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Mobile Learning by Using Ad Hoc Messaging Network

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Abstract— **The requirements of modern e-learning techniques change. Aspects such as community interaction, flexibility, pervasive learning and increasing mobility in communication habits become more important. To meet these challenges e-learning platforms must provide support on mobile learning. Most approaches try to adopt centralized and static e-learning mechanisms to mobile devices. However, often technically it is not possible for all kinds of devices to be connected to a central server. Therefore we introduce an application of a mobile e-learning network which operates totally decentralized with the help of an underlying ad hoc network architecture. Furthermore the concept of ad hoc messaging network (AMNET) is used as basis system architecture for our approach to implement a platform for pervasive mobile e-learning.**

***Index Terms*— Mobile learning, ad hoc learning, community, e-learning platform, AMNET, ad hoc messaging network, pervasive learning**

I. Introduction

In recent years the technological development in the sector of internet applications accelerated. Mobil applications, virtual communities, and flexible web based solutions are realized by the new possibilities of web 2.0 techniques [1]. Therefore, functional requirements for modern e-learning systems are growing.

Traditional e-learning architectures with a centralized server principle can not meet these requirements. Our approach presents a solution that allows learning in mobile and changing groups by using the concept of AMNET, an ad hoc messaging network [2].

Current research focuses on social aspects such as learning and educational concepts. However technological aspects are hardly discussed reflecting on modern ad hoc communication protocols. This contribution follows a new approach and focuses on 'messages' as the central point of interest.

As a result of an intensive analysis of current literature the paper identifies new requirements for modern e-learning systems and shows how to provide message-centric mechanisms of ad hoc message networking in local learning environments by simple means and protocols like store-and-forward routing and points out applications that use these network specifics. Considering aspects of new challenges in mobile e-learning, several criteria for a successful and practical mobile e-learning network can be identified:

- Availability (anytime, anywhere)
- Broad community support
- Group and broadcast discussions
- 1-on-1 communication
- Capable for heterogeneous devices
- Decentralized information sharing

Those criteria should be considered in the decision making process for an adequate e-learning platform for mobile e-learning projects. All content must be sharable for everyone but not all information needs to be accessible instantly. Therefore a permanent connection to the central learning content repository is not mandatory [2]. This leads to our concept of a mobile e-learning model that introduces the mobile e-learning network.

Chapter 2 is dedicated to new challenges of e-learning such as mobility, and community orientation. Chapter 3 focuses on technological aspects for a decentralized e-learning platform by using the AMNET approach. Furthermore applications such as peer–to-peer and location based services are described.

II. New challenges in e-learning

A. Mobile E-Learning

E-learning is of an increasing importance in modern education systems. Therefore, methods and content of e-learning changes and sets new challenges for technical and social tasks. New aspects arise of how people deal with information, how they expect to be provided with content and in what situations and places they want to learn. Furthermore community learning is a new approach and focuses on interaction aspects between people [3]. Modern e-learning platforms have to reflect on these new challenges.

Our approach is to focus on different applications for e-learning solutions to meet these challenges. One of the most important strategies for mobile e-learning is to focus on ubiquitous learning, communication in dialogues, and connectivity to meet the arising community aspects of learning

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platforms [4].

Ubiquitous Learning

Learning is not bound to courses, time, and places. Many situations during a day can be seen as individual learning environments. The term `ubiquitous learning' describes learning environments as they are: pervasive and omnipresent. In literature and research pervasive learning is discussed broadly [5]. Ogata and Yano characterize pervasive learning with the following terms: permanency, accessibility, immediacy, and interactivity as well as classical situations of instructional activities. Combining pervasive learning and mobile learning will bring up ubiquitous learning. By using RFID technology Ogata and Yano show that location based learning can improve traditional learning concepts. However, technology is not the dominate aspect of a successful e-learning concept. Human interactions between e-learning participants can provide more intensive and sustainable outcome [3].

Dialogue

Knowledge gains takes place in close interaction among members of social networks. That can be in a common teaching environment such as a course, a group of friends that share the same interests or just in transient everyday situations. As a personal learning experience former foreign knowledge is added to ones own knowledge repository. This knowledge contents represent potential learning items for other participants of the leaning group or course. As knowledge is not a rare resource knowledge can easily be shared among members in a social group. Thus the gaining of knowledge in groups is not only profitable for one member but as well for other members or for the whole group. Networks effects become important and accelerate the learning process [6].

