Making Motor Bikers Come Together - Fast Moving Users and Mobile Ad Hoc Networks

Mattias Esbjörnsson, Oskar Juhlin & Mattias Östergren
Mobility, Interactive Institute, P.O. Box 24081, SE – 104 50 Stockholm, Sweden
{mattias.esbjornsson, oskar.juhlin, mattias.ostergren}@interactiveinstitute.se

Abstract. This paper introduces the Hocman prototype, which supports mobile interaction among motorcyclists. The design is based on findings from an ethnographic field study. Motorcyclists are a community with a strong social commitment. They use their bikes together, which allows for visual interaction. However, their extreme mobility creates problems in coming together. Recently the group studied have started to use a website on the Internet, but interactional issues still remain. For this reason we have developed a new application based on web technology. It is built for handheld computers and wireless communication, allowing the users to share rich content when in the vicinity of each other during motorbike activities.

1 Introduction

Motorcycling is a popular and highly mobile activity where people spend a considerable amount of time on the roads mostly to enjoy themselves. They also enjoy riding in the presence of other motor bikers. Due to the high speed they interact visually and display their actions and equipment for others to see. However, we have conducted ethnographic fieldwork that reveals problematic issues in establishing visual interaction as well as accounting for their brief meetings. The main issues concern the handling of contingent meetings and the possibilities of expressing identity. The group we have studied spends a considerable amount of time on a public web site in order to minimize the impact of these problems. For instance, they use a message board to organize their joint rides. Being public and asynchronous, discussions are often confusing and lack proper context.

The aim of this paper is to introduce a prototype supporting mobile interaction, which bridges the gap between mobile activities in the physical world and virtual life. We present the Hocman prototype (Esbjörnsson, & Östergren, 2002), which is a peer-to-peer application, over wireless ad hoc networks, for handheld computers. It allows the motorcyclists to share personal information during brief meetings when in the proximity of each other.

This work assumes it is possible to take technical resources designed for stationary or semi-stationary environments and apply them to a mobile setting where the participants are almost constantly in motion. This is an ideal context for proximity-based interaction; the related systems address settings, where there are a large number of alternative ways to configure communication and provide service. The technical test presented here is of importance for this particular application, but also in a wider sense, as it validates this assumption and paves the way for many new applications.

2 Related Work

There are several research projects that propose badges, devices, and software applications to provide interpersonal awareness and support collaborative activities. The principal ones are the Hummingbird device, GroupWear Tag, the Meme Tags System, and the Proem system. These systems vary in their ability to mediate personal expression. However they all have in common that they are designed for semi-stationary settings. The users must be in close range, standing still or moving slowly relative to each other.

Hummingbird (Holmquist, et al, 1999) is a device used to monitor the presence of other Hummingbirds in the close proximity. Sending and receiving a beacon signal of limited range achieve this. A predefined "humming" sound is played and a unique symbol, denoting the detected devices, is displayed upon approaching other devices. The GroupWear (Borovoy, et al, 1998A) is an active badge system that lets user share and compare answers to a set of multiple-choice questions. In the GroupWear system, the badges store the answers and automatically exchange them with other badges over infrared links. Users store a choice by putting it close to a badge-programming device dedicated to a particular answer. When users meet face-to-face, the set of answers are exchanged and a pattern of lights is illuminated, indicating their common opinion. The GroupWear tags system does not handle questions. Instead they are printed on billboards and placed close to a set of answer programming devices. The Meme Tags System (Borovoy, et al, 1998B) also provides mechanisms to monitor other user's presence, but at a shorter range than the Hummingbird device. In this system all users carry a badge that stores "memes". These are sets of short sentences, comprising a poem, an aphorism or any message the user finds appropriate. When two users meet face-to-face, their MemeTags will exchange the stored memes. From the users' perspective, the opposite tag will activate and present a meme not stored on the users own tag. If the user likes it he or she selects the meme by pressing a button on the tag. Workstations linked to the tags in an ad hoc fashion provides the user with the capability to author fresh memes. Finally, the Proem system (Kortuem, et al, 1999) is a Java application that let users share profile information during encounters. In this system the user enters his or her personal information in a document formatted with an XML syntax. The syntax is pre-defined by the system developers. When two instances of the application come within close proximity of each other they will automatically exchange profiles. When a profile meets a criterion, as specified by a simple query language, actions, such as alerts or automatic savings of profiles, are executed. The proximity awareness is similar to the Hummingbird device. The profile exchange is implemented with Jini over a campus wide WLAN.

3 Method

The purpose of our research is to invent new and useful applications based on the experience of people's mundane habits. This is achieved in a three-step process involving preparation through ethnographic fieldwork, generation through associative work in an interdisciplinary research group, and finally evaluation. Knowledge about users' social practices is a resource when inventing support for situation dependent interaction. The users often find it difficult to express the logic and methods of their collaboration and interaction. To overcome this we apply techniques of ethnographic fieldwork, which involve, the researcher participating, overtly or covertly, in people's daily lives for an extended period of time (Hughes, et al, 1992).

The ethnographic fieldwork was mostly conducted by one of the researchers who owns a bike and uses it every day during the summer. Specifically, he attended ten weekly biker meetings with approximately 200 to 400 participants between July and September 2001. He also participated in three organized one-day tours with at least 10 000 participants. During the same period, we also visited the message board on practically a daily basis. The material, which includes field notes as well as recordings of a message board, were then transcribed and coded. We went through the transcriptions, identifying a set of themes. A few sequences from the transcribed recordings were then chosen as showing the issues we examine in this paper.

