tunA: Local Music Sharing with Handheld Wi-Fi Devices

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ABSTRACT

In this paper we will present the research process that led to the development of tunA, a mobile peer-to-peer application that allows users to share their music locally in a synchronised way. Implemented on Wi-Fi enabled Pocket PC iPaqs, the application can be seen as part of a large-scale case study on ad-hoc wireless networks, developed in order to validate a theoretical and user-centred research methodology on innovation in the ICT field.

After summarizing the main aspects of this framework, and mentioning the project that inspired tunA, WAND (Wireless Ad-hoc Network for Dublin), we will describe in detail the concept, interface and technology behind the application, as well as mention the qualitative study that has been recently conducted to assess its usability and potential value to a specific target group of users.

INTRODUCTION

tunA can be considered as part of a broader research methodology on innovation in the ICT field that we have been working on for a few years now. We will only summarize it for the purpose of painting the context of this specific application. The main idea behind it is to suggest a theoretical framework that can help innovators to develop new ICTs and applications that address real needs and problems of a specific society and that adapt to its characteristics. When talking about ICT we refer not only to the development and commercialization of Information and Communication Technologies, but also to the contents and services that these are supposed to create, support and distribute. In the ICT field nowadays a number of technologies, devices and applications are introduced in the market without considering how they could really improve people's life. Even though global trends in ICT research seem to stress the importance of adopting a more user-centred approach, it is still a quite challenging goal to attain.

THEORETICAL FRAMEWORK: SUMMARY

As a first step in this direction we extensively analyzed a wide range of literature concerning innovation [1][2][3][4], trying to gather the concepts that could be integrated into a broad theoretical framework, and improve them with our own theories. Among these:

- The identification of the main actors of innovation: academia, industry, government. This led us to the realization that an important actor is often neglected by researchers in this field, the *user space*, usually because of the difficulty in integrating it into the innovation process. With the term user space we refer to the all the people who will eventually make use of the technologies introduced in the market. During the development of tunA we have also realized the relevance of another innovation actor: the *media space*, which helps to inform, define, and constrain the design and the use of new products. With the term *media space* we refer to the combination of information, news, and advertisements made available through mass media and the Internet.

- The importance of the cooperation and communication among the actors involved in this process.
- The relevance of the local scale in terms of physical presence of the innovators, and in terms of the development and adoption of the innovations.

Apart from the research in the innovation literature that stresses the importance of the local dimension, other empirical studies demonstrate how new media adoption can be successful at a local scale [5]. After a decade of enthusiasm for the potential of global communication, achieved through the Internet and the mass penetration of mobile phones, researchers have been concentrating more in the last few years on the importance of developing ICT that can better facilitate communication flow and content/service distribution and access at a local level, in order to support the users in their everyday approach to their "physical reality". We believe also that it is important to concentrate on ICT innovations that can contribute to reinforcing the "social capital" of a certain sociality, argued by researchers such as Putnam [6] to be of crucial importance for human well being.

As a second step in making the research on innovation more user-centred and to develop a method that gives more space to the user for participating in this process, we investigated the opportunity to include social research in our methodology. Social research has only recently been considered relevant for understanding how technology adoption could happen inside a specific society, and how industry could design new products that are actually relevant to social needs. So far social research in the communications field has studied the usage of media by people, and the ways in which these media have contributed to socio-cultural change. Our intention is to use it also during the innovation process. In particular, we are interested in applying a qualitative approach, that is, a set of methods used to understand in-depth the social issues defined by the research. We believe that the use of qualitative methods provides:

- The possibility to understand better the socio-cultural dynamics of the area considered for the technological introduction.
- The possibility to identify the social spheres that could become excluded, in the future, from the benefits of innovation and growth processes.
- The opportunity to involve indirectly the user space in the innovation process.

