# Report of visit to Dr. Boris Koldehofe, University of Stuttgart*

Hugo Miranda

University of Lisbon

September 7–13, 2008

## 1 Introduction

In the scope of the Short Visit Grants Programme of the Middleware for Mobile and Networks Eccentric Applications (MiNEMA) programme of the European Science Foundation (ESF), the author visited Dr. Boris Koldehofe at the University of Stuttgart during the week of September 7–13, 2008. During the visit, the author had many interesting and fruitful discussions with Dr. Boris Koldehofe and made an invited talk. The discussions focused on the problems faced by publish/subscribe algorithms for mobile networks. As a result, a number of different and original approaches emerged. Plans are to continue the collaboration with the evaluation, revision and possible publication of these algorithms. This report overviews the topics that have been addressed during the visit, addresses its results and outlines the plans for the continuation of this cooperation.

## 2 Motivation

### 2.1 Mobile Ad Hoc Networks

Mobile Ad Hoc Networks (MANETs) are infrastructure-less, fully decentralised networks. The absense of a supporting infrastructure makes the application development particularly challenging, given that one can not rely on some reliable and resourceful server. Therefore, services like reliable data storage, unique addressing or even packet routing must be provided by the participants. To centralise any of these services in a single participant is also undesirable, given that one can not predict when the device will be disconnected or moved out of the transmission range of the remaining. Redundancy is therefore fundamental for the provision of reliable services as the probability of the simultaneous disconnection of multiple nodes is lower. However, in the design of distributed services for MANETs, one must also take into account the limited energy available at the devices. Elsewhere [3], it was shown that the wireless network interface

---

accounts for a significant proportion of the energy expenditure of mobile devices. In the scope of our work, this means that a good replication protocol for MANETs should send as few messages as possible.

## 2.2 Data Replication in Mobile Ad Hoc Networks

In many distributed application nodes communicate using a decoupled model. In this model, nodes can play either the roles of producers or consumers of information or even both. Data is stored by producers in a repository. Consumers access the repository to retrieve the data. In the scope of MANETs, interesting examples of this kind of applications are virtual flea markets (possibly in conjunction with physical ones), VoIP applications (using the repository to make the SIP records available to the interested parties) or resource location (where the repository would store SLP records).

To achieve their goals, repositories in MANETs must be distributed (to attend to the limited resources of the devices) and replicated (thus mitigating the problems of devices low reliability). However, implementing a suitable replication algorithm for MANETs is challenging. On one hand, one must consider the limited resources of the devices, which claim for a moderate number of replicas. On the other, the device's unpredictable movement and disconnection suggest that data should be replicated as much as possible. Finaly, to attend to environmental factors like localised interference, replicas should be geographically distributed.

PCACHE [5] is a data replication middleware specifically designed to address the problems posed by MANETs. PCACHE replicates data items, distributing them by participants that are geographically distant. An interesting aspect of PCACHE is that it does not require devices to be aware of their location, thus making it suitable for a broad number of applications and networks.

## 2.3 Publish/Subscribe Systems

Publish/subscribe (pub/sub) systems are characterised by their scalability and strong decoupling between producers and consumers of information. These properties make of pub/sub an interesting paradigm for many types of applications, including those typically associated to MANETs. For example, in a search-and-rescue operation, different teams like firefighters, rescue personal or doctors are required to attend to different situations. A pub/sub system can help to alleviate the overflow of information by addressing each request to the adequate personnel.

Two particular problems that must be handled by pub/sub systems are: *i*) the expressiveness of the subscription information, so that matches between publications and subscriptions can be correctly identified and *ii*) the selection of the most adequate location for storing subscription information so that it can be efficiently matched with publications.

The evaluation of pub/sub systems usually focus on latency and in the number of messages exchanged, given that these are the dominant factors on wired networks. Aspects like power-consumption (reflected by the number of messages sent by each participant), memory consumption or number of hops between source and destination of the messages are usually neglected. For this reason, publish/subscribe systems developed for wired networks can not be directly

applied in wireless networks without observing a degradation of the device's lifetime.

