Bubbles: Navigating Multimedia Content in Mobile Ad-hoc Networks

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Abstract

We aim to support spontaneous and opportunistic human behavior by taking advantage of an emerging environment for mobile ubiquitous multimedia applications enabled by the fusion of ad-hoc networks, peer-to-peer computing, and media-rich mobile devices. Guided by an ethnographic study of spontaneous and opportunistic human behavior, a new concept, called the *Bubble* concept, is proposed that helps users navigate multimedia content made available in mobile ad-hoc networks. The concept is intended to guide the design of user interfaces that provide users with impulses that may trigger spontaneity and opportunism. We used the *Bubble* concept to design and implement a portable audio player application that provides music impulses to users. The application runs on WLAN-equipped iPAQs.

Keywords: spontaneous behavior, ad-hoc networks, multimedia content, user interface.

1 Introduction

Constant progress in hardware and software technologies brings us closer to the vision of ubiquitous computing where information technology becomes an integrated part of our daily lives. One recent technological development is the fusion of wireless ad-hoc networks, peer-to-peer computing, and multimedia content on network-enabled, mobile devices. Local, wireless ad-hoc networks form spontaneously as devices move within radio range of each other, briefly establishing connections before further movements bring devices beyond communication reach [Perkins]. Peer-to-peer computing enables decentralized applications to discover and to exchange resources that happen to be available on peer devices currently connected to the network [Oram]. We are now witnessing the rapid emergence of a variety of new network-enabled, mobile multimedia devices. A major trend is the addition of local networks, digital cameras, audio players, and gaming to mobile phones. Another trend is the addition of local networks and powerful computing hardware to both stationary and portable consumer electronic devices, e.g., cameras and audio/video players. The result of these technological developments is a new environment for multimedia applications, a highly dynamic, decentralized environment spanned by increasingly ubiquitous mobile devices within radio range that spontaneously discover each other and share multimedia content. A user carrying a device in this environment may experience connections and be exposed to subsequent interaction opportunities—typically of highly variable durations—in a completely unplanned and non-deterministic fashion. There may be no permanent (centralized) infrastructure to fall back on when connections are broken due to movements or other reasons.

We are interested in developing applications for this new dynamic environment that spontaneously makes multimedia content on nearby devices available to users. In order to do this we need to take actual human behavior and practice into account prior to developing concepts for new applications. We argue that the said technological environment for multimedia applications has its analogy in normal spontaneous and opportunistic human behavior and practice. Humans continually make spontaneous and opportunistic choices in response to impulses from their immediate environment. This is a type of practice that by nature is fundamentally unpredictable and ad-hoc. Knowledge about the processes of human spontaneity, choice making, and interaction is therefore fundamental and should inform both the design of applications and how information is presented to users.

We conducted an ethnographic study to guide the development of a concept, the *Bubble* concept, to support users in navigating multimedia resources in wireless ad-hoc networks. A key finding from the ethnographic study was that unplanned events and spontaneous actions lead to a constant redefinition of one's self-understanding and goals, in addition to the identity one seeks to convey to the surroundings. This, we argue, implies a need to convey to users the full nature and extent of the resources currently available in the environment, but to do so in a way that is un-confusing and easily navigable.

An information bubble metaphor is central to how we expose users to content sources briefly available in the environment. The metaphor derives from the notion that the extent of the short-range radio waves emitted from a mobile device may be pictured as a sphere. Advertised content stored on a device is available inside its information bubble; when a device moves, its information bubble moves with it. When two devices move within radio range of each other, their information bubbles merge and the combined advertised content of the two devices becomes available to both. Conversely, when two devices move away from each other, causing a connection break between the two, content belonging to either device will no longer be available to the other (their information bubbles become disjoint). The sudden appearance of information bubbles enables users spontaneously and opportunistically to access any content of interest before the inevitable, and equally sudden, disappearance of the same

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information bubbles. Content access, in the context of our Bubble concept, translates technologically into the direct transfer of content between peers.

