On Social Dynamics and Their Importance for Large-Scale Pervasive Computing

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Background and Experience of the Participant in this Field

Mads Haahr is a Lecturer (roughly equivalent to Associate Professor in the US) in Computer Science at Trinity College Dublin. He holds BSc (1996) and MSc (1999) degrees from the University of Copenhagen and a PhD (2004) from Trinity College Dublin. His research interests include mobile and pervasive/ubiquitous computing, self-organising systems, computer game studies and artificial intelligence for games. Mads is former Course Director for Trinity College's taught MSc in Computer Science (Mobile and Ubiquitous Computing) and designed the 'vision course' on that programme, a course that takes a technical-critical approach to the visions that are driving research into pervasive/ubiquitous computing. Mads has authored/co-authored a total of 47 peer-reviewed papers on his research interests, including papers documenting SimBet, the first social-based routing algorithm for MANETs. He has led research projects for a total in excess of €1 million ($1.3 million), primarily in the areas of mobile and pervasive/ ubiquitous computing, and is currently co-editing a special issue of *Ad Hoc Networks* (Elsevier) on the topic of Social-Based Routing in Mobile and Delay-Tolerant Networks. Mads also edits a multidisciplinary academic journal called *Crossings: Electronic Journal of Art and Technology* and has built and operates the Internet's premier true random number service RANDOM.ORG.

The Vision of the Participant

For years, humans have been building a global communications network – a pervasive computing platform – set eventually to bring all members of our species within range for potential communication and to support new types of networked applications. The totality of this network is growing particularly quickly along its frontiers, such as the infrastructure-challenged computing environments found in developing countries and the more conventional mobile networks used in developed countries. These network frontiers suffer from intermittent connectivity and changes in topology that can be difficult or impossible to predict, and for that reason they have been subject of considerable research. For many years, researchers in this field assumed traffic and node movement to be random, but in reality, mobile nodes are of course used by people, whose behaviours are better described by social models. This realization opened up new possibilities, for example for social-based routing protocols, which showed that knowledge about social behaviour patterns allows better routing decisions to be made. Because humanity's global (and even extra-global) network is set to grow considerably along infrastructure-challenged boundaries, such social-based routing protocols could play an important and very real role in helping to interconnect our species and to support new types of networked applications that reside on the infrastructure-challenged boundaries of the network.

The two insights that (1) social dynamics govern the movement patterns of mobile devices; and (2) knowledge about these dynamics can be useful – together constitute a special case of a deeper realization that complex social dynamics govern the use of the entire global communications network that is becoming humanity's pervasive computing environment and that this knowledge is likely to be useful in a broader context.

It is my view that such social dynamics will become significantly more important than we currently think – even in this age of social networking services – and that the example of social-based routing is a first example. Many current systems (e.g., Facebook) are concerned with facilitating social interactions and collecting data about them, but pervasive computing systems contain sensors that allow them to infer much more, not merely about user *context*, but about the *social dynamics* that govern their use. It is my view that to make pervasive computing infrastructure both genuinely scalable and maximally useful, we need a much better understanding of these social dynamics than we currently have.

I propose to introduce the idea of *social reasoning* as a feature of any pervasive computing environment. The core idea is to allow pervasive computing platforms and applications that operate in them to capture information about the relevant *social dynamics* and make (likely probabilistic) inferences about them. A possible implementation could be in the form of an extension to the traditional protocol stack in which each layer collects data about events related to social dynamics and performs inferences that are of particular relevance to that layer. The social reasoning performed by each layer is essentially a computation based on captured intra- and inter-node behaviour on a local scale and used to make inferences about a much larger social behaviour of the system.

For example, at the mobile routing layer, the relevant social dynamics are spatial-temporal node encounters, and possible inferences relate to the social network structure that arises from the encounters. The resulting inferences can help route data through the network as has been shown by social-based routing protocols, such as SimBet. At other layers, different social dynamics and inferences will be relevant. A comprehensive social reasoning model for pervasive computing would include a map of the different social dynamics and the social knowledge that can be inferred for each individual layer in the stack. I consider the notions of *social dynamics* and *social reasoning* more sophisticated than the popular notion of *context*, because they capture not only an individual node's situation but also inter-node dynamics over time and (with some degree of confidence) the overall social behaviour of the system.

Evidence that Pursuing the Vision will Lead to Major Advances in the Field

The gradual entry of social dynamics into existing technology stacks is already happening all the way from the application/platform layer (e.g., Facebook) down to the routing layer (e.g., SimBet); and at the same time across a wide range of users, from technologically saturated communities (e.g., users of LinkedIn) to minimally saturated ones (e.g., users of DakNet), and even to non-human social mammals (e.g., ZebraNet). For example, my team and I have been successful in developing algorithms for distributed and mobile systems that achieve high routing performance and scalability characteristics through decentralized social reasoning, but we have only touched the tip of the iceberg in several important regards: (1) the variety of *social dynamic* data collected is minimal (we use only node encounters and neighbour relations); (2) the sophistication of our *social models* is low (basic social network analysis and Schelling's model for urban population segregation); and (3) our approach to *social inference* is far from comprehensive (confined to a single layer in the stack). However, we believe that a more comprehensive approach is highly topical and will be helpful in building the pervasive computing infrastructure of the future.