The majority of the proposals of pub/sub systems for wireless networks are extensions to systems initially developed for wired networks (see, for example [2, 4]). Others (e.g. [1]) try to benefit from the particularities of some networking topologies, like mesh networks, to define a structure that facilitates the location of the subscribers.

# 3   Work Carried During the Visit

The first day of the visit was used to present the fields of interest of both researchers and their more recent results. The goal was to refine the connection points that have been identified prior to the visit, establishing common ground for the development of the work. Topics addressed included publish/subscribe systems (in general and in the scope of mobile networks) and data dissemination in MANETs.

The problem of publish/subscribe systems in MANETs was rapidly identified as a good joint research opportunity. The following days consisted in brainstorming sessions aimed at devising event routing algorithms that could fit well into the MANETs networking model. In particular, we investigated the possibility of using the PCACHE dissemination model for storing subscriptions.

In complement, the author made an invited talk with the title "A Framework for Data Dissemination in Mobile Ad Hoc Networks", attended by PhD students and researchers of the IPVS.

## 3.1   Outcomes

Results of this visit can be broadly cathegorized in two categories: preliminary specification of routing algorithms for pub/sub in MANETs and dissemination of the research work performed at the University of Lisbon and at the University of Stuttgart.

Preliminary specification of four algorithms for event routing in MANETs where devised. These algorithms have in common the particularity of assuming that nodes are unaware of their location. Additionally, another algorithm was devised for location-aware MANETs, i.e. networks where all nodes are capable of determining, with a reasonable accuracy, their location (for example using a GPS device).

The descriptions and specifications of the algorithms for event routing in location-unaware MANETs have been compiled in an internal document which will now circulate for discussion and evaluation by researchers of both universities. Hopefully, the document will serve as the basis for a future paper, to be submitted to a relevant international conference.

In addition, the author had the opportunity to learn and discuss about the research carried at IPVS in the scope of the NEXUS international project.

# 4   Continuation of the Work

As expected, the visit served mostly to trigger cooperation in aspects where the research of both participants is complementary. At the end of the visit,

it was decided to involve PhD students of both Universities in the project. In the following months, a selection of the algorithms will be revised and their performance evaluated using a network simulator.

Preliminary results, mostly detailing the results achieved during the visit have already been accepted for publication as a position paper [6].

# References

[1] Jorge A. Briones, Boris Koldehofe, and Kurt Rothermel. SPINE: Publish/Subscribe for wireless mesh networks through self-managed intersecting paths. In *Proceedings of the 8th IEEE International Conference on Innovative Internet Community Systems (I2CS 2008)*, Schoelcher, Martinique, June 16–18 2008. IEEE Computer Society.

[2] M. Caporuscio, A. Carzaniga, and A. Wolf. Design and evaluation of a support service for mobile, wireless publish/subscribe applications. *IEEE Transactions on Software Engineering*, 29(12):1059–1071, December 2003.

[3] Laura Marie Feeney and Martin Nilsson. Investigating the energy consumption of a wireless network interface in an ad hoc networking environment. In *Proceedings of the Twentieth Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM 2001)*, volume 3, pages 1548–1557, Anchorage, AK USA, April 22–26 2001. IEEE.

[4] L. Fiege, F. Gärtner, O. Kasten, and A. Zeidler. Supporting mobility in content-based publish/subscribe middleware. In *Proceedings of the 4th ACM/IFIP/USENIX International Middle ware Conference (Middleware 2003)*, pages 103–122, 2003.

[5] Hugo Miranda, Simone Leggio, Luís Rodrigues, and Kimmo Raatikainen. An algorithm for dissemination and retrieval of information in wireless ad hoc networks. In Anne-Marie Kermarrec, Luc Bougé, and Thierry Priol, editors, *Proceedings of the 13th International Euro-Par Conference, Euro-Par 2007*, volume 4641 of *Lecture Notes in Computer Science*, pages 891–900, Rennes, France, August 28–31 2007. Springer.

[6] José Mocito, J. Alfonso Briones-García, Boris Koldehofe, Hugo Miranda, and Luís Rodrigues. Geographical distribution of subscriptions for content-based publish/subscribe in manets. In *Proceedings of the ACM/IFIP/USENIX 9th International Middleware Conference - Poster Session*, page (to appear), Leuven, Belgium, December 1–5 2008.