We believe that the *Bubble* concept is a promising approach for keeping users up to date about the overall nature and fluidity of multimedia content available in the nearby surroundings. Unfortunately, the limited rendering resources of a small-size mobile device greatly reduce the level of completeness and detail that may be visualized. Profiles are a common tool to help reduce the effects of information overload on users of mobile devices. However, we argue that the concept of profiles runs counter to our aim of supporting spontaneity and opportunism. Instead we propose to extend our *Bubble* concept with an alternative heuristic mechanism more tailored to generate impulses in users. This mechanism randomly and continuously selects atomic units of multimedia content currently available on other devices and briefly renders a description of the selected content.

Based on our proposed *Bubble* concept, we designed an audio player that allows users to navigate available audio resources in an ad-hoc networking environment. We present the user interface design and report on an expert evaluation of the interface. A technical prototype of the application has been implemented and tested with a small number of users.

This paper is organized as follows. We start by briefly describing related work. Then, as a motivation for the *Bubble* concept, we go into some detail about spontaneous and opportunistic behavior and report on the findings of an ethnographic study that we conducted. A more in-depth analysis of the relationship between the elements of the *Bubble* concept and their theoretical underpinnings is given next. Then, we give an account of the design and evaluation of the user interface of our audio player application. We also give a brief description of the technical prototype that we implemented. Finally, we offer our concluding remarks.

2 Related work

This section presents related work. We start by considering a prototype application that enhances the experience of chance encounters and whose design was guided by ethnographic fieldwork. Next we present two applications aiming to support opportunistic interaction. Then, we compare our work to work on social, location-based information spaces that are open to all mobile users. Finally we describe two recently proposed application concepts for joint music listening in mobile ad-hoc networks.

Hocman is a prototype mobile application for motorcyclists designed to enhance the social experience of encountering other motorcyclists on the road [Esbjörnsson]. Basically, Hocman prototypes detect each other when spontaneous connections are established in mobile ad-hoc networks and the establishment of a connection is signaled to the driver as an audible icon. During such brief connections on the road, information in the form of a simple web page is exchanged. The road encounter is enhanced in two ways: both by the early alert and by the knowledge that information about the other driver will be available for browsing. The researchers behind Hocman chose to conduct an ethnographic study of motorcyclists and how they encounter each other on the road. The results from the study informed the design of Hocman. Similarly, we also use ad-hoc networks, peer-to-peer exchanges, and mobile devices with multimedia content to support specific human behavior, i.e., spontaneity and opportunism. We also decided to conduct an ethnographic study to better understand the behaviors and practices in question. Our focus differs from that of Hocman in that we aim to generate impulses to be acted upon immediately rather than at a later time.

The Aquarium is an information retrieval metaphor and application for opportunistic exploration of on-line stores [Bryan]. The main aim of the Aquarium metaphor is to find a fun way of exposing millions of products in a store's inventory so as to agitate active or latent interests in the user or to create new interests. The proposed metaphor lets pictures of random inventory move across a screen like fish in an aquarium. The pictures are tied to product categories and simple operations allow users to ask for more or less of the category in question. A main challenge is to adjust the width and scope of categories to match the intensions of users. As a metaphor, an aquarium is an interesting alternative to information bubbles, though we deal with a far less centralized and structured content base. An interesting similarity to our work is the mechanism of picking random items from a vast inventory to generate impulses.

Proxy Lady is an application for mobile ad-hoc networks that aims to facilitate pre-meditated opportunistic communication between users [Dahlberg]. Basically, a user A decides that she wants to talk to user B and tells Proxy Lady to notify her should she happen to come within (radio) range of user B during the day. Our *Bubble* concept does not include the notion of subscribing to notifications. This is mainly because we aim to support opportunism in a more spontaneous (i.e., less pre-meditated) setting than Proxy Lady.