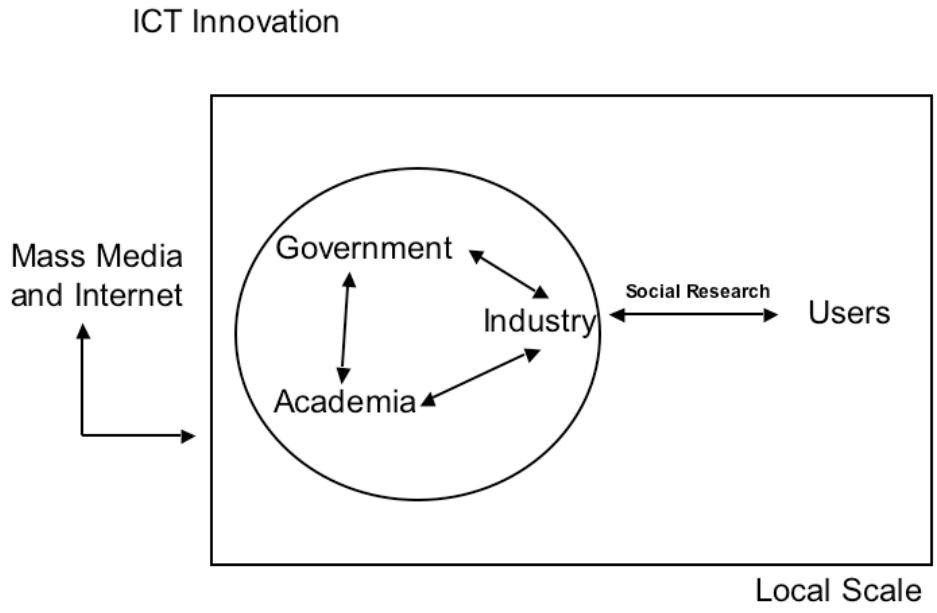

Figure 1: Summary of our theoretical Research Methodology for ICT Innovation

This is so far only a very theoretical approach that needs concrete case studies to prove its validity. Sometimes in the ICT field strongly grounded theories are not followed by empirical data or they are only based on existing case studies, and on the other side, applied projects do not have a relevant theoretical framework to support them. From the perspective of researchers and not industrial innovators, we wanted at the same time to focus on the theoretical aspects and to demonstrate their validity in practice. Case studies in fact usually represent existing phenomena that researchers analyse "after" they took place; our approach is more of an active one, meaning that in order to contribute to an improvement in innovation techniques, we believe researchers have to actively engage themselves in developing and analysing case studies, which need to be grounded on a strong theoretical framework at the same time. This represents a very hybrid approach, where technical and social research combine to make the innovation process more systemic and complete; a very interdisciplinary team of researchers is necessary to bring forward this type of project development.

DEVELOPING A CASE STUDY FOR THE RESEARCH METHODOLOGY

Traditionally, "[…] case studies are often intensive empirical studies of small size entities such as groups, organizations, individuals, systems or tools with the researcher distinct from the phenomena being studied" [7]. Instead, we are suggesting that the researcher becomes a the main actor in creating a case study in a certain ICT domain, on a local scale. We could somehow extend a research approach, mainly applied so far in the field of education and social sciences, called "action research", which is "[…] intended to achieve both action and research. It is suited to situations where you wish to bring about action in the form of change, and at the same time develop an understanding which informs the change and is an addition to what is known" [8]. This very theoretical paradigm, which refers in particular to social phenomena, could be imported into the ICT field and adapted with the meaning of giving to researchers the responsibility to actively contribute to the shaping of technical and social innovation.

The design of a case study for our innovation research methodology can be described with a schematic definition of steps for planning and development (Figure 2).

