Scientific Report for Exchange Visit to Trinity College Dublin

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Introduction

This document is a scientific report about my visit to the Distributed Systems Group (DSG) at Trinity College Dublin from September 1, 2004 to February 1, 2005. The purpose of the visit was for me to engage in a project about *mobility prediction in ad hoc networks* under the supervision of Vinny Cahill. The goal of that was two-fold. The Distributed Systems Group at Trinity College has been developing location-aware protocols for group communication in mobile wireless ad-hoc networks, which may benefit from mobility prediction. Furthermore, the Pervasive Object Model Project (POMP), in which I have been engaged at the Univeristy of Aarhus, includes plans of working with location information in ad-hoc networks. The project would benefit from more experience with ad-hoc networks. Both of these goals have been partially fulfilled. The performance of the model for mobility prediction, which was developed, has not yet been tested, and therefore its benefit for the communication protocol is unsure. The focus of my visit has been mobility prediction in general and using Bayesian networks to predict mobility, so the knowledge gained on ad-hoc networks is not extensive.

Mobility Prediction in Ad-Hoc Networks

I have spent time familiarizing myself with the work done in DSG related to my project. This includes CORTEX and AITHNE, sentient object model projects, the TBMAC protocol, a medium access protocol for wireless communication, and STEAM, a location-based communication protocol for ad-hoc networks, and the work in progress to make it work in real time.

Various ways of doing mobility prediction have been evaluated. No technique stood out. We settled on using Bayesian networks in our model because they have performed well for location estimation, a research area related to mobility prediction[1].

A Bayesian Network for mobility prediction was developed. The network only uses pervasively and locally available information, and will in that respect be suited for mobility prediction for a mobile device in an ad-hoc network.

By working with the problem many open questions emerged. These will be presented in the following section along with plans for further work on resolving some of them.

Open Questions

- How well the Bayesian network for mobility prediction will perform in terms of
  - how far into the future a prediction can be made,
  - how large the margin of error is and how often the prediction is within this margin of error,
  - what the size in bytes of the Bayesian networks for mobility prediction is,
  - and what the latency of the inference on them is.

  Tests of the model using the simulator developed at DSG with simulated traces are being planned and are expected to be carried out during February 2005.
- How well the Bayesian network for mobility prediction performs compared to other techniques for mobility predcition. The mobility prediction projects reviewed do not contain comparable results.
- How well the Bayesian network for mobility prediction performs on real-world data. If real-world data is obtained, experiments will be carried out to test the Bayesian networks on this data.
- Whether an abstract mobility model, with zones and routes between zones, can cover both indoor (zone-room) and outdoor (zone-cell) mobility prediction. There is a possibility of working on Bayesian networks for mobility prediction in an indoor setting with Colin Harris, DSG.
- How the distribution of mobility information to train the Bayesian networks can be carried out in practise in an ad-hoc network. A part of this consists of determining how the Baysian networks will react to wrong information, which may be distributed purposely by other devices. And what the privacy issues of sharing mobility information are.
- Whether mobility prediction is a benefit for cluster-based communication in ad-hoc communication protocols, e.g., because it enables selection of longer lasting routes. In [2] they conclude that mobility prediction is a benefit for their cluster-based communication. Their experiments show that routes last longer in a specific routing protocol, when mobility prediction is used in order to chose long-lasting routes. It is still an open question whether this is true without the assumption of a free space propagation model (basically that there is no obstacles to the wireless communication, so the strength of the signal decreases regularly with the distance), and when a more complex mobility model or real-world traces are used to test the performance. Furthermore, when the prediction does not have access to accurate location information, its performance may deteriorate.
- What the requirements for real-time mobility prediction are. And which implementation of Bayesian networks that is best for real-time inference of the probabilities.
- What the benefit of mobility prediction is for a resource reservation protocol. A possibility is to test mobility prediction in PMRR, the routing and

resource reservation protocol used in the event-based communication protocol RT-STEAM. The medium access control protocol TBMAC, that lies below these protocols provides, with a high probability, time-bounded access to the wireless medium to mobile hosts in a multi-hop ad hoc network.
The cluster algorithm in PMRR is special, because the groups are fixed by the physical layout of a cell. This characteristic stems from the real-time communication goal and determines the scale of the prediction to be the cell. It is envisioned that the application will ask for real-time communication specifying an area and an acceptable delay. PMRR will adapt the area but will guarantee a maximum delay. The larger the area the more cells will be involved in the communication and the longer the delay.

The question of the benefit of mobility prediction for a protocol (eg. PMRR and TBMAC) and the question about real-time requirements for mobility prediction crosscut the indoor-outdoor topic and the questions about techniques for mobility prediction.

Papers and time It is envisioned that the planned experiments on the existing Bayesian network for mobility predection will result in a paper. If real-world data is obtained, we will try to publish the test of the Bayesian network for mobility prediction on this data. I will continue working on the open questions until August 2005, when I will decide whether to spend another 5 months to work on mobility prediction and make my PhD thesis on this topic or whether to return to a project I was working on earlier and make a broader PhD thesis that covers earlier projects as well as mobility prediction.

Conclusion

It has been a very good experience to stay with DSG for the last five months. It is an interesting and dynamic group. The project I was engaged in has not been carried to an end, but points to the future. Besides writing a paper about the part of the project already carried out in the immediate future, the collaboration betweeen Aarhus and Trinity on this project will continue at least a half or a whole year into the future.

References

[1] V. Fox, J. Hightower, D. Lin Liao Schulz, and G. Borriello. Bayesian filtering for location estimation. *Pervasive Computing, IEEE*, 2(3):24–33, 2003.

[2] Sung-Ju Lee, William Su, and Mario Gerla. Wireless ad hoc multicast routing with mobility prediction. *Mobile Networks and Applications*, 6(4):351–360, 2001.