The decentralized, almost anarchistic nature of information spaces built with peer-to-peer computing technology on top of mobile ad-hoc networks invites users to advertise personal multimedia content to the world around them. This leads to a social and dynamic information system similar to that envisioned by researchers working on GeoNotes [Espinoza]. GeoNotes is concerned with digital, location-based spaces that are open to anyone to leave their "notes", e.g., messages or statements. The group behind GeoNotes predicts that this could lead to information overload and that users risk being bombarded with heaps of unwanted, irrelevant information. Filtering is therefore a key focus of GeoNotes. However, lack of experience from real usage makes it hard to judge the magnitude of the information overload problem in information systems focused on the immediate, local setting. As our focus is on generating impulses to support spontaneous and opportunistic behavior, we try to avoid explicit filtering. Nevertheless, our *Bubble* concept does provide some means of limited, implicit filtering, i.e. rendering all resources from a single device as one information bubble and picking a few random items from the entire, available content universe to hint at its flavor. Also, in a similar fashion to GeoNotes, the *Bubble* concept may allow each user some control over how their information bubble is rendered on the devices of other users (making a statement), in effect creating a kind of social filter.

[Axelsson] and [Bassoli] introduce the concept of mobile music listening as a shared, social activity. The idea is to equip portable music players with ad-hoc networks and to allow nearby users to connect to each other's players to hear what is currently being played. [Axelsson] has focus on music players in vehicles and aims at providing entertainment for occupants of cars. [Bassoli] envisions an urban setting where shared music experiences help form local communities. Music is also a central theme in the portable audio player we designed and implemented to test our

Bubble concept. Our player currently does not include the notion of joint listening since we focus primarily on supporting spontaneity and opportunism. We do, however, consider support for socializing an interesting feature and our *Bubble* concept provides some support for it through identity statements.

3 Spontaneous and Opportunistic Human Behavior

We are interested in supporting spontaneous and opportunistic human behavior. At an early stage, we saw a strong relationship between such behavior and characteristics of emerging ubiquitous computing environments based on mobile ad-hoc networks and peer-to-peer computing. We will now briefly describe some of those characteristics before taking a closer look at the nature of spontaneity and opportunism.

Ad-hoc Networks and Peer-to-Peer Computing

Mobile ad-hoc networks are spontaneous, self-configuring, wireless networks with no fixed infrastructure. Connectivity in an ad-hoc network is governed by distance and radio range. As devices move about they are able to detect and connect to other devices that are in sufficient proximity. When connected devices move outside of radio range, connections are broken. This means that in ad-hoc network settings, mobile devices come and go, and thus create a highly dynamic network structure. The local aspect of ad-hoc networks must also be emphasized, i.e., that typical radio ranges typically stay well within about 100 meters. We therefore say that ad-hoc networks are geographically situated locally. This attribute of ad-hoc networks relates them strongly to the situated-ness of human spontaneity, a point that will be further discussed below. The decentralized nature of ad-hoc networks fits well with the principles of peer-to-peer computing. Peer-to-peer computing refers to a class of applications that enables users to form logical networks on top of any infrastructure and to share and exchange digital content. Interactions between peers in a peer-to-peer network are by definition independent of central servers. Pure peer-to-peer networks also allow peers to join the peer-to-peer network and to discover peer resources without a server infrastructure. As such they are similar in spirit to ad-hoc networks and emphasize the autonomy of the individual user in being able to connect to and to exchange content directly with any other user in the network. Combined, ad-hoc networks and peer-to-peer computing lay a foundation for spontaneous digital information exchange and communication between nodes in a very rapidly changing environment.