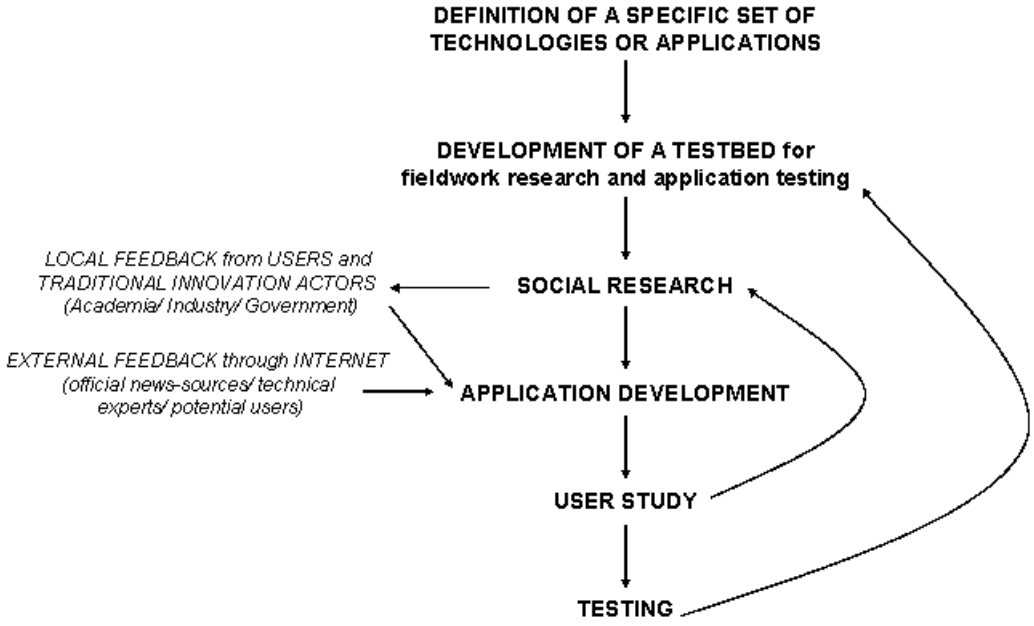

Figure 2: diagram of the Case Study for our Research Methodology

The choice of a specific set of technologies is an important starting point of the research, as it defines a particular domain of ICT where the case study can be applied. This domain should be, in general, relatively new and not well established, as we are talking about innovation, and there needs to be space for further improvements. Once this domain is chosen, the creation of a *testbed* is important to better frame the research, and to stress the localised aspect of the methodology. The implementation of a testbed in a specific socio-cultural setting defines the findings of the social study, the characteristics of the innovation actors involved and their interactions, and eventually the nature of the technologies/applications developed as a result of the process. The investments in terms of the infrastructure necessary to implement the testbed depend of course on the ICT selected, in conjunction with the existing penetration of it in the chosen society. Concerning Internet-based applications, for example, researched in a western location, it may not be necessary to invest in any extra infrastructure, as the penetration of this medium is already very high, but for applications that require uncommon technologies (i.e. optical fibre) substantial expenditure may be necessary to make it possible for future testing to take place.

As we previously assessed, the social research, for which qualitative methods are suggested, helps the innovators to understand the socio-cultural dynamics of the place considered, and to create a dialogue and a communication channel with future potential users of ICTs. This research phase leads to the definition of a set of ideas for applications/technologies in the ICT domain that fit with the characteristics of the socio-cultural area analysed, and with the local trends in terms of academic and industrial R&D.

Following these results, and depending also on personal interests, the researchers and the companies involved in the case study may decide what specific application to design and develop. During this process it is valuable to maintain a communication and an open dialogue among all the innovation actors, and to welcome external feedback that may come through forms of media like the Internet, by either official sources of news, experts in the field, or potential future users.

In order to prove the validity of the applications developed, a series of user tests are then suggested; the support of qualitative research methods in this stage of research could be helpful to involve again the local communities for which the applications were designed in the first place; these communities could provide insights on potential uses of the technology, and suggestions for further steps of its design and development.

In the last phase of the case study process, the physical testbed originally implemented can be used to test the application on a larger scale, simulating an implementation that is close to launch on the market of commercial products, but which is still linked to a research process, and is specifically targeted to the local communities analysed. These two final steps of the case study will demonstrate the success or the failure of the theoretical research methodology.

WAND AND tunA; A CASE STUDY DEVELOPED AT MEDIA LAB EUROPE

Nowadays a lot of effort in terms of research and development is addressed to mobile communication, especially because of the existence of technologies in this field that allow the creation, reproduction, consumption, and distribution of content and information in a dynamic and ubiquitous way. This constitutes a new paradigm that generates opportunities in terms of access and use that were not available before.Because of the personal interests of the researchers involved, we designed our case study around the field of ad-hoc wireless networks.

> "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. […] in ad-hoc network settings, mobile devices come and go, and thus create a highly dynamic network structure. […] ad-hoc networks are geographically situated locally. […] 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" [9].