Connectivity

Using mobile devices can support the broadcasting of experiences to a larger group. The messages may be time-shifted but still the content is shared. Therefore the devices must offer various interfaces for different situation to be capable of the exchange of parts of knowledge repository anytime and in any situation [2]. In order to make content on various devices accessible for end users, a unified communication service platform must be introduced. Message sharing should rely on standard interfaces and should be transparent to the applications that end users operate with.

B. Community Aspects

Most of e-learning arrangements focus on individual learning experiences. Participants are able to choose time and place where they want to precede the lessons. However, even in traditional leaning arrangements, where learning takes place in courses and leaning groups, knowledge is spreaded among the group members and the net outcome, respectively the resulted knowledge gain for the group is greater than the sum of the individual gains due to network effects [6]. E-learning may not reject those advantages and concentrate on community aspects as well.

Tools that support knowledge management in learning communities can be internet or intranet portals, wiki installations, forum software, classical online learning platforms, or other web 2.0 applications. The success of these applications, especially wikis and forums, strongly depends on network effects [6, 7]. The benefit for every single user who is contributing in such a community rises with the amount of members and the amount of postings. Usually, in common learning environments there is a limited number of participants. Therefore, network effects could hardly be realized. In many situations the need of being connected to a central server is a limiting factor for the growth of an e-learning community. Thus it is necessary to provide a network platform that can be used by members anywhere and anytime without the need of being connected to a central server [3].

Most important is the way of communication that is used among participants sharing content without a continuous connection to the central repository. Mechanisms of ad hoc networking are used for off-course knowledge distribution.

III. A PLATFORM FOR MOBILE E-LEARNING ENVIRONMENTS

A. A Concept for a Decentralized E-Learning Platform

In recent years a growing number of mobile services have been offered connecting the internet to PDAs and mobile phones. However, these innovations are hardly used in the sector of e-learning. Most of data based applications follow the mechanisms of 'fixed internet' that are adopted to mobile networks by the use of complex routing protocols. This approach reflects the attempt to transfer internet applications to mobile networks under conditions of stability, speed, and flexibility but not the warranted reliability of common internet networks. Furthermore the structure and characteristics of the network should be transparent for applications that can be used in e-learning environments such as in universities.

The approach presented in this contribution relies on the use of ad hoc messaging. Thus, for the direct exchange of messages and learning objects among participants, an ad hoc messaging network (AMNET) is suggested. In this network peers run software, which detect other members, which are in a reachable range. This process does not require any user interaction, a connection is established and information is shared automatically [2]. The content of repositories among two repositories is compared and new content will be transferred, stored and shared. This synchronization process takes place continuously and all learning relevant content is spread in the group.

With the combination of decentralized synchronization processes and a fixed synchronization point, a static AMNET node, a platform is created that covers all issues for modern mobile e-learning environments. Such an AMNET node can be localized for example in the e-learning provider's facilities where participants meet on fixed dates.

B. Ad Hoc Messaging Network (AMNET)

The AMNET approach bases on the principles of ad hoc messaging networks. In contrast to conventional mesh networking ideas, which achieve stable and reliable networking clouds as the foundation for common IP-based applications, this approach focus on the deployment of mobile devices for spontaneous data transmission without a formal infrastructure, where message exchange does not rely on end-to-end connections among the involved nodes. This highly reduces, if not eliminates, the route maintenance complexity compared to mesh networks [8].

In a wireless environment which consists of a network of mobile nodes, different types of messages can be distinguished, according to the respective applications. For instance, instant messaging is a compatible and attractive technology which can be integrated in the AMNETs. For this case, the following criteria are applicable, aiming for maximum user benefit:

- Message exchange should be organized in a way, that data will be send and received completely and accurate.
- While real-time message forwarding is not required, message exchange should happen within a considerably short time, so that the user experiences a message dialogue.
- The requirements for message validity and integrity differ with the type of messages and the character of the dialogue. For instant messaging scenarios where this is less important and the deployment of cryptographic authentication and encryption is optional, a great amount of complexity is removed from the system.

The basic concept of AMNET focuses on the message exchange between two or among more nodes being neighbors in the sense of wireless radio range. When these nodes move and hence their neighborhood change, they constitute a network which is characterized by receiving messages, storing, 'carrying', and delivering them asynchronously. Although no persistent end-to-end connections exist, this highly partitioned network offers potential for e-learning platforms.