The following scenario further illustrates the technical environment of this paper. Imagine people gathering at a bus stop with their mobile devices. Instantly, an ad-hoc network is forming, and as people leave with their buses and others join the crowd, the topology of the ad-hoc network changes. Also, multimedia content such as pictures, music, video, etc., may be available on devices for others to discover using peer-to-peer computing mechanisms. A highly dynamic and complex landscape of resources has been established, changing continually and unpredictably, perhaps even as a user is trying to access another user's content. From the individual user's point of view, resources appear and disappear, offering impulses to be acted on quickly or forgotten.

Exploring Spontaneity and Opportunism

We believe that the emerging environment for multimedia applications described above also has a strong foundation in social life, namely spontaneous and opportunistic behavior. Spontaneity refers to that human state of mind where choices and actions are made voluntarily based on momentary impulses; while by opportunistic behavior we mean taking advantage of opportunities as they arise, i.e., grabbing what is offered if it catches your interest. This type of behavior is basically unplanned, not necessarily (though often) guided by social demands like norms and trends, and responsive to the impulses we are continually exposed to, as we perceive our surroundings. This behavior is always situated, i.e., impulses are perceived here and now, and are reacted upon (or not) in a geographical, local setting. This is true simply because we as human beings are physical in essence, and thus always located. Our perception of the world therefore always includes a perception of our immediate context. An important question arises next: How do people make spontaneous choices, and what does this imply for our concept?

We performed an ethnographic study to examine this question more closely [Bach]. Through a qualitative microanalysis[1] we have investigated the relationship between what people say they are going to do and what they actually do, and how meaning is formed in situations where something unforeseen happens. The research was conducted through a participant observation of two core informants during several weeks. In addition to this, several interviews were conducted. Through participant observation we were able to identify the meaning related to actions and behavioral patterns, which the informants normally took for granted in daily life.

Our findings show that unforeseen events and actions during the day were redefined and became legitimized to fit the informant's understanding of his or her surrounding whole (context). In other words, the informants redefined their contexts and ultimate goals to accommodate surprising events or unplanned actions. The whole, the ultimate goal of the informant, was thus continually refitted to accommodate its unexpected parts, and these parts thus became meaningful to that person. There is, in other words, a strong relation between a person's understandings of context, i.e., its meaning, and the spontaneous, opportunistic choices that person makes.

An empirical example from our fieldwork describes this redefinition of ultimate goal: X is planning to watch a soccer match later the same day. His ultimate goal is to watch the game at night with his friends. During the day, several incidents occur and he watches the match with a completely different crowd. The meaning X ascribed to the football match was thus redefined because of the incidents during the day [Bach]. Following this argument, the meaning people assign to a predefined goal has to be seen in relation to unexpected events that occur: these events are continually re-contextualized. By neglecting to consider this hermeneutic circle, we run the risk of missing the meaningful aspects people give social contexts.

We now look at implications of the said findings in terms of our goal of supporting spontaneous and opportunistic behavior through the use of a technological environment based on a fusion

[1] A qualitative microanalysis is a type of methodology that covers a very large number of variables for a small number of informants. The 'micro' in microanalysis does not mean a small study, but rather a study of many minute details [Pelto].

of ad-hoc networks, peer-to-peer computing, and media-rich mobile devices. Firstly, we argue that the environment must be flexible and open enough to tolerate the continual redefinition of context intrinsic to spontaneous behavior. Also, this type of behavior implies a constant redefinition of one's self-understanding and the identity one seeks to convey to one's surroundings. The environment must therefore be as flexible and distributed as possible, and avoid pre-planning, filtering and central control. Secondly, we argue that the environment must be able to convey the nature and complexity of the context (the landscape of multimedia content) to the user, but at the same time making it intelligible and navigable. There is potentially a danger of information overload. However, filtering out information based on pre-conceived notions about relevance to the user in a particular context should be avoided. The rendering of the context should reflect its high level of dynamism. This is important to ensure a closeness between a user's perception of his or her surroundings and that user's understanding of the visual representation of these surroundings.