We have described in another paper [10] the first stages of a project called WAND (Wireless Ad-hoc Network for Dublin), which is meant to constitute a testbed for ad-hoc wireless applications. WAND, a collaboration between Media Lab Europe and Trinity College Dublin, is currently being implemented in the city centre of Dublin. The network is formed by a set of fixed nodes, precisely custom-built wireless-enabled (802.11b) embedded PCs, which are hosted by apartments and shops, traffic lights and phone kiosks along a specific route, to provide a minimum level of connectivity. Due to the short range of each mobile host's wireless transmission, a certain density of nodes is needed in order for messages to be delivered. Since today mobile Wi-Fi-enabled devices have not reached a mass penetration yet, it is not easy to test ad-hoc applications in the real world, and a dedicated testbed had to be created. An ad-hoc routing protocol has been installed on the nodes to test the stability of a multi-hop communication technology. This large-scale project has involved from the beginning a number of companies and institutions interested in experimenting with new applications in the field, and will be soon a working platform for testing prototypes in real-world conditions.

While designing the physical implementation of the network, we conducted an ethnographic study, using different qualitative methods, with the aim to understand which communities are populating the area covered by the network, their general problems and needs, their feelings toward the place, and the level of penetration of various technologies. Many ideas for applications already came out from the ethnographic interviews we conducted with representatives of each community identified. The findings of this analysis were discussed during a focus group with other local innovation actors involved in the project (universities, companies and governmental institutions) in order to define a set of potential ad-hoc wireless applications targeted to the local communities and addressed to some of the general problems and needs that emerged. Very interesting ideas came out from this brainstorming, among which some related to education and technology adoption by a disadvantaged local community. Other ideas related to location-based applications targeted to tourists.

We will not explain in detail here the methods and results of this study because they have been described in other contexts, but it is nevertheless necessary to start from the WAND testbed in order to understand the development of the tunA application in relation to the research methodology previously mentioned.

THE ORIGINS OF tunA

The result of the qualitative social study we conducted for WAND was a report targeted to all the innovation actors interested in developing and testing locally new applications for ad-hoc wireless networks. From our side, we wanted to start from this, combine the insights we obtained by this analysis with our personal interests, and focus on a particular application in order to bring forward our case study for the research methodology. Our specific interest lies in the opportunity to use peer-to-peer mobile applications to support and improve social connections happening in a specific local context. The area of peer-to-peer mobile applications is relatively new and still not well explored, even though other researchers are currently working in this domain. Various technologies allow the development of these types of applications nowadays; we have focused in particular on Wi-Fi and PDAs for reasons that we will explain later.

As we said before, the dynamic creation of wireless networks fits very well with the spontaneous everyday flow of human traffic in an urban environment; the difficulty lies in how to exploit this potential to improve social bonding and a useful exchange of resources and information among people. We wanted to find an opportunity to foster social connections among people sharing the same physical environment, in a way that would be perceived as non-intrusive. Some peer-to-peer applications that have been developed so far use very direct ways to create connections, such as automated dating systems that find the "ideal match" in physical proximity, often relying on the construction of a detailed personal profile. While these methods seem successful in a virtual space like the Internet (consider social networking sites like Friendster and Orkut), it is not assured that they will be as successful in a "real world" context. We personally believe this

is not the right direction to go. Especially in urban settings, people can have the tendency to be very suspicious of each other and might have more difficulty in exchanging personal information with nearby strangers. This was confirmed during the user study we conducted for tunA.

Instead of focusing on the creation of a direct communication channel between users, we wanted to find interests around which people already form communities and that could represent topics of discussion to start or bring forward a conversation. As our approach is very localised, it would have been possible for us to find issues or topics that are only relevant for the local Irish population, among which some have been highlighted in our social study. At the same time, looking at what has been happening in the "virtual space" over these years, in terms of the creation of groups of interests, is another option for discovering cultural spheres that could help bringing people together through mobile devices as well. We decided that the optimal solution was to combine these approaches, and find a common ground between existing trends coming from the "Internet experience" and from our knowledge of the local area analysed.

During the social study we conducted for WAND some people interviewed as representatives of the communities of students and skaters, which we defined in general a "youth" community, expressed interest in applications that involve music. Also from the focus group we conducted with representatives of local innovation entities, music was a topic that stirred some brainstorming concerning potential ad-hoc applications. At the same time through personal observation we noticed that in the area many people frequently use portable music devices while moving around. This area of Dublin is in general very busy in terms of businesses, bars and restaurants, car and bus traffic, and human traffic as well. Combining this empirical information, specific to the area analysed, with the general facts that the portable music player was the first mobile device that reached a mass penetration, and that music is the main digital resource exchanged through existing peer-to-peer applications, we decided to focus on this artistic form as the main content/topic around which social connections can be established and sustained.