Nodes store messages for a maximum amount of time and deliver them to close-range nodes, with storage time and maximum hop count as limiting factors, so that messages do not live forever within the network and congestion can be reduced. Newly received messages are added to the message repository, if the message is not yet in there. Messages can be identified by sender address, message payload message authentication code (MAC), hop count, among others. This constitutes a multicast-like procedure in order to synchronize message repositories of nodes within a certain distance.

Repository organization and message storing are key areas within the AMNET concept. Since the main platform envisioned for AMNET consists of mobile phones and other small digital devices with considerably limited storage and computation capabilities, the repository handling has to be carefully designed, along with message caching and efficient storage techniques. Corresponding to existing approaches for data management in explicitly resource-limited systems, a filtering system has been implemented [9, 10], which can also be used and extended by applications for various message filtering purposes.

The AMNET approach inherently requires a large number of AMNET-enabled devices in order to provide effective message transfers. With a growing density of AMNET nodes, message delivery speed and reliability increases considerably. It should be noted that real-life Bluetooth implementations in mobile devices often do not implement all properties required in the Bluetooth standard, and specifically do not allow multiple simultaneous Bluetooth connections [2, 11]. This stresses the need for a high AMNET node density. Standard mobile phones pose considerable limitations on J2ME applications, and especially low-end consumer devices do not allow for applications that use more than 512kB of memory. The reason for this stems from earlier CDLC specifications, which is empirically validated by Huepaniemi et al [12].

The focus of the AMNET approach is to develop a method for the transfer of data of different categories among mobile devices, for example personalized and anonymous messages without the need to establish a centralized communication structure. This approach allows new applications that make use of the specific network characteristics. For example building up interdisciplinary learning groups or invite other students into expert-discussions can be realized via messaging ad hoc networks.

In order to obtain detailed information about such an asynchronous peer-to-peer message transfer network a project was set up. The aim of this project was to build an AMNET prototype and to test this prototype in a simulation environment. In a next step, the platform was tested in a real environment by studying data transmission in so called mobile ad-hoc networks (MANETs) using Bluetooth on mobile devices. There has been a lot of research in routing in MANET [13-15] and the limitations of the routing protocols [16]. Several reactive and proactive routing algorithms are designed for different purposes and network situations, allowing for route discovery either in advance or during packet delivery. Unfortunately, these protocols suffer from a number of shortcomings: Scalability becomes problematic with growing network sizes, performing well only under certain network conditions. The influence of mobility, network load, and network topology on performance is described by Broch et al. [17].

There are mobile networks which have to change their topology frequently and continuously due to the rapidly moving nodes, which requires routing discovery techniques to permanently assure valid routes as abstracted by Chlamtac [18]. These networks can be described with the organic term 'vivid', pointing out the vibrant nature of mobile networks.

We find these vivid networks in e-learning environments, when participants use their devices only sporadically while moving and interacting. Therefore the available MANET routing mechanisms are not satisfactory and the AMNET project was set up to overcome the difficulties while considering the particular requirements of a vivid mobile e-learning environment.

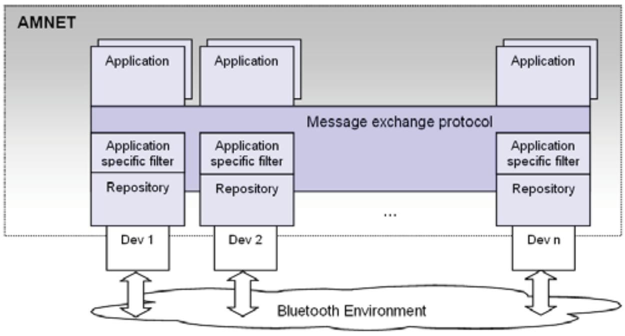

Fig. 1. AMNET- Architecture.

Prototype Implementation

A prototype for mobile phones has been set up which implements message exchange via Bluetooth. In accordance with typical layer models, as know from the ISO-OSI layering, the architecture has been designed as follows.

Figure 1 shows the requirement for a programmable Bluetooth interface, along with a message repository as data storage. Configurable message filters control the access of applications towards the repository content. Message properties, set by the various applications by means of message filters, allow for certain message exchange rules between the mobile devices. Apart from that, the applications have direct connection to the message exchange process itself.

The mentioned reference implementation is Java-based and uses the Java Platform 2, Micro Edition. For interacting with the device's Bluetooth stack, we use the Java API for Bluetooth (JSR-82). Along with this prototype, a program interface has been implemented that allows for simulating numerous mobile devices moving within a simulation environment, which provides a test bed for message exchange and routing behavior.