4 The *Bubble* Concept

In the last section we arrived at the conclusion that in order to provide application-support for spontaneous and opportunistic behavior, we need to solve the problem of simple and effortless navigation of multimedia resources available in ad-hoc, peer-to-peer environments. To solve this problem we have formulated the *Bubble* concept. Central to this concept is the vision of users carrying mobile, media-rich devices able to engage in spontaneous communication and content exchange. Devices and their multimedia content can be thought of as comprising information *bubbles*, i.e., as resources surrounded by a sensitive sphere, that, when overlapping with other information bubbles, would connect and facilitate communication and content sharing (see figure 1).

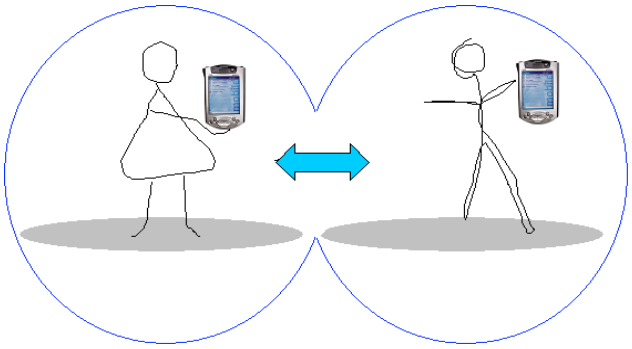

Figure 1: Overlapping information bubbles facilitate sharing of content.

The main mechanisms underlying the *Bubble* concept are those of discovery of other information bubbles and interaction in the form of content browsing and sharing. These mechanisms are always rooted in the local setting. The *Bubble* concept also includes the idea of letting users express their social identities and social group memberships. In practice this is done through the possibility of choosing or designing one's own iconic representation, and enabling users to make public statements such as grafitti, tags, or exclamations. In the Bubble system, this feature has some valuable navigational significance (see below).

A central question in systems that aid a user in navigating and understanding the immediate context is how to build systems that filter information often available to users and offer only that which the user wants. A common solution to this problem is to make use of user profiles that informs the system of the user's preferences. In relation to the behavioral context of spontaneity and opportunistic behavior, however, the use of user profiles is problematic: predicting or deciding how, when or where to be spontaneous in advance is impossible. In principle, therefore, user profiles work counter to the idea of spontaneous behavior. Furthermore, the constant redefining of identity that a user executes as he or she moves through various contexts makes it hard to predefine a given user profile; the profiles themselves changes as users move through different social contexts. This basic sociological insight has been illustrated by Erving Goffman [Goffman], and can be exemplified by the way most of us communicate radically different personalities to the world at work and at home. Moreover, the idea of an environment based on ad-hoc principles is incompatible with the idea of pre-defined user profiles. A system has the same problem as the individual user: it cannot predict when and where spontaneous behavior will occur. In addition, the continual redefinition of the context itself by the user further complicates such predictions.

The question of how to help users attain a minimum of context awareness still remains, though. For the *Bubble* concept this is an issue that we continue to work on. For the time being this problem rests heavily on users themselves. Firstly, as we have argued, there is a strong connection to actual place in the *Bubble* setting. The range of the radio technology used in the system and the demands of immediacy and spontaneity firmly roots the *Bubble* concept to a limited geographical area. This may suffice as an information filter for many applications, i.e., leaving it to users to decide which impulses are relevant. Secondly, the social identity features of the system work as an information filter and navigational aid. Social identity markers, like music taste or use of slang, are important ways of showing the rest of the world who we are and where we belong. This is a type of knowledge we use daily when we categorize, sort, and filter the impulses and information around us. As such, identity markers and statements can be used as a basis to choose the information one finds interesting in a particular situation. In other words, it is a simple filtering mechanism based on social navigation (see for example, [Forsberg], [Höök], or [Munro] on social navigation issues).