The findings from the fieldwork played a major role in the design process, where it informed the development of a prototype. New design ideas were generated through an on-going discussion in the group starting after the ethnography had been pursued for a while and ending with the decision to implement an idea. This discussion took place in an interdisciplinary research group that combines an interest in social science with mobile computing. Finally, the prototype will be evaluated to determine its technical performance, and whether bikers will appreciate it.

4 Motorcycling as a Social Activity

Motorcycling is a highly mobile practice where people spend a considerable amount of time on the roads mostly to enjoy themselves. For most of them this is not an individual activity. They get pleasure in riding in the presence of others, and interacting both with acquainted and unacquainted bikers. This attitude is expressed in interviews during our fieldwork and also commented upon in other studies of motorcycle communities (McDonald-Walker, 2000).

The possibilities for direct communication with each other while biking are scant and restricted to gestures, honking the horn, flashing the lights, or using intercom technology. The latter is only of limited use among bikers. Instead, the most important interaction is provided through visual contact. This interaction normally concerns indirect matters such as impressing others with one's the choice of bike and its details, or with one's personal equipment. On other occasions they show off by performing tricks. Visual interaction is pursued to achieve identification. It is important to identify the person to give credit, or to identify a person as part of a specific group through icons and messages on their clothing. Finally, it is of importance to find friends and people to challenge.

A primary prerequisite for visual interaction is the need to be at least two persons at the same time and place, that is, one performing the act and one observing it. However, communication between motorcyclists is problematic due to the extreme mobility of each individual. They travel at high speed, which makes it difficult to get a good look at specific objects as well as very difficult to know where other bikers are located.

4.1 Opportunistic interaction, co-movement and place-centered movement

Interaction can take place in many settings. Mostly, it occurs as *opportunistic interaction* in situations where bikers occasionally meet while driving along the roads. This only allows for quick exchanges of impressions. Therefore bikers organize their movement in several ways to prolong the visual interaction. In the following, we will discuss how this coordination is handled and the problems, which are met.

One way of increasing interaction is to move together, or to move around a specific site. When moving together, (hereafter called *co-movement*,) bikers organize trips to explore untried roads with familiar bikers; they teach each other how to maneuver on familiar ones; or they simply go together to enjoy the bends on a particular route. When moving around a specific site, they select a location for visual interaction. We refer to this as *place-centered movement*. The stage is often given by tradition, i.e. places where bikers usually meet. During the summer there is a weekly gathering at a specific place “the Yellow Café” in the outskirts of Stockholm (Figure 1). A good portion of the activities taking place here concerns showing off. They impress each other with newly modified bikes, equipped for instance with high performance exhaust pipes, modified breaks, seat cowls, etc. They also show off by performing stunts, such as balancing on the front, or rear wheel (Figure 1). The site can also be selected through contingent negotiation, for instance, by cell phone communication. Often towards evening smaller groups end up leaving the place and heading towards more quiet areas such as industrial sites, where they race against each other.

In situations of place-centred movement, they use their motorcycles, or themselves, to carry information. At the weekly meetings, they benefit from the number of bikers present, by equipping their bikes with for-sale ads, or with stickers expressing their membership of various groups. At “the Yellow Café”, they park their bikes alongside the road and walk around commenting on other bikes. They often show interest in bikes either similar to their own, or ones they consider spectacular.

Fig. 1. This figure illustrates the weekly bike meeting at a specific place (to the left) and bikers performing stunts (to the right).

4.2 Interaction on the web

Motorcyclists have come to embrace the web to increase interaction. Although they achieve coordination through co-movement or place-centred movement, they crave more interaction. Recently several motorcycling web sites have evolved in Sweden. We are interested in a particular message board on a public website, which is used by a loosely knit community of bikers. We chose this community, since it has been possible to follow some of their activities in the physical world. The message board is popular, with approximately 5000 visitors each week, and almost 300 registered users.

The site hosts a number of discussions related to motorcycling such as interpreting what they have seen, and negotiating appropriate behavior. It is also used in similar ways as the road network. Many of the bikers express their identity on the web by using pictures or movie clips that demonstrate their skills. They have thumbnail pictures in their signature on the message board to show off, and take an interest in giving and receiving recognition for their performance. The thumbnails also facilitate the coupling between individual members of the message board and the bikers met on the roads, reconciling the virtual and the physical. Thus their identity is of great importance. But they are cautious about revealing themselves to unknown visitors. This is evident in how they edit out license plates, before publishing pictures and movie-clips on the web site.

But the web is a different media than traditional road use. We have chosen two excerpts, which display some of the benefits and problems of using a message board on the Internet to increase interaction.

Eyesight and interpretation of mobile contingent meetings

A common topic on the message board is specific situations experienced along the road. The encounters are normally very brief, and they would like to jointly interpret their impressions. The web is used to find persons with similar local interests to sort out the situation. This is the evident in the excerpt given in Figure 2. In this case, a group of bikers are making efforts to identify a motorcyclist someone saw being hailed by the police. The discussion is held during the evening, after a day filled with activities on the roads.