The complete description of the AMNET architecture and its prototype implementation can be found in [2].

C. *E-Learning as AMNET Application*

In a wireless environment, where mobile nodes build up the network, typical applications can be categorized regarding the user's communication habits. As aforementioned, instant messaging is a common application with a high potential to be used within MANETs. In this case these identified criteria can be seen as technical requirements when trying to achieve a high customer satisfaction:

- Data transmission is beneficial only when a transaction is completed. Concerning *completeness of data*, the entire message has to be delivered, not only parts of it.
- Concerning *time response*, message delivery has to be in scope. That means the message should be available in a suitable period of time which allows the user to handle a dialogue.
- The need for proper *validity* of messages depends on the usage of the instant messaging application. Assuming, validity is not a critical point; customers' needs can be fulfilled with other means than relying on complex routing procedures.

There are different situations and settings which are built upon the particularities that are pointed out by AMNET implementations. In these applications the problems are addressed specifically. Here are two examples of AMNET principles used in different existing environments:

Peer-to-peer (P2P) file sharing systems: A system for distributing information retrieval, called Peer Search introduced by Tang, Xu, and Mahalingam, has to overcome the same problems that led us to the consideration of AMNETs. Index flooding can be compared to caching issues and query flooding is opposed by heuristic-based message filtering mechanisms. Like in Peer Search the scalability problem of common MANETs is avoided by using decentralized e-learning repositories [19].

Locations Based Services (LBS), Who-is-around-lists: Deployed LBS applications depend on centralized databases providing localized information. In AMNET, LBS could be adopted when accepting a certain degree of haziness, since message validity can be coupled with the count of forwarding nodes, providing a 'proximity-based' information service without the need for central service providers or information repositories. In the matter of e-learning this could for example be used for establishing spontaneously interactive learning groups.

Community applications such as configuring a personal profile, using who-is-online lists or complex reputation systems can be provided by mobile ad-hoc networks. One of the most important aspects of these applications is building up a learning community [20]. Generating social network effects can be used as one key element to increase diffusion of the described standard. To send a self-administrated personalized user profile can be used in many ways. For example to meet people with special interests, or to be informed if one of your friends of your who-is-online list is in your current local area [2].

D. *Network Effects in AMNETs*

As aforementioned, the number of participating users represents a critical factor concerning the success of AMNETs. Only a sufficient amount of network nodes guaranties the successful deployment of applications that deliver messages by diffusion. The common impact of network externalities has been discussed on the basis of various technologies, with special regard to the introduction of new standards [21].[1]

One main factor to accelerate technology diffusion as per Erber et al., is the obtainment of a critical mass of users. Such critical mass is achieved when the benefit for new participants has become so big that [22]. It can be hypothesized that similar effects apply accordingly to AMNETs.

Special problems result from the initial (phase) when only very few users participate. Previous research on positive external effects assumes a small increase of benefit for every user when new participants join even throughout the start phase [22]. This is not the case with AMNETs where a certain fixed quantity of existing nodes is mandatory for the message transfer. Beyond that quantity of nodes no added value exists for users, thus the aforementioned theory only applies when this quantity is reached. A possible solution to bridge the gap is the implementation of connected stationary network participants.

In a dedicated mobile e-leaning course at school or university this critical amount of nodes can be achieved quickly because all participants start using the AMNET implementation at the same time. Nevertheless a numeric simulation show that the speed of message propagation can be increased when static nodes which are permanently connected with each other are part of the network.

Simulation Environment

To analyze the effect of connected stationary network participants we developed a simulation environment which is capable of displaying a varying number of mobile and stationary nodes. The dynamically designed round-based model provides information about the number of rounds necessary until a message is spread to a certain quota of mobile nodes. In round 0 one node at random receives a message which is to be transferred to other nodes in his simulated radio range.

The following parameters and data describe our simulation environment:

- Simulated area: 6 * 4 km urban area (Berlin, Germany)
- Pseudo-realistic urban landscape using street maps
- Participants move on streets and open spaces
- Pace rate of the simulated nodes matches walking speed, which is up to 3 km/h
- Radio range of participants is restricted to 10 m (according Bluetooth standard)
- Round-based simulation: One step of simulation equals one second.
- Connection to other devices is only established after 5 rounds of mutual visibility (according to previous tests regarding Bluetooth discovery times [2])
- Up to 3 message transfers per node per round
- Different patterns of movement can be assigned to network participants

[1] A discussion concerning well-known problems in networking environments, e.g. free-rider behavior, tipping effects or the existence of malign nodes is omitted here.