The process of perceiving and conceiving of the surroundings is a semiotic process. David Benyon has conceptually divided the world we live in into an information space and an activity space [Benyon]. These different but interconnected quantities represent an attempt to express this semiotic process. As a person perceives something in the activity space, this something is interpreted, contextualized, and finally understood, i.e., conceived and fitted into the information space. The information space is therefore based on the activity space, but also vice versa. As we conceive, we reconfigure our information spaces and thereby allowing ourselves to perceive our activity space from a new perspective. This semiotic process is at the hart of our proposed *Bubble* concept's context awareness. It is this process that the system is meant to support, namely to facilitate an understanding of one's context based on how this context changes as the available information changes. This process is at the heart of making spontaneous choices.

Limitations of the Bubble concept

We believe our *Bubble* concept is well suited as a foundation for user interfaces that expose users to impulses, hence supporting spontaneous and opportunistic behavior. We are, however, aware

that the *Bubble* concept may suffer from two potential limitations. Firstly, it is central to our vision of supporting spontaneous and opportunistic behavior that as little information as possible in the *Bubble's* vicinity be filtered away. This lack of information filtering may result in a situation of information overload, e.g., at big gatherings such as concerts. Secondly, the *Bubble* concept is targeted at a mobile setting while at the same time requiring the user's attention in order to communicate impulses. Currently, the *Bubble* concept provides little help for solving this user interface challenge of communicating impulses to mobile users without requiring too much attention. The severity of these potential limitations can only be determined through evaluations that we hope to conduct as part of future work.

5 An Audio Player Providing Musical Impulses

As a demonstration of our proposed *Bubble* concept, we now present the design and implementation of a prototype audio player application that provides users with musical impulses. The idea behind the application is that of a mobile audio player capable of discovering other player applications and sharing music playlists and other content. The goal is to provide users with music impulses by exposing available playlists and letting users navigate those that catch their interest.

User interface Design

The user interface should be dynamic and flexible without confusing the user. We have chosen a fairly large color display on a portable device as the medium of the user interface.

The audio player application's core feature is to exchange playlists and music, but content such as pictures and winks [Microsoft] are also supported. In this description we will focus on how users spontaneously connect to other bubbles and how content is exchanged.

Figure 2: The start-up screen

Figure 2 shows the main screen of the Bubble application. Note that all screen-shots are mock-ups; the complete user interface is still not implemented and tested on real users[2]. The screen is divided into three areas. The main area in the middle shows other bubbles within range. According to the physical locations and radio ranges of nearby users carrying wireless devices, bubbles may appear and disappear, thus the picture is reflecting the dynamic nature of the environment. The bubbles are placed randomly on the screen. The screen shows up to 7 bubbles at the same time, but the number of bubbles within range may be higher. The user may therefore use a zoom-tool to get a full overview of all bubbles.

The area on the top is a ticker, where the user is exposed to a random sampling from all the MP3-files that are advertised in playlists. The list moves from the right to the left. The user may select one of the icons and the MP3-file will immediately start streaming. The user can then decide to download the file or to go directly to the Bubble from where it is streaming and check out other content. This is a bottom-up approach meaning that the user is presented directly to the content. The ticker provides impulses that may trigger spontaneous or opportunistic behavior from users.

The area at the bottom is a collection of functions such as a shortcut to the user's own files, setting of configuration properties, searching in the currently available content, zooming, and help. The functions are context-aware and adapted to the task the user is performing.

The bubbles in the middle area are the main door step to content. To each icon, is augmented with information about how many files are available in each of three different categories: music, pictures and winks. The users themselves design the icons that represent the bubbles. This gives the users an opportunity to reflect their identity and give other users an idea of what kind of interest they have. This gives a user a first impression as to whether the content correspond to his or her interest. Furthermore, when a bubble is explored by clicking on it, a new screen shows more detailed information about the bubble and the content. Here the users can express themselves by writing a statement to show their identity. An example is shown in figure 3. From this screen the user can decide if he or she wants to explore and download content or go back to explore other bubbles. This method of navigating is based on identity, appearance, fashion, social statement and culture and is inspired by social navigation.

