and autonomic computing.

2.2 Paul Grace, Lancaster University (Local Organiser)

Paul Grace is a post-doctoral researcher at Lancaster. His research interests are in the field of middleware, systems software, and component technologies. His Ph.D. covered the topic of middleware and protocol heterogeneity, and in particular the problem of service discovery protocol heterogeneity whereby many services are advertised by different protocols, and how these services are to be found by clients.

2.3 Carlos Flores Cortes, Lancaster University (Local Organiser)

Presentation - "A multi-protocol framework for service discovery in ad-hoc networks"

Carlos Flores Cortes is a Ph.D. student at Lancaster University. His research interests are MANETS, and in particular service discovery middleware for these networks. Carlos presented a talk that described a middleware-level multi-protocol component framework that allows applications to discover and advertise services using one or more protocols that are active in the MANET. The heterogeneity problem has emerged due to the many MANET

discovery protocols that are now available, e.g. ALLIA, GSD, etc and the dynamic nature of MANET interactions. Carlos' approach is a component framework that decomposes each discovery protocol into six component elements i.e. each protocol has a request, response, network, advertise, cache and policy component. These components can then be re-used across multiple protocol types to optimise resource usage to allow hosts to participate in multiple ad-hoc discovery protocols e.g. five protocols share the cache and policy component. Additionally, the common pattern supports efficient configuration and dynamic reconfiguration of protocols at run-time; in his talk, Carlos showed how when new protocols had been detected it was easy to apply common reconfiguration algorithms to change the behaviour at run-time.

2.4 Sonia Ben Mohktar, INRIA-Rocquencourt

Presentation – "Efficient Semantic Service Discovery in Pervasive Computing Environments"

Sonia Ben Mohktar is a PH.D. students at INRIA Rocquencourt in Paris. Her research interests are in semantic technologies such as semantic web-services, and semantic service discovery in pervasive environments. Sonia presented a talk that described an approach for semantically describing services in diverse environments in an efficient manner. She identified that common syntactic standard approaches that are use to match services requirements, are insufficient in dynamic environments. Dynamic services that are discovered by the mobile device may be semantically close to providing the requirements however the syntactic description is far apart. Sonia talked about how the approaches of Semantic Web technologies, in particular ontologies, can be unambiguously and automatically interpreted in open pervasive computing environments, where agreement on a single common syntactic standard for identifying service semantics cannot be assumed. However, Sonia also identified that the efficient matching of semantic Web services to effectively automate the discovery and further consumption of networked resources remains an open issue, mainly due to the costly underlying semantic reasoning. In the remainder of her talk, Sonia, proposed an efficient matching solution for semantic Web services, and demonstrated how it had been integrated into a service discovery protocol for open pervasive computing environments.

2.5 Raphaël Kummer, University of Neuchâtel

Presentation – "Efficient Lookup for MANETS"

Raphael Kummer is Ph.D. student at the University of Neuchâtel. His research is focused on infrastructures for information lookup and distribution in mobile ad-hoc networks (MANETS). During the workshop, Raphael presented a talk headed "Efficient lookup for MANETS". He studied the problem of applying distributed hash tables to mobile ad-hoc networks. The proposed approach builds a minimalist logical overlay structure. Nodes are organized in a logical ring like in Chord or Pastry, but it does not use logical long-range neighbors. Indeed, the maintenance cost of those links in mobile ad-hoc networks could be prohibitive. The algorithm relies on the physical neighborhood of traversed node to quickly converge toward the destination in the logical overlay. Furthermore, Raphael presented improvements of the basic solution that: considered an extra level of visibility in the physical neighborhood (neighbors of neighbors), and maintained a history of past requests to exploit possible logical shortcuts. The algorithm has been tested by the means of simulation. To conclude, the results demonstrated that the approach is efficient and scales well to a large population of nodes.

2.6 Vincent Lenders, Swiss Federal Institute of Technology

Presentation – "Service Discovery in Mobile Ad Hoc Networks: A Field-theoretic Approach"

Vincent Lenders is a Ph.D. student at ETH Zurich. His research interests are wireless and mobile networks and in particular service discovery protocols for these networks. Vincent Lenders presented a talk that described a new service discovery protocol for ad hoc networks. Service discovery in mobile ad hoc networks is challenging because of the absence of any central intelligence in the network. Traditional solutions as used in the Internet are hence not well suited for mobile ad hoc networks.

In this talk, Vincent Lenders presented a novel decentralized service discovery mechanism for ad hoc networks. The basic idea is to distribute information about available services to the network neighborhood. We achieve this by using the analogy of an electrostatic field: A service is modelled by a (positive) point charge, and service request packets are seen as (negative) test charges which are attracted by the service instances. In our approach, we map the physical model to a mobile ad hoc network in a way where each network element calculates a potential value and routes service requests towards the neighbour with the highest potential, hence towards a service instance. Our approach allows for differentiation of service instances based on their capacity. We define the required protocols and methods, which we implemented in a network simulator. Using extensive simulations, we evaluate the performance and robustness of the mechanisms. The results indicate good performance and convergence even in highly mobile environments. We believe that this technique can and should be further exploited, e.g., as a routing protocol in mobile ad hoc networks.