(23:28) Na: Saw a white/red/blue (?) CBR 900 which had been stopped at the Uppsala exit on the Stockholm highway southbound this evening around 11 pm. Was that one of 'us' and if so how'd it go? I buzzed by at a steady 70km/h and hurt with you... think it was the dark blue unmarked 850 seen earlier that evening which stopped the bike in question... /Na

(23:31) Ma: Sounds like Se unfortunately!!! ☹☹☹ He rides that way anyway, really hope it wasn't him, in any case that's eally too bad. ☹ Hope he doesn't lose their license! /Ma

(23:32) No: What carrot would stop because of one of those...Fre you know what I mean? Must have been an anticarrot!!!!!

(23:34) Gu: They just never give up. Saw him waiting there on the onramp right when I was getting ready to go for a wheelie. After that it was 70 all the way home. Almost forgot how slow that is...

(23:36) Pe: Sh** man... that sounds like Se... he dropped me off here in Gävle then he tool off for home... do you have to go by Uppsala and Company if you're going to Västerås?

(23:39) Gu: Heck of a detour via Uppsala from Gävle. Can't have been Se unless he was really itchin to ride...

(23:39) R1: Nope you don't go by Uppsala if you're going to Västerås...that was probably someone else unless he went the wrong way...Keep your fingers crossed for whoever it was anyway. Also I think we should take it a bit easy with names and the like from this evening..it seems we've stirred things up tonight...or as Mi said "We killed the queen in the hive next door and now they're a wee bit angry..." ☺

(23:44) Gu: "Queen in the hive next door" Hahahaha...ought to be a poet or something.

(23:46) Re: Just hope they don't have any fun film-clips shot tonight to work with tomorrow ;-)

(23:48) Pe: There's a real chance Se got lost on his way to the freeway tonight..☺ He ought to be home soon and be able to answer..

(10:07) Na: I dunno...probably wasn't Se... was a little newer bike than what he's got...I'd guess between 9700 but only saw it for a sec and it was dark so I could be wrong...well well, just hope things turned out all right

(11:23) Se: Nope! It wasn't me...whew! Lucky. There was a lot of the back wheel going home. Thanks for the kind thoughts anyway. I only got stopped by the police at The Yellow Cafe at 0 km/h.

Fig. 2. Excerpt of a follow-up discussion on the web after having seen a motorcycle stopped by the police.

Na has seen a white/red/blue CBR900 stopped by the police, at the exit to Uppsala. He initiates the discussion by asking whom the police hailed? Ma (line 10) guesses it is Se based on the description of the bike. Pe (line 23) agrees, telling that he was probably the one who met Se last. Later postings oppose the conclusion that it could be Se, since this would not be the normal route for him to drive. The mystery remains to be solved until Se ends the discussion (line 54) twelve hours later. Luckily, he was not the one who got caught by the police.

This excerpt shows how they end the evenings by using the message board to discuss what they have seen. There is a great deal of interest in identifying the motorcyclist stopped by the police, since they think it could be a member of the group.

It is clear that the bikers benefit from the increased interaction on the web. But in the case discussed, it is evident that the interaction could be more meaningful if the participants were more aware of the situation, in terms of who should address whom and at what time. In this particular case, the forum provides the means for too many unaware people to engage in the conversation, which keeps the conversation going, but without getting an answer to the initial question.

Organization of co-movement and place-centered movements on the web

The following excerpt from the message board depicted in Figure 3 shows how a group of bikers organize a joint ride. It indicates the problematic issues that arise when deciding on time and place for them to meet.

(09:03) R: I CAN'T TAKE IT ANY MORE! We have to get out and ride on wed again...who's coming? come on now, there should be more of us than ever...after all I'm going to show you what I've learned...I'm going to fall on wed...... muhahahahahahaha!!!!!

(16:11) T: I'm in!! 18:15 it's on????????? ☺☺

[excl. transcripts of seven confirmations]

(22:30) Ba: Couldn't we meet at mcd in Tyresö instead? Maybe we could let it rip a few times before all the "Bike-haters" go to bed. It'd be so f**ing great if we could let it rip some before the cops came☺

(22:43) E: I guess I'll be there and it doesn't matter to me where we meet.. If we meet in Tyresö then we could take a spin on little curvy and nice roads towards nynäshamn ☺ Ba you want a revenge race, right?☺

(22:45) Ba: Any time!

(23:18) P: If I get my piston rings like promised tomorrow, then I'll probably be able to take a spin with you! In any case I want to go to the Yelbw Cafe first....

(09:38) D: Coming later, have to work at a race first. Ought to be in at svea by about 21 And you guys who are out earlier, be sure to let loose properly, preferably right by Chairman Bluelight on one wheel.

(14:40) R: Awesome!!! but I'l l probably go to Donk's on Sveavägen...18:15.18:45 C U WHEN YOU GET THERE

(14:42) M: not coming if it's pouring...

(15:36) U: also not coming if it's raining at the stroke of 19

(15:44) Be: Might come...depends a bit..☺

(15:46) G: F**, is it raining up there in Stockholm? Here in Gothenburg we're suffering from brilliant sunlight...well ok some cumulous clouds☺ I'm in the best mood there is because my buddy's gonna drive me my 22km home from work on his new fireblade ☺☺☺☺ oh believe me if you don't have a bike and have only passed the theory test then this is the closest thing to total happiness you can get!!!