The functions area of the statement screen is different from that of the start-screen. A new function for getting in touch with the user in question by sending a wink and start chatting has been added. The zoom feature is not relevant in this context and has been removed from the function-list.

[2] Though, a subset of the interface has been implemented in a technical prototype.

Figure 3: Identity statement

If the user decides to explore the content of music files, the screen in figure 4 will appear. It is a simple list of MP3-files sorted alphabetically. Information about size and quality of the file is attached to each file. When a user clicks on the filename, the corresponding song (or perhaps a short thirty second, say, version) starts streaming across the network. This helps the user decide whether to download the song or not. To download one-by-one, the user selects a song and then clicks on a download button. It is also possible to download all music files by clicking on a single button.

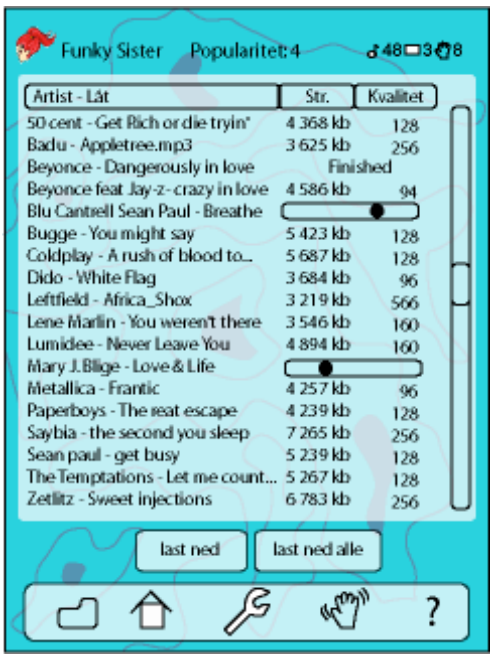

Figure 4: Exploring and downloading content

Expert Evaluation

The process of user interfaces design is iterative. In order to get feedback in the early iterations we conducted an expert evaluation. We ran three workshops where user interface experts and designers worked together in pairs. They were first presented with a scenario that explained the core functionality of the audio player application and then presented with mock-ups of screen-shots. Evaluations focused on metaphors, navigation and interaction design.

The feedback from the workshops was positive with regards to how we resolved the *Bubble* concept in the user interface. The evaluation resulted in several suggested changes related to interaction design and graphic design. The overall concept and metaphors received the approval of the experts.

System Description

To perform user evaluations, we implemented a technical prototype of the audio player. The prototype currently runs on WLAN-equipped iPAQ PDAs (see figure 5). Ideally, we would have preferred to run our prototype on mobile phones and portable MP3 players, but such devices currently lack support for wireless ad-hoc networking. Many advanced mobile phones currently support the Bluetooth local network interface, and also come with advanced software development platforms, but ad-hoc networking is not supported sufficiently (Bluetooth is a point-to-point protocol lacking support for IP broadcast-based discovery).

The prototype is implemented in C++ for the PocketPC 2002 operating system. For peer discovery and exchange of playlists, we use OpenTrek [OpenTrek], a middleware designed for mobile multiuser gaming in wireless ad-hoc networks. OpenTrek is based on a fully decentralized, peer-to-peer architecture and offers a notification-driven programming model. OpenTrek constantly monitors the ad-hoc network and issues a notification every time a device running our prototype enters or leaves the network. The OpenTrek network protocol, in addition to peer discovery, also offers limited support for the transmission of C++ objects, and we use this feature to exchange playlists and other metadata between peers.

Figure 5: The audio player prototype

The GapiDraw [GapiDraw] graphics toolkit is used to render the user interface. GapiDraw gives direct access to the device display and offers a range of powerful graphics commands, including limited animation support. We implement MP3 audio file streaming through a custom extension of the PocketPC version of the FMOD sound system [FMOD]. Access to MP3 files is through

HTTP servers running on each device. Figure 6 shows an overview of the implementation architecture.