The idea to share music through mobile devices may have been for a while in the mind of researchers, but it has been so far almost impossible to implement in an "optimal" and stable way, mainly because of technical reasons. Nevertheless, now that new technologies and devices are making it possible to achieve, legal issues related to this idea may create delays in the actual commercialisation of applications that support it.

We decided to explore this very interesting field through the creation of a mobile music sharing application, which we called tunA. tunA has been developed keeping in mind as main target groups the previously mentioned communities of young people populating the WAND area. But considering the universality of music consumption, even in mobile situations, we see the application as potentially relevant to an audience broader than the one analyzed in our case study.

tunA:: A MOBILE PEER-TO-PEER MUSIC APPLICATION

The concept of tunA implies that music can be shared through handheld devices connected wirelessly among people who happen to be in the same physical space. As we mentioned music constitutes the interest around which new social connections can be made and existing ones can be maintained. The localised dimension stresses the importance to create a link between the virtual world of digital communication and file exchange and the reality where users are immersed every day, together with the opportunity to use new ICTs to make people more aware of their surrounding environment, and to contribute to the improvement of the "social capital" of a certain place.

Considering as a starting point the characteristics of the area studied, we envisioned various usage scenarios for the application, which we then extended to other potential urban spaces. The music sharing could in general take place whenever people happen to be in close proximity for a variable amount of time, like:

- on busses, trains, underground
- in queues

- in parks, beaches
- in venues, events (maybe artistic installations)
- in colleges

And the interactions could take place among:

- groups of friends
- strangers
- "familiar strangers" – first introduced by B. Milgram [11] in 1972, the concept of familiar stranger refers to those individuals that we regularly observe but do not interact with.

In fact an application as tunA has the potential to create new social connections, but can also be seen as a tool that allows friends to share their favourite music in public places, while keeping the feeling of "individual consumption".

Figure 3: potential usage scenario for tunA: people sharing music at the bus stop

DESIGN AND IMPLEMENTATION OF tunA

Various technologies could have used to implement the tunA concept. We decided to work on Wi-Fi enabled HP iPaqs with Windows CE. The choice of a PDA may seem not appropriate because of the relatively low market penetration of these devices; in order to be successful, an application such as tunA needs in fact to be broadly spread and used. Like any other network, an ad-hoc network gains value as the density of nodes grows, and a high variety of content and information is made available through it; tunA in particular, as it addresses social interactions, should rely on a mass penetration of the devices needed. Nevertheless among the existing technologies Wi-Fi seemed the most suited to obtain the ad-hoc connectivity between devices, allowing a higher bandwidth and range compared to other wireless standards (i.e. Bluetooth). Mobile phones, because of their penetration, would have been a good platform for implementation, but they don't support Wi-Fi yet, and PDAs offer more flexibility in terms of interface design, because of the wider size of the screen. Our goal now is to generate a stable and fully working software to can be easily installed by anyone on a Pocket PC-based and Wi-Fi-enabled PDA.

Mobile Peer-to-Peer

Peer-to-peer Internet-based applications allow users to share their resources without the aid of central servers. This type of communication has been much emphasised because it allows the creation of big networks where "free" resources can be accessed by any user, and also for the same reason it has been criticized by people involved in copyright protection. We won't go into detail here about the legal aspects of P2P networks, but we will focus instead on the potential that they have when applied to mobile devices, not only for file sharing but also in terms of social bonding. Technologies like Wi-Fi, Bluetooth, mobile phones and PDAs made it recently possible to have peer-to-peer connections in mobile settings, and this is resulting in radical changes to the whole concept of peer-to-peer. Ad-hoc networking (multi hopping) could allow in theory the creation of global networks without the aid of any infrastructure and central server, but even just a one-to-one connection at the time could support relatively small and spontaneous networks, where communication among peers and the exchange of digital resources is strictly linked to their physical proximity. This aspect brings up once again a totally different range of potential social and cultural practices, and maybe new paradigms in the field of communication.