(16:31) F: Be, you have to come and bring with you one of those little tops that you should have on you a little...☺

(16:35) S: Coming, absfalutely...☺

(16:37) S: Forgot...was tyresö or svea????? ☺☺

(03:45) S: Okay I'll swing by tyresö first hope there's some carrots there, otherwise i'll/we'll come to svea....☺

(08:48) Mi: I'll come sputtering into Ronald's Place except in the event of precipitation...Seems like there's some mixed signals about where to meet and what time but I vote we just ride like usual, it doesn't get so complicated that way....☺

(16:52) N: McDonalds right??? What shitty weather we got!!!!! The Weather gods must love us carrots!!!!!

(17:05) 9: In at the last minute, are you guys going out to the yellow cafe or will it be some other local route? I won't be coming to the M, am sitting at work in Solna, will probably ride directly to the cabin and have a look then we'll see if I find any carrot peels.

(17:11) Be: McDonalds we'll be driving at between 18:1518:45...(like usual that is).... ☺☺

(17:14) U: Have to see if yer all still around when I get there. Have to go home and get the bike first. Otherwise see ya'll somewhere else along the way.

Fig. 3. Excerpt of an asynchronous web discussion when organizing a joint ride

R initiates the discussion by inviting the others for a joint ride two days later. The interaction goes smoothly during the next eight turns, i.e. while people only accept the invitation. It starts to get complicated when Ba (line 10) starts to negotiate the invitation and suggests another meeting place. This suggestion is explicitly confirmed by a second person. Then follows a series of short confirmations, which do not make it explicit whether they mean the first or the second place. Then D confirms the first place. Thereafter R, who made the initial request, acknowledges all those confirmations without commenting upon the discussion on a possible second place. The confirmations and the discussions continue, but nothing more is heard of R, Ba or E. In line 52, one of the participants raises the questions as to which place he has agreed to go to. He gets no answer for eleven hours and then puts up a message that he will go to both places! In line 57, Mi complains that they have not come to any conclusion regarding either time or place, and instead suggests that they should do it the traditional way and skip the negotiations on the web.

Much effort is put into deciding the specific place and time, but it is still not obvious when and where to meet, and who will turn up. We think that the deficiency of this particular interaction is due to two issues. First, it is difficult to reach consensus since the participants step in and out of the forum in unpredictable ways. When a message is posted it is not immediately obvious who receives it. This is the case where the objections to where to go, in line 10, are left uncommented. The cause may be the initiator (R) having already left the forum and thus not being available for negotiation. It is also difficult to repair misunderstandings, as visible in the eleven-hour delay to the request for clarification made by S on line 52. Second, the process of achieving mutual agreement is flawed by the website being public. People not familiar with the context may confuse the discussion. This is visible in the digression made by G on line 38, where G posted a comment on the weather in a different city. There could also be case of subtle digression in line 10. The objection by Be is perhaps ignored due to he or she is being in the fringe of the group, lacking context awareness, and being unacquainted with what he or she may suggest. This may explain why Mi and Be later, on line 57 and 72, state what the group usually does on Wednesdays.

In the light of these two cases, we propose a complimentary application that bridges the gap between the interactions on the road with the interaction on the web.

5 Requirements

What are the design implications of our ethnographic fieldwork? In this section we discuss our fieldwork in terms of the needs of the bikers as well as the problems they face in the current situation. We suggest that the bikers would benefit from a system that meets the following requirements:

The system should support an increase of interaction among bikers. Motorcyclists exert effort in coming together. This is visible in the ways they organize their movements. It is also clear, through the way they constantly adopt new technologies, such as the web, mobile phones, digital cameras, video recorders etc, that they have an interest in increased interaction.

It should use visual interaction as a resource. Current interaction is conducted during brief moments when the bikers are in eyesight. It is important to build upon the bikers' knowledge gathered in such moments to make the application meaningful and useful.

The system should facilitate interaction during biking, and not replace it with virtual activities. The interaction on the web is a way to increase interaction on the road, and not an alternative to road use. The system should bridge the gap between Internet and road use. Thus, it must be designed to work in highly mobile situations.

It should support the bikers when interpreting mobile contingent meetings. The prototype must be a helpful tool when answering the questions: Who did what/that, then and there? These situations mostly occur during opportunistic interaction.

The system should support the organization of co-movement and place-centered movement. Organization of movement is an important means to increase interaction, but difficult to achieve.

The system should provide a tool for the bikers to express themselves for many different purposes and in different ways. Bikers interact for various reasons, and they do it in ways that are sensitive to the context. It is essential that the bikers are in control of the means to express themselves.

The system should be built on publicly available resources. The system should be built on such software that the users are familiar with, in order to increase their ability to control the medium. It should also use standardized and commercially available technology to make it plausible to create a critical mass of users.

6 Implementation

The related devices and systems only address part of the requirements raised in our fieldwork. First, they do not recognize the extreme mobility conditions present during motorcycling activities. Second, they fail to provide means to meditate personal expression appropriately. Furthermore, these systems are constructed with non-standardized technology.