2.7 Adnan Noor Mian, University of Rome

Presentation – "Service Discovery in Mobile Ad hoc Networks - A brief Survey"

Adnan Noor Mian is a PhD student from University of Rome, "La Sapienza", Rome, Italy. His research interest includes the problems of service discovery and searching in structured and unstructured p2p networks and in Mobile Ad hoc Networks (MANETs). He presented a brief overview of the state of the art in the Service Discovery Protocols (SDPs) in multihop MANETs. First he highlighted the difference of his survey work with the already existing surveys. Basically, he said that, one could categorize three types of networks as far as the research in service discovery is concerned. First are the wired networks, second are single hop wireless networks and third are the multihop wireless mobile ad hoc networks. The SDPs suggested for one type of network are not suitable for another type of network because each network is based on different assumptions, the most important being the mobility and rate of joining and leaving of devices from the network. In the first type devices do not move at all and there is no join/leave at all or the join and leaves are few and far between. In the second type the network formed is ad hoc with very restricted mobility and having low rate of join/leave. There are one or more nodes that are fixed. But in the third type of network the devices are assumed to have unrestricted mobility and these can join or leave the system at any rate. There may be no fixed node. Due to these assumptions the problem of service discovery is very challenging in the third type of networks. There are some good surveys of the service discovery protocols that also include SDPs for MANETs but these surveys survey the SDPs for all of the three types of networks and none of the survey go deep into surveying SDPs for only the multihop mobile ad hoc networks. His focus is on SDPs for multihop MANETs only.

Adnan identified six different aspects of a SDP and then compared twelve SDPs with respect to these aspects. These aspects are the service discovery architectures, management of service information, search methods, service selection methodologies, mobility support mechanisms and service description. Regarding the service discovery architectures, Adnan gave a new categorization, which has four groups, namely directory-based with overlay support architecture, directory-based without overlay support architecture, directory-less with overlay support architecture and directory-less without overlay support architecture. He explained that the management of service information and search methods mainly depend on the type of service discovery architecture. He then explained the differences in mobility

support and service selection mechanisms in different SDPs. Interestingly the mobility support and service selection methods are independent of the SDP architecture. Similarly the description of services, mostly being described using XML or the extensions of XML, is independent of the SDP architectures. At the end of the talk Adnan presented his ongoing research work in the field of random walk based service discovery in MANETs. In this work he gave the justification for using biased random walk in MANETs. He also presented a generic random walk based protocol, which used velocity of MANET nodes to calculate the hints.

2.8 Androkinos Nedos, Trinity College Dublin

Presentation – "Scalable Discovery of Autonomous Semantic Service in MANETs"

Andronikos Nedos is finishing his Ph.D in the Distributed Systems Group in Trinity College Dublin. His research interests include mobility, semantic services, scalable overlay topologies, gossip protocols and stochastic modelling. Andronikos presented a talk centered around the concept of discovering services that are developed without a priori agreement on a common ontology. A brief state of the art was presented illustrating a gap in the current literature for semantic discovery protocols that operate without implicit assumptions of semantic agreement. A solution in the form of a concept-based gossip protocol was subsequently presented. The protocol facilitates distributed semantic agreement by running a lightweight ontology matching algorithm in each node, while providing probabilistically-bound service discovery through a simple random walk protocol. The protocol randomly replicates concepts at random nodes allowing progressive semantic agreement and unicast-based discovery.

2.9 Liam McNamara, UCL

Presentation – "Mobility and Trust aware Service Provision in Pervasive Computing"

Liam McNamara is a Ph.D. student at University College London. His research interests are in mobile computing, trust management, service discovery and models of mobility. In his talk, Liam talked about a number of interesting dimensions that can be considered important to the realm of service discovery; first he discussed how trust can better support informed and intelligent selection of service, particularly when unreliable or malicious nodes form part of the ad-hoc network. He presented a distributed trust algorithm for allowing ad-hoc nodes to determine the trust-worthiness of service providers and hence, discover only trustworthy services. Secondly, he looked at how mobility models, predicted movements and current context also impacts on service selection in a MANET. That is, a host being aware of its own movement, and the movement of nodes surrounding it, can make improved decisions on which providers to use; selecting providers moving in the same direction will promote service completion and longer lasting relationships. Liam presented example mobility traces that demonstrate this behaviour. Liam also identified that the dissemination of service requests and offers can also benefit from knowledge of the local topology and the existence of node clustering.