6 Conclusion

In this paper we have reported on the development of the *Bubble* concept as it was guided by our own ethnographic findings on spontaneous human behavior. The development of this concept has been motivated by the emergence of a new environment for multimedia applications. This environment is highly dynamic, decentralized, and spanned by increasingly ubiquitous mobile devices within radio range that spontaneously discover each other and share multimedia content. It is also an environment that relates naturally to spontaneous and opportunistic human behavior.

We argue that in order to develop good multimedia applications for this dynamic environment, we need to base or concepts on studies of actual human behavior and practice. As a foundation for the development of the *Bubble* concept, we conducted an ethnographic study of spontaneous choice-making. Our assertion was that this type of behavior could be a good analogy to the said dynamic environment as it is basically unpredictable and ad-hoc. One of our principal findings in this study was that unplanned events and spontaneous actions lead to a constant redefinition of the way we understand our contexts, our goals, and ourselves. This insight, we have argued, implies a need to convey to users the full nature and extent of the resources available in their environment. However, this must also be done in a way that makes this complex environment less confusing and more easily navigable.

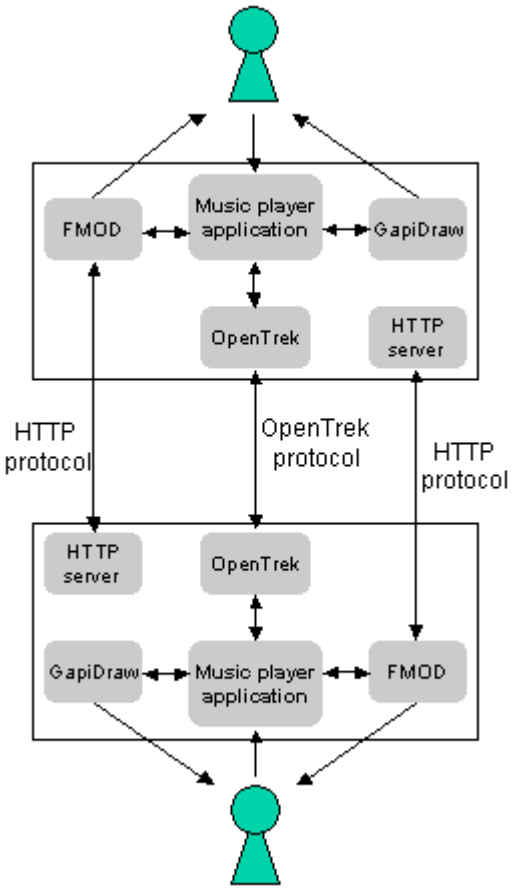

Figure 6: Overview of implementation architecture

We have developed the *Bubble* concept to meet the special requirements of spontaneous behavior in highly dynamic settings. In this concept, an information bubble metaphor is central to how we expose users to sources of content that are only briefly available. As information bubbles join and disjoin, the content available on the corresponding mobile devices becomes available and disappears, respectively, to others. The sudden appearance of information bubbles enables users to spontaneously and opportunistically access digital content from their immediate surroundings before the content just as suddenly disappears.

Our belief is that the *Bubble* concept is a promising approach for keeping users up to date about multimedia content in such a dynamic environment. To test this assertion we have made a technical prototype of an audio player that allows users to navigate available, local audio resources according to the principles of the *Bubble* concept. The user interface of the audio player emphasizes strongly the dynamics of the user environment and has been optimized for immediacy and ease of use. Our hope is to be able to deploy a full prototype of the audio player on mobile phones and portable MP3 players with support for ad-hoc networking when these become available. This would allow us to conduct field trials of the *Bubble* concept. At this stage, evaluation amounts to expert evaluations of the user interface design.

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