To meet the requirements, we implemented Hocman, an application for a handheld devices enabled with wireless communication. Since all interaction takes place within visual proximity, it is inherently co-located in time and place. However, the exact time and location where the interaction takes place is difficult to plan and even harder to predict. It is in these situations where functions, based on ad hoc networking, are highly applicable. Hocman is a peer-to-peer system that monitors the proximity of other peers and let users share data over ad hoc networks. To aid in the interpretation of contingent meetings we designed Hocman to record proximity events. Moreover, in order to have a meaningful track of meetings, the data recorded must somehow indicate from whom it was collected. However, this information must be contained in a very flexible format to encompass a wide variety of other purposes. We chose HTML, which supports text as well as other multimedia content, such as pictures and audio clips. HTML is a popular standard for documents and there is a large array of tools to generate documents. Finally, Hocman is assembled out of parts that are widely available. We chose the PocketPC operating system as our computing platform. The communication was implemented with IP over IEEE 802.11 WLAN network interface cards. The application includes a custom discovery protocol, implemented over UDP, and HTTP in order to accomplish file sharing.

The Hocman prototype supports two complementary modes - *cruise mode* and *explore mode*. Cruise mode is designed to run in the background, after being activated it need no further supervision. This lets the motorcyclist remain focused on the interaction at hand. Cruise mode is designed to, upon discovering a new peer, download that peer's index-page. If the download operation is successful, the index page, together with a time stamp, is inserted in a database. Later on, these pages may be inspected through a built-in HTML browser. The explore mode, on the other hand, provides group awareness. This mode is always active, even if cruise mode is running on top of it. Whenever this mode detects a new peer it is appended to the list of accessible peers. Apart from the awareness mechanism this mode also lets user inspect an accessible peer's pages through the browser.

By using Hocman, mobile contingent meetings, such as exemplified in the excerpt of Figure 2, could be interpreted easily. In this case, if the hailed biker carried a Hocman and the passer-by had its Hocman in cruise mode, the passer-by could examine the log to find the index-page of the stopped biker. If this page contains a nickname, a photo or any hint that could confirm his identity, the question would be answered. Hocman would also be of great help when organizing co-movement or place-centred movement. By using Hocman and having a digital reference to real world meetings, situations, such as in the excerpt of Figure 3, would not occur. In this case, if all bikers that go to the weekly meetings carry Hocmans in cruise mode; they would all have a record of the people to refer to. If the index-pages contains, e-mail addresses, or phone numbers, they could contact each other in a straightforward manner. If the pages only contain identity information as hinted by pictures or nicknames, they would at least be able to consistently address each other in the web forum.

The prototype is implemented in C/C++ interfacing the PocketPC system API. We tested the prototype on two sets of devices: Compaq Ipaqs 3660, equipped with a Lucent Orinoco WLAN card; and Symbol PPT 2700 with a built-in Spectrum24 WLAN card. In order to enable ad hoc communication the network cards are configured to communicate in IEEE 802.11 IBSS mode. However, each device is statically configured to a predefined IP number.

6.1 Peer discovery

The related devices and systems accomplish peer discovery by customized mechanisms. The Hummingbird, GroupWear, MemTags and Proem system use a beacon signal in order to detect other devices. However, constructing a scheme to find peers in the proximity that is compatible with standard technology is possible.

The problem of discovering and selecting network services has been addressed in the computer networking research literature and has been the target of many standardization attempts. It is related to locating peers, since a peer could be seen as exporting at least one service. The principal protocols and services are: Service Location Protocol (Guttman, et al, 1997), the Ninja System Service Discovery Service (Czerwinski, et al, 1999), and the Simple Service Discovery Protocol (Goland, et al, 1999). In these protocols and systems the service discovery builds on the assumption that the process can be clearly divided into either clients or services. In peer-to-peer systems all peers carry the exact same functionality; a peer can at some points act as a client and use another peer service capability; at some other points, the situation may be reversed. Hence, a discovery protocol for peer-to-peer systems must provide means to let all peers promptly discover all other peers' services. Furthermore, the related systems and protocols use the assumption that when a service has announced its presence it will stay present. However, a peer-to-peer system running over a wireless mobile ad hoc network is exposed to sudden connectivity changes. Thus a discovery protocol can never assume that once a service is found it will remain present for any longer period of time. At the same time a peer must be careful of its resources, broadcasting or polling announcements frequently may waste available system power, and have a detrimental effect on bandwidth. Also, due to the transient nature of ad hoc networks, a discovery protocol cannot rely on special devices or centralized services, found in SLPv2 and NSDS. Finally, the protocols except, for SSDP, support locating services in remote sub networks. In Hocman, the most interesting peers are close-by and the others can be ignored. Thus an appropriate discovery protocol only needs to monitor peers at close proximity.

DEAPspace (Hermann, et al, 2001) is a discovery algorithm that addresses most of the issues raised by peer discovery in mobile ad hoc networks. The evaluations of DEAPspace algorithm show that it is power saving and bandwidth efficient. However, for applications that support contingent meetings during conditions of high mobility, the most important aspect is to keep the time from zero knowledge to mutual discovery, as short as possible. In DEAPspace it may take up to five seconds until this is probable. A peer passing by at a speed of 50 km/h may travel up to 70 m before the discovery procedure is finished. Even at this moderate speed a peer may soon be out of wireless reach.