3. Open Issues

The current research conducted by the participants of the workshop did not directly address a number of aspects of service discovery. Therefore, one session of the workshop consisted of an open discussion between all participants to identify topics that have yet to be researched, or are being researched by other research groups not represented at the workshop. We briefly describe these in turn.

3.1. Richer Service Descriptions

Service discovery protocols for MANETS typically advertise remote procedure style services. That, is the service interface consists of a set of methods/operations that can be called by the

client. However, alternative interface styles are also important e.g. event-based service interfaces, and streaming services. Therefore, existing service description approaches must be extended to provide more than simple service type and attribute lookup, but also match the style of interface with the type being searched for.

3.2. Integration with Service Composition

Service Oriented Architectures in the fixed domain, particularly in the Web community present techniques to compose applications into a choreography of services i.e. an application cannot typically be satisfied by a single service rather by the combination of a set of services, and "workflow" style interactions between them. A number of languages and technologies e.g. BPEL, WS-Choroeography, etc. have already been defined; however, the problem of discovery and composition in ad-hoc networks is a more challenging problem due to the constraints of mobility and dynamic availability.

3.3 Evaluation Methodologies

Like any new field of research, the accepted approaches to evaluate service discovery protocols have yet to emerge. What are the standard traces and mobility models that can be used to evaluate one service discovery protocol from another?

3.4 Quality of Ontologies

How can we measure and ensure that the quality of particular ontologies is accurate? That is we must research into ensuring that the level of service provided by a particular semantic approach (ontology and reasoning) must accurately reflect the service environment. Services should reasonably expect their request to be agreed if it is there, not that the semantic discovery technology cannot deal/understand the request.

3.5 Microformats

Microformats are lightweight, typically domain specific formats for data. In the Web community, these are beginning to be used as a method to describe and discover services. Given the inherent performance benefits of lightweight descriptions, is it possible to utilise micro-format descriptions in ad-hoc discovery protocols?

3.6 Secure Service Discovery

Many application types will require secure service discovery in MANETS e.g. military applications. Services must be private to allow only authentic users to find out about what services are available. There is some work on secure discovery protocols in the fixed domain; however, as far as we are aware no ad-hoc protocol considers the security dimension.

3.7 Context-Awareness

Context awareness is an important feature of mobile applications, which must be aware of their context to improve functionality. Service discovery benefits from context information; for example, finding services that are local to the user, etc. Context-aware service discovery protocols, and toolkits for context information retrieval have already been researched and developed. How do these protocols relate to the MANET domain, and how can these technologies be integrated into MANET based middleware systems?

3.8 Hybrid networks

MANETs are typically considered to be mobile devices that perform communication using wireless ad-hoc network technologies. However, future hybrid networks that consist of fixed networks (the Internet), wireless hotspots, and MANETS that are connected through a variety of gateways are beginning to emerge. The participants identified that these networks offer

potential new challenges to service discovery, and there will be a stronger reliance on overlay networks to advertise and discover services in these diverse environments.

4. Collaboration

A significant section of the workshop involved open discussions between individuals on how they could collaborate in the future. This largely involved splitting the participants into smaller groups based upon the identification of connection points. These connection points were related to the key themes presented in the introduction i.e. researchers in one theme would talk to people in their own theme and then with people in each of the other themes. The outcome of these discussions is the list of potential collaborations that are described as follows.

4.1 INRIA (David Bromberg, Sonia Ben Mohktar, Valerie Issarny) and Lancaster (Carlos Cortes, Paul Grace, Gordon Blair)

Although not all relevant parties attended the workshop, it was identified that the research groups at Lancaster and INRIA are working on related systems with a common goal; that of resolving the problem of service discovery protocol heterogeneity. It was identified at the workshop that the two groups' approaches may be highly complimentary, and can be deployed simultaneously in the environment to produce a more complete solution.

In addition, Lancaster and INRIA are also working on service discovery across hybrid networks, and the increased heterogeneity that this produces i.e. the change from one protocol to another in different domains. Furthermore, the semantic approaches developed by Sonia can be integrated atop all these middleware approaches (and initial work solely at INRIA has produced initial promising results). Therefore, we believe that further collaboration between the two groups on these topics can be of benefit to both parties, and potentially produce a new approach to tackling the problem of service discovery protocol heterogeneity.

The initial collaboration plan is for a Minema funded short exchange visit between the two groups hosted at INRIA Paris; with one or two members of the Lancaster team visiting for a short period in October/November 2006.