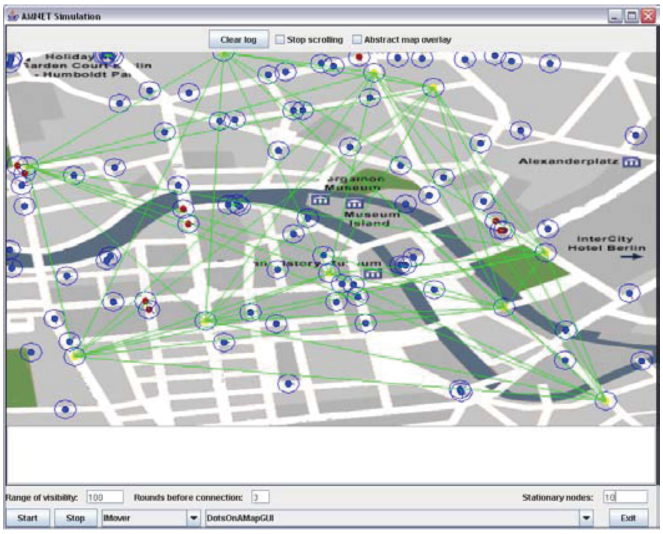

Fig. 1. Simulation software.

Figure 2 shows a screenshot of the application during simulation, with the GUI displaying a map of the center of Berlin, the capital of Germany, which was integrated as the basis and zoning for the motion algorithms. Blue nodes symbolize network users without messages, red nodes have already received messages, and yellow nodes represent stationary nodes, connected permanently (e.g. via internet) and capable of synchronizing messages with mobiles nodes in the vicinity.

After reception of a message a stationary node immediately forwards it to all other stationary nodes, into the same or another network segment. Supposedly this also increases the speed of the spreading altogether, independent of the quantity of mobile nodes. Within the scope of the simulation a statement concerning the effects of the ratio of mobile and stationary nodes regarding the speed of message transfer is intended. To research the effects of stationary network participants their quantity is being varied in different simulation runs, and the speed of message distribution is documented.

Essential statements of the analysis, proven by a multitude of simulation runs with varying parameters are:

- More nodes accelerate the message distribution to the entirety of users.
- Stationary nodes speed up the message transfer irrespective of the quantity of mobile nodes.
- The "geographical" positions of the stationary nodes are important. If stationary nodes are close to each other and nodes are spread widely, the accelerating effect of network of message transfers are less significant.
- Stationary nodes are especially effective when only few mobile nodes are involved. With an increasing number of mobile nodes, stationary ones lose significance.

By increasing the complexity of the simulation we will be able to calculate the optimal quantity of stationary nodes in proportion to a varying quantity of mobile nodes. This is an important conclusion which can help to increase the efficiency of MANETs in mobile e-learning projects. In this concept, mobile nodes can be used additionally to perform the process of synchronization of learning objects with the underlying conventional e-learning platform.

IV. Conclusion and Further Work

Within this contribution relevant aspects for mobile e-learning environments are identified. These new requirements are hardly met by existing platforms because if these installations support mobile learning on mobile devices such as PDAs, they rely on a static intra-/internet connection to an e-learning application server. Therefore we introduced a platform based on AMNET technology that allows message sharing among mobile devices without the need of a centralized server.

The findings in the field of the application of AMNETs suggest that valuable message communication can be introduced for vivid ad hoc networks that serve applications in e-learning environments. This is a realistic and appropriate alternative for porting e-learning relevant common internet communication features to mobile devices. Stationary nodes in the network setting increase the network efficiency and may lead to a higher user's benefit.

A lot of research has been conducted on ubiquitous mobile e-learning but yet there are no platforms that cover all the new challenges. This paper depicted an approach towards a technical solution that realizes all these requirements. Our further work will conduct analyses on the impact of AMNET platform on an existing e-learning platform. A prototype will provide insights that bring out new requirements that will be covered with further development of the platform. However, using AMNET technology is a promising approach that provides a technical solution for known issues in the field of ubiquitous mobile e-learning.

References

[1] T. O'Reilly, "What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software," O'Reilly-Verlag, 2005.

[2] C. Fuchß, S. Stieglitz, and O. Hillmann, "Ad-hoc Messaging Network in a Mobile Environment," presented at International Conference of Internet Technology and Secured Transactions, London, 2006.