Peer discovery protocol in Hocman

In order to accomplish rapid mutual discovery in a group of Hocman peers, a slightly different approach than DEAPspace is needed. At each node a list of present peers is kept. Each entry in this list contains simple connectivity information, such as which port that peer's Hocman application listens to and its network identifier. Each entry is also associated with a timer. When it times out the entry is removed and the corresponding peer is deemed unreachable. At a regular interval, however slightly jittered, to avoid synchronization, each peer announces its presence by broadcasting a *hello* message. The hello message contains the basic connectivity data for that peer. When receiving a hello message from a peer present in the list, the timer for its corresponding entry is reset. Otherwise an entry is created and appended. However, this scheme cannot by itself ensure fast mutual discovery. With a broadcast rate set to x seconds, a peer must wait up to x seconds before receiving all hello messages from the other peers. What we want to achieve is: when a peer receives an announcement from an unknown peer it must immediately somehow declare its own presence. A naïve implementation, where a node blindly replies to every previously unheard announcement, would yield a message exchange of O(n^2), where n is the number of peers within wireless reach. This quickly gets out of hand even for a small numbers of n. However, to determine connectivity in a group of peers by broadcasting messages yields a transitive property. If peer C heard a message from peer A and later hears peer B tell that it knows A, then C can safely assume it is connected to B. This reduces the number of messages exchanged to achieve mutual discovery to O(n). Thus, we chose the following scheme: when a peer receives a hello message from a new peer; it appends it to the list and then waits a small random time before it broadcasts a *reply* message. A reply message contains the connectivity information from the sending peer as well as the peer that triggered it. When receiving a reply message, the peer checks if the following condition is present: is the reply sent from a new peer and is either the triggering peer present in the list, or is the reply triggered by this peer? If so, then the receiving node can safely assume it can reach the new peer and appends it to the list. Most importantly, it refrains from sending a reply message. In any other case the reply message is ignored.

6.2 Data Sharing

Besides discovery, a data sharing function is common to all peer-to-peer systems. All related systems use custom data transfer mechanisms except for the Proem system. The Proem system use Jini in order to accomplish this. First, Jini relies on centralized directory agents to store service availability information. However, data sharing in ad hoc networks must be fully distributed. Second, Jini is designed for Java and data sharing is accomplished through exporting methods to be invoked remotely. Thus, a program must be implemented in Java in order to accomplish sharing. We believe that in order to gain acceptance and widespread use, a data sharing mechanism must be independent of — yet accessible to — any programming language.

Data sharing protocol in Hocman

In Hocman, data sharing of HTML documents and embedded resources is achieved with the HTTP/1.0 (Berners-Lee, et al, 1996) protocol. In the Hocman prototype, a limited implementation was assembled, supporting a sub-set of HTTP commands. Servers support *GET* and *HEAD* commands. The *GET* command is the key in sharing documents. It attempts to map the incoming request to the local file structure and if there is a match the file is returned. The *HEAD* command checks the timestamp for a particular file and returns when it was last modified. In order to limit the bandwidth consumption, the servers implement the *If-Modified-Since* option for *GET* commands. If this option is present, the server returns the file only if the client's copy is out of date. Furthermore, in order to limit the time overhead for clients establishing connections with the servers, the *Keep-Alive* option is implemented for both commands. If the *Keep-Alive* option is present, servers keep the existing connection open for a maximum of three seconds, waiting to receive further commands.

The HTTP clients are modeled around two caching policies. The first is called the *get* method and the second the *reload* method. When the client receives an indication to request a particular file from a peer via the get method, it examines the cache for local copies. If a copy is found, it returns immediately and no communication is performed. Otherwise, if no local copy exists, a regular HTTP/1.0 *GET* command, with the *Keep-Alive* option, is issued. If the downloaded document is a

HTML document with references to embedded resources, the client will automatically retrieve them in a similar fashion, but using the open connection. However, if the reload method is used, the client explicitly issues a *GET* command with the *If-Modified-Since* and the *Keep-Alive* option included.

In Hocman, automatic downloads in cruise mode are implemented using the get method. In cruise mode, when the peer discovery protocol reports a fresh peer, an attempt is made to download that peer's index file. If this download is successful, a local copy is stored, with all pointers to embedded resources re-linked so that they point to their respective location in the cache. This is necessary in order to allow inspection of downloaded pages in retrospect, when the source peer is not present. Also, when the download is finished and successful, an entry is recorded in the discovery database. In explore mode, on the other hand, the get method is used when selecting a peer from the presence list. The reload method is used when the user pushes the "reload" button.

7 Testing

In order to determine whether the Hocman constitutes a reasonable technological approach to fulfil the requirements, we devised a test to measure its performance. There are several studies of how the performance of the communication sub layer is affected by mobility. Typically a particular set of routing protocols (Broch, et al, 1998) (Das, et al, 2000) (Johansson, et al, 1999) or variations of TCP (Holland & Vadiya, 1999) are evaluated for their relative performance under various forms of mobility. The performance is measured in fundamental metrics such as throughput, delay and loss rate. In these test the dominating definition of mobility is a relative large number of nodes moving randomly within a flat open rectangular area. Johansson et al (1999) demonstrate an alternative to this, where they define mobility by artificial movement scenarios and objects that possibly obstruct the communication path. All evaluations are similar in that data on performance is gathered from tests performed in discrete-event simulators. This investigation differs from the related work in that the test subject is a distributed application, not a communication sub layer; all testing is performed in a real world implementation, and the choice of mobility patterns is motivated from a study of motorcyclists' praxis. Furthermore, this study is not concerned with fundamental performance metrics directly but rather the implications they have on perceived application functionality. Finally, the performance evaluation of the Hocman prototype is somewhat more limited than the related work, since it is implemented over a single hop mobile ad hoc network.