4.2 Neuchatel (Raphael Kummer) and Lancaster (Paul Grace)

Raphael has developed a distributed hash table (DHT) resource lookup protocol for ad-hoc networks. Current middleware research at Lancaster, being carried out by Paul Grace, has produced higher-level middleware services (e.g. tuple-spaces, group communication, etc.) that are layered atop rich overlay networks such as tree multicast and DHTs (Pastry, Chord). Therefore, an initial coloration between the two groups will investigate how these higher layered services can be developed in the ad-hoc domain by simply replacing a fixed network DHT (such as Chord) with an ad-hoc DHT. What are the software architecture issues here? Furthermore, there is potential here to investigate dynamic reconfiguration; when a node moves from a fixed network to an ad-hoc network it may need to change its DHT implementation. Therefore, further investigation into how the networks are migrated from one to the other is required.

Both parties should benefit from this collaboration. Lancaster can validate its middleware with new requirements from the ad-hoc domain, plus it opens further questions about dynamic reconfiguration for them. Neuchatel can discover how well the approach benefits higher-level middleware services.

The initial collaboration plan is to perform separate work at both sites investigating the others approaches, and identifying how they can be placed together. This could potentially lead to a co-authored paper. Lancaster is also investigating whether an MSc. Student project can be undertaked to develop the algorithm using dynamically replaceable software components.

4.3 INRIA (Sonia Ben Mohktar) and TCD (Andronikos Nedos)

The work being conducted in TCD and INRIA are highly complementary. Both institutes are concerned with the utilisation of ontologies and specifically semantic services in small, low-powered devices. Andronikos' interests are moe focused on topologies that support the scalable discovery of semantic services, with a secondary interest in the performance of reasoners in small devices. This latter issue is important for the uptake of semantic services and is part of the domain that Sonia is actively involved in. During a short workshop session, a number of projects that are of common interest were discussed. They include the porting of the FaCT++ C++ reasoner in an ipaq-style device and the characterisation of perfomance in such a setting. Second, the incorporation of the subsumption optimisations undertaken in INRIA in FaCT++. Both of these projects will benefit two communities; the ad hoc community by providing a reasoner for low-powered devices and the semantic community by expanding the use of an available reasoner.

4.4 University College London and University of Rome, La Sapienza (Liam McNamara and Adnan Noor Mian)

Liam is working on efficient service selection mechanisms and trust among the clients and service providers getting advantage of the mobility patterns of nodes in MANETs. The existing approaches simply select services based on theirs names, etc. while not taking into account the proximity and QoS. Liam is trying to exploit some of the regularities in node mobility patterns found after having observed these in different cases.

Adnan is working on service searching mechanisms based on probabilistic methods. His recent work, which he also presented, is service discovery mechanism based on random walk that has been biased with a hint. The hint is calculated using the velocity information of nodes. But at the moment his work is not concerned with the service selection mechanisms.

For a service discovery protocol both of the aspects, the searching as well as the service selection, are important. Thus the possibility of collaboration and integration of Adnan’s and Liam's work was discussed. Adnan can benefit from the research work done by Liam on the service selection mechanism and also from the findings of the mobility patterns to improve the searching and Liam can take advantage of the service discovery mechanism developed by Adnan. Initially it was decided that Adnan and Liam would study each other’s work and then at a certain point start collaboration for a co-authored paper.

4.5 ETH Zurich (Vincent Lenders) and Inria (Sonia Ben Mohktar)

ETH Zurich developed a routing integrated service discovery protocol for ad hoc networks. Inria has a efficient mechanism to express services and match queries. We identified a possible collaboration. The goal would be to combine a rich semantic service discription mechansim as proposed by Inria with the protocol from ETH Zurich.

Initial collaboration plans is for a joint paper about this issue.

4.6 INRIA (Sonia Ben Mohktar), UCL (Liam McNamara) and Neuchâtel (Raphael Kummer)

The main idea for a future collaboration is the integration of a directory into the UCL service discovery infrastructure. The directory would be supported by the Mobile ad-hoc DHT approach of Neuchâtel. There are two main challenges here. The first is the integration of the DHT concept as a directory in the Liam’s service discovery solution. The second is in developing a new extensible DHT key model which integrates the concept of ontology (from INRIA) and keeps the semantic information.

We identify a first possible collaboration is to integrate the DHT as a directory in the UCL approach, then a second is to transform the service descriptions of the system into an extensible DHT key system, using a newly defined semantic hashing approach. This subject is interesting but challenging given our available resources. We decided, firstly, to work offline

in order to identify what has been done in the different areas bound to this approach, and to then have further discussions afterwards. We didn't consider this subject as a main priority but it could lead to some papers and we are convinced that it should be explored.

5. Summary

This thematic workshop brought together researchers in the field of service discovery and ad-hoc networks to allow them to discuss their work with related researchers from across this workshop. The key successes of the workshop were as follows: the researchers involved have increased their knowledge of related fields of research; several collaboration plans between individual researchers and groups have been created; and a small research network in the topic area has been initiated to ensure that the results of this workshop are actively followed up.

6. Acknowledgements

The organisers and participants of the workshop would like to acknowledge Minema and the ESF for both funding and helping to organise the workshop.