[3] C. Lattemann and S. Stieglitz, "eLearning Strategien für das universitäre Massenstudium - zukünftige Herausforderungen und Lösungswege," in *Multimediale Technologien - Multimedia im E-Business und in der Bildung*, C. Lattemann and T. Köhler, Eds. Frankfurt: Peter Lang Verlag, 2006.

[4] U. Markus, *Integration der virtuellen Community in das CRM: Konzeption, Rahmenmodell, Realisierung*, vol. 15. Lohmar, Köln: Josef Eul Verlag, 2002.

[5] H. Ogata and Y. Yano, "Context-aware support for computer-supported ubiquitous learning," presented at Wireless and Mobile Technologies in Education, 2004.

[6] B. W. Wirtz, "Wissensmanagement und kooperativer Transfer immaterieller Ressourcen in virtuellen Organisationsnetzwerken," *Zeitschrift für Betriebswirtschaft*, vol. Ergänzungsheft, pp. 94 - 114, 2000.

[7] F. Fuchs-Kittowski and A. Köhler, "Wiki Communities in the Context of Work Processes," *Proceedings of the 2005 International symposium on Wikis*, pp. 33-39, 2005.

[8] B. Zhen, J. Park, and Y. Kim, "Scatternet formation of Bluetooth ad networks," presented at 36th Annual Hawaii International Conference on System Sciences, Hawaii, 2003.

[9] P. Guangyu, M. Gerla, and C. Tsu-Wei, "Fisheye state routing: a routing scheme for ad hoc wireless networks," presented at IEEE Internations Conference on Communications, 2000.

[10] T. Yu-Chee, N. Sze-Yao, C. Yuh-Shyan, and S. Jang-Ping, "The Broadcast Storm Problem in a Mobile Ad Hoc Network," *Wireless Networks*, vol. 8, pp. 153-167, 2002.

[11] M. Leopold, M. B. Dydensborg, and P. Bonnet, "Bluetooth and sensor networks: a reality check," presented at 1st international conference on Embedded networked sensor systems, 2003.

[12] J. Huopaniemi, M. Patel, R. Riggs, A. Taivalsaari, A. Uotila, and J. v. Peursem, *Programming Wireless Devices with Java (TM) Platform*: Addison Wesley Professional, 2003.

[13] X. Kaixin, H. Xiaoyan, and M. Gerla, "An ad hoc network with mobile backbones," *IEEE International Conference on Communications*, vol. 5, pp. 3138-3143, 2002.

[14] K.-W. Chin, J. Judge, A. Williams, and R. Kermode, "Implementation experience with MANET routing protocols," *SIGCOMM Computer Communication Review*, vol. 32, pp. 49-59, 2002.

[15] E. M. Royer and T. Chai-Keong, "A review of current routing protocols for ad hoc mobile wireless networks," *IEEE Wireless Communications*, vol. 6, pp. 46-55, 1999.

[16] T. Yu-Chee, N. Sze-Yao, C. Yuh-Shyan, and S. Jang-Ping, "The Broadcast Storm Problem in a Mobile Ad Hoc Network," *Wireless Networks*, vol. 8, pp. 153-167, 2002.

[17] J. Broch, D. A. Maltz, D. B. Johnson, Y.-C. Hu, and J. Jetcheva, "A performance comparison of multi-hop wireless ad hoc network routing protocols," *Proceedings of the 4th annual ACM/IEEE international conference on mobile computing and networking*, pp. 85-97, 1998.

[18] I. Chlamtac, M. Conti, and J. J.-N. Liu, "Mobile ad networking: imperatives and challenges," *Ad Hoc Networks*, vol. 1, pp. 13-64, 2003.

[19] C. Tang, Z. Xu, and M. Mahalingam, "Peer Search: Efficient Information retrieval in Peer-Peer Networks," *Hewlett-Packard Labs: Palo Alto*, 2002.

[20] C. Lattemann and S. Stieglitz, "Coworker Governance in Open-Source Projects," in *The Economics of Open Source Software Development*, J. Bitzer and P. Schröder, Eds. Amsterdam: Elsevier, 2006, pp. 149-164.

[21] G. Erber, T. Köhler, C. Lattemann, and B. Preissl, "Rahmenbedingungen für eine Breitbandoffensive in Deutschland," Potsdam, Germany 2004.

[22] U. Witt, ""Lock-in" vs. "critical masses" -- Industrial change under network externalities," *International Journal of Industrial Organization*, vol. 15, pp. 753-773, 1997.