7.1 Mobility metric

Our field study reveals that motorcyclists interact during place-centred movement and co-movement. These could be divided into four patterns. Two patterns emerge when the motorcyclists remain in the vicinity of each other. The first is when standing still or walking about, which is one extreme of place-centred movement. The second pattern occurs in co-movement i.e. cruising together along the highway. Additionally, two more patterns are evident during mobile contingent meetings. The first happens when a biker or a group of bikers *pass* a stationary individual or group, which occurs in place-centred movement. This is similar to the case when passing somebody moving relatively slower in the same direction, which occurs during co-movement. The final case is evident when meeting somebody travelling in the opposite direction. A closer examination reveals that what is different from case to case is the relative speed between each pair of bikers. This is captured by the *mobility metric* (Johansson, et al, 1999).

The mobility metric, denoted M, captures the overall mobility in a particular scenario with a single value. The movement of each node in the network is interpreted as a vector, as it has both magnitude (i.e., speed) and direction. The value M is an average of the mobility measure M_{xy} between every pair of nodes (x,y) participating in the scenario. M_{xy} is the absolute relative speed between node x and node y averaged over the time the scenario lasts. By definition, the mobility metric expresses the average relative speed between all participants of a particular scenario. Hence, the value of the mobility metric in a scenario where all are standing still, or moving together at the same speed and direction, is zero. In a scenario where two people meet walking straight towards each other in a corridor, the mobility metric is about 2.

Re-interpreting the movement patterns, we found that they map to three intervals of mobility-metric values. The first is concerned with a range of low values, 0 to 5.0, which happens when the motorcyclist remain in the vicinity of each other.[1] The second spans a range of medium values, 5.0 to 15.0, which occurs during contingent meetings, typically when passing a group standing still or travelling in the same direction. The last range is concerned with high values, above 15.0, which happens when meeting someone going in the opposite direction. Browse mode must withstand conditions of low to medium values. Cruise mode must endure the whole range from zero to high values.

7.2 Performance evaluation strategy

When evaluating the performance of the sharing as affected by mobility, three factors are relevant. The first is concerned with the number of active prototypes in a scenario. A large number will increase the contention for media access, affecting throughput and delay and thus having an impact on the functionality. The second concerns the amount of data, which the prototype is able to distribute. Large files will take longer to download, which in turn makes it vulnerable to connectivity changes due to mobility. For instance, if a device quickly moves out of range the download operation of a large file runs a larger risk of failing. A third aspect of data size is the amount of embedded resources. An HTML page with single embedded file of size N will be less intensive, in terms of bandwidth and processing power to download than a page with three embedded files of size $N / 3$.

We evaluated the Hocman prototype in three variables: mobility as measured by the mobility metric; the number of devices in each scenario; and the size of shared data. The goal of the evaluation was to locate the limits of the functionality; that is, to find the mobility conditions when the prototype ceases to operate as intended. We set this condition to: when a file failed to download, failed to be added to the log, or failed to appear visually (or audibly). In order to derive meaningful results, a primary condition was set to: the system must be able to initiate sharing of data of a size greater than zero. We chose to evaluate the performance of automatic downloads in cruise mode from previously unknown nodes. In this situation, all Hocman peers present do the following; first they locate the other peers and then they download each other's index files. When a download operation completes, a log entry is made, the index file are examined and the embedded resources are downloaded.

---

[1] We estimate that the systems presented in related work are designed for settings where the mobility metric is in the range of low values.

7.3 Reults

In order to test the functionality according to the strategy we decided on the following scenario. The scenario involves three Hocman peers. Each peer was running on a Compaq Ipaq 3660 with a Lucent Orinoco Network Cards, set in IBSS mode with no encryption. We constructed three sites that we think represent typical usage and assigned each site to a particular peer. The size of the index page, the number of embedded resources and their collective size are depicted in Table 1.

Peer	Index Page Size [Bytes]	# Embedded Resources	Resource Size [Bytes]
A	1 310	2	67 914
B	921	1	8 597
C	1 241	1	7 138

Table 1. The peers and their assigned resources

We placed the *B* and *A* peers next to a straight, flat road and drove by with the *C* peer at various speeds. The road was lined with trees on the opposite side of the stationary peers. About 4 meters behind them was a slope — the section of the road we used in the test resided on an elevation — about 2 meters higher then the surrounding ground. The elevation rose about 200 meters away on either side of the stationary peers. The *B* and *A* peers were placed 2 meters apart, however the *A* peer was one meter behind the *B*. We drove by with the *C* peer from right to left and each test run was repeated 5 times. For each repetition, the log and the cache of each peer were cleared. The success criterion was set to: while running cruise mode the *A* and the *B* peers must download, log and display the index page and the corresponding resources of the *C* peer; however, the *C* peer must download and log from both *A* and *B*. The success rate for each peer and the mobility metric for each speed, are given in Table 2.

