Some Open Aspects of Mobile Ad-hoc NETwork, Peer-to-Peer, and Self-organizing Systems

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Abstract. This document summarizes the results of the working group discussion on Mobile Ad-hoc NETworks (MANETs), peer-to-peer (p2p) and self-organizing systems held at the workshop on Mobile Information Management in October 2004 in Dagstuhl, Germany. The goals of the discussion group and of this document were to study the characteristics of these systems and to identify some of the open research issues that need to be solved in order for such systems to be implemented successfully.

1 Introduction

This document reports on the results of a Dagstuhl working group on MANETs, p2p and self-organizing systems. The goals of the working group were to discuss and identify open research issues within the fields of MANETs, p2p and self-organizing systems. Research issues in these fields include conceptual and architectural facets.
A key point among the architectural issues is whether or not a layered network architecture is appropriate for these technologies and if so, which layers need to be influenced by research in this field. Within layered networking systems that distinguish an

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application layer from a transport layer and a networking layer, p2p systems and self-organizing systems motivate changes to the transport layer and to the application layer, whereas MANETs additionally involve research at the application layer.

In our opinion, there are performance requirements in different areas like routing, caching, searching and consistency that require cross-layer optimization techniques which use “application knowledge” for optimization purposes in lower layers. As a consequence, architectures for MANETs, p2p and self-organizing systems may weaken a strongly layered design for the sake of efficiency.

2 MANETs

Requirements:

MANETs should provide a possibility for both a general optimization of algorithms and the ability to customize algorithms for the following task:

- Enhanced routing protocols for data transfer and search are needed. For many applications it would be desirable that the performance is as good as the performance of wired protocols.
- Protocols should take advantage of the context of a task to be executed. This includes context information, such as the knowledge of location, neighbors, mobility and energy availability of nodes as well as considering quality of connection like bandwidth and stability.
- Protocols have to handle situations that are an exception in fixed-wired networks, but a common situation in MANETs, including lost connections, partitioned networks and unreachable nodes. They even have to handle unknown routing to participants.

Challenges in MANETs:

Although a lot of research has been done in the area of routing for MANETs, the available routing mechanisms are not sufficient in the following aspects:

From the application point of view, the performance is still far from what is achieved in fixed networks. From the algorithmic point of view, it seems to be promising to use information about the context of the single network node within routing algorithms. The context information to be used includes a node’s location, neighbors, energy consumptions and available bandwidth. Such information could be gained leaving the common network layer model behind and using a cross-layer approach.

One of the key research challenges in routing algorithms for MANETs is to exploit the knowledge about nodes’ context in order to improve the overall performance of MANETs. For example, the information about their movement could be used in order to determine better routing paths, the information about their neighbors could be used to select the most efficient node for caching. Furthermore, routing protocols should consider energy constraints, security constraint (e.g. don't route through an insecure area) and in some applications, real-time constraints (delivery in time).

3 p2p Systems

Requirements:

P2p systems rely on overlay networks that completely hide the underlying network topology from the application. This leads to the same issues as in MANETs because knowledge about the underlying physical topology could be used to optimize query processing and caching of query results. However, the requirements usually are not handled at the network layer, but at the transport and application layers. This includes how to handle transparent disconnections, how to support offline processing of data, and how to make use of transaction context and provide for scalability.

Open research issues:

Open research issues in the field of p2p systems include the overall performance and better support for certain types of queries. Overall system performance and scalability require cross-layered approaches to search, caching, and query optimization because the layered approach to computer networks introduces an abstraction level that loses useful information. The required support for query processing includes support for location-based queries, range queries and top-K-queries, similarity search and sophisticated hash-functions at a lower level.

A further aspect is how we can optimize topologies accommodating solutions, for the above issues (e.g. topologies that support better cooperative caching and storage strategies).

4 Self-organizing systems

Characterization and requirements:

Self-organizing systems cover a wide range of decentralized systems. We limit our discussion to specific kinds of self-organizing systems, i.e. to self-organizing p2p systems and self-organizing MANETs.

The main characteristic of self-organizing systems is the complete lack of centralized control. Entities cooperate with each other to achieve a common goal. Because global knowledge is not available within a single point of the system, every entity decides its actions autonomously based on its local knowledge. Self-organization is a continuous process which has to adapt to a variety of changes or failures, including a changing set of cooperating participants and link failures. A further key requirement that self-organizing systems are expected to fulfill is scalability.

This allows applying self-organizing systems to very large or unstable environments where central control is not available or can not be guaranteed.

Open research issues:

One key challenge is to divide a desired global behavior into local rules to be followed by each entity. This involves defining and implementing local decision rules and independently acting entities in such a way that the overall system architecture

leads to a scalable and robust system that follows the desired global behavior. This challenge is closely related to the problem of how to prove correct global behavior on the basis of a set of local rules and general assumptions on ratios of node and network failures, network topology and node movement.

A further challenge is to improve the system's adaptation to all kinds of changes or failures including failing participants and links. In a more general perspective this also includes the system's self protection from malicious participants. An additional challenge occurs in self-organizing systems that include participants which follow possibly conflicting individual goals, while all participants use and provide some support functionality to keep the overall system running. In such scenarios, it may be required to balance between the participants' goals to achieving a local maximum advantage and the overall system's welfare. Therefore, an additional challenge is to establish properly designed reward and punishment mechanisms that keep a self-organizing system running even in case of selfish, miss-behaving or malicious participants.

5 Summary and conclusions

We have discussed some aspects of MANETs, p2p and self-organizing system that may be relevant for further research including scalability, optimization issues and self-organization. In our opinion, optimization and scalability require a new view of network architectures that allows using certain kinds of contextual information in lower network layers. Altogether, these fields open up many challenging research questions, some of which we have discussed briefly in this document.

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