Peer	Download From	Object	Mobility Metric		
			9.0	12.6	16.2
C	A	index page	100	100	100
		resource 1	100	100	40
		resouce 2	100	100	20
	B	index page	100	100	100
		resource 1	60	100	60
A	C	index page	100	100	100
		resource 1	100	100	80
B	C	index page	100	100	100
		resource 1	100	100	100

Table 2. Success rates (in percent) for each mobility metric. 9.0 in mobility metric corresponds to driving by at a speed of 50 km/h; 12.6 to 70 km/h; and 16.2 to 90 km/h. *Walking* by (at a speed of 3.6 km/h) corresponds to mobility metric 0.7

In the column, showing the success rates for mobility metric 9.0, the *C* peer failed twice to download the embedded resource from the *B* peer. We have not found the cause for this. In the column showing the rates for mobility metric 16.2, we note that all peers except, the *B* peer fails to download the embedded resource it is supposed to, however all nodes are successful in downloading the index pages. We believe that the bottleneck is the processing capabilities and not the bandwidth; the devices are not able to process the requests quickly enough.

8 Conclusion

Our work contributes to the research area of ubiquitous computing in the following ways:

Interdisciplinary work that combines an interest for social science with mobile computing has played a major role when inventing new and useful applications based on acquaintance with people's mundane habits. The fieldwork is of importance in searching for interesting environments and application areas.

The activities we explore take place in an extreme setting, where the mobility by far exceeds what has been reported in earlier work. Despite these conditions, the motorcyclists struggle to express themselves to others, and the prototype will facilitate their attempts to interact.

When developing a system it is desirable to use standardized and commercially available technology. It should be built on software that the users are familiar with, in order to increase their ability to control the contents and thus their personal expression.

The complex setting makes apparent the importance of stepping out of the controlled test-lab or the theoretical simulations to get an understanding of the functionality. The technical evaluation is performed in a real world implementation and the choice of mobility patterns is motivated by the fieldwork. The prototype supports the discovery and sharing of data in the proposed setting.

References

Berners-Lee, T. Fielding, R. and Frystyk, H. (1996). *Hypertext Transfer Protocol -- HTTP/1.0*, RFC 1945.

Borovoy, R. Martin F. Vemuri, S. Resnick M. Silverman, B. and Hancock, C. (1998A). MemeTags and Community Mirrors: Moving from Conferences to Collaboration. In *Proceedings of CSCW'98*, ACM Press, New York.

Borovoy, R. Martin, F. Resnick, M. and Silverman, B. (1998B). GroupWear: Nametags that Tell about Relationships. In *Proceedings of CHI'98*, ACM Press, New York.

Broch, J. Maltz, D. Johnson, D. Hu, Y. and Jetcheva, J. (1998). A Performance Comparision of Multi-Hop Wireless Ad Hoc Network Routing Protocols. In *Proceedings of Mobicom'98*, Dallas, Texas, USA.

Czerwinski, S. Zhao, B. Hodes, T. Joseph, and A. Katz, R. (1999). An Architecture for a Secure Service Discovery Service, In *Proceedings of Mobicom '99*, Seattle, Washington, USA.

Das, S. Perkins, C. and Royer, E. (2000). Performance Comparision of Two On-Demand Routing Protocols for Mobile Ad Hoc Networks, In *Proceedings of Infocom 2000*, Tel-Aviv, Israel.

Esbjörnsson, M. and Östergren, M. (2002). Hocman: Supporting Mobile Group Collaboration. In *Extended Abstracts of CHI'02,* ACM Press, New York.

Goland, Y. Cai, T. Leach, P. Gu, Y. and Albright, S. (1999). *Simple Service Discovery Protocol version 1.0 - Operating without an Arbiter*, Internet Draft, draft-cai-ssdp-v1-03.txt, Work in progress.

Guttman, M. Perkins, C. Veizades J., and Day, M. (1997). Service Location Protocol Version 2, RFC 2165.

Hermann, R. Husemann, D. Moser, M. Nidd, M. Rohner, C. and Scade, A. (2001). DEAPspace - Transient Ad-Hoc Networking of Pervasive Devices. In *Computer Networks 35*, volume 4, pp 411-428, Elsevier Science.

Holland, G. and Vadiya, N. (1999). Analysis of TCP Performance over Mobile Ad Hoc Networks, In *Proceedings Mobicom'99*, Seattle, Washington, USA.

Holmquist, L.E. Falk, J. and Wigström, J. (1999). Supporting Group Collaboration with Inter-Personal Awareness Devices. In *Journal of Personal Technologies*, 3 (1-2), pp. 13-21, Springer Verlag.

Hughes, J. Randall, D. and Shapiro, D. (1992). Faltering from ethnography to Design. In *Proceedings of CSCW'92*, (pp. 115-122). ACM Press, New York.

Johansson, P. Larsson, T. Hedman, N. Mielczarek, B. and Degermark, M. (1999). Scenario Based Performance Analysis of Routing Protocols for Mobile Ad Hoc Networks, In *Proceedings of Mobicom'99*, Seattle, USA.

Kortuem, G. Segall, Z. Thaddeus, G. and Cowan, T. (1999). Close Encounters: Supporting Mobile Cooperation Through Interchange of User Profiles. In *Proceedings of HUC'99*, Karlsruhe, Germany.

McDonald-Walker, S. (2000). Bikers – Culture, Politics and Power. Berg, Oxford.