> "'Mobile ad hoc social network' is a longer, more technical term than 'smart mobs'. Both terms describe the new social form made possible by the combination of computational, communication, reputation, and location awareness. The mobile aspect is already self-evident to urbanites who see the early effects of mobile phones and SMS. Ad hoc means that the organizing among people and their devices is done informally and on the fly […] social networks means that every individual in a smart mob is a "node" in the jargon of social network analysis, with "social links" (channels of communication and social bonds) to other individuals. Nodes and links, the elements of social networks made by humans, are also the fundamental elements of communication networks constructed from optical fibres and wireless devices – one reason why new communication technologies make possible profound social changes." [12]

While the mobile Internet was supposed to become the next big thing, mobile peer-to-peer seems to have the characteristics to better adapt to existing social mobile interactions. Problems to be addressed remain the creation and diffusion of technologies that can reach a mass penetration and can exploit the peer-to-peer potential without allowing a totally anarchic and free-of-control model to take place. It is very important at this stage, and very challenging for innovators, to lead the future of peer-to-peer mobile applications by creating useful and successful applications and by defining a business model behind them. We are for the moment only interested in investigating some aspect of this field, again with the development of a case study for research.

tunA: what it does

tunA works like a standalone MP3 player, and it also displays a list of all the people in range who are using the same application; with Wi-Fi the range where users can "see" each other is approximately 100 meters. If a user is listening to a particular song, other users nearby can connect and listen to the same song at the same time. The music is distributed through streaming, and the intention behind the choice of this modality of access is to create a shared experience. We believe that listening to the same song in synchrony could give a better sense of connectedness, and could enable people to feel part of a community even if they are strangers to each other.

The core aspects of the application are the following:

Shared music experience: A person can listen to their own music just like a normal Walkman or portable MP3 player, but they can also tune in and listen to what other people are listening to on their tunA devices, resulting in a shared music experience.

Handheld devices: The device itself is small and meant to be holdable in the hand, like a Walkman, iPod, or other such music player. It is not, for example, meant to be run on a laptop computer or on some other kind of "installed" audio hardware in a building or car.

Ad-hoc Wi-Fi network connectivity: tunA devices communicate and stream MP3 encoded audio via ad-hoc 802.11b wireless network connections.

Audio synchronization: The audio stream timing/delay algorithm enables the audio playback to be perfectly synchronized on the source and any destination devices, so that people tuned into a particular person's device can be listening to exactly what the other person is listening to. This enables someone to be, for example, sitting across a train or a bus from someone they are tuned into, and each person could be nodding heads, gesturing, or dancing in perfect synchrony, just as if they were both listening to the same standard FM radio station.

Multi-hop connectivity/synchronization: A person (X) might tune into someone else (Y) that in turn is tuned into someone else (Z) who is out of range of the original person (X), and the experience would remain synchronized. (This has not been implemented yet, but is part of our concept.)

Personal profile: Users can store personal profile information in their tunA players and set permissions setting for which parameters can be shared with other tunA players that might be tuning in.

Bookmarking a song: tunA users can "bookmark" a song that they hear while tuned into someone else's player, and later review these bookmarks, or download them to a computer where they might purchase the song for themselves.

Bookmarking a person: tunA users can "bookmark" another person they've come into contact with through tunA, and be notified if that person comes into range again. These bookmarks can also be downloaded to a regular computer where they might communicate with the other person via email or other means (if the bookmarked person's profile provided this information).

Instant messaging: tunA users can send instant messages, similar to SMS text messages, to each other while they are in range. A tunA user can set preferences as to whether they wish to allow incoming instant messages from anyone, just from people they know, or not at all.

Buying, selling, sharing songs: tunA users could purchase new songs from web-based song download sites (like iTunes) or via services offered by record stores, for example, that the tunA user might be standing near or inside at the time they wish to buy songs.

Related work

Soundpryer [13], made by the Mobility Studio of the Interactive Institute in Sweden is probably the closest relative of tunA. Soundpryer focuses on a shared music experience between nearby cars, while tunA focuses on personal mobile music uses in urban settings. Soundpryer does not include tight synchronization of that shared audio as part of their concept and implementation, and users don't choose which cars they are connected to.

Sotto Voce [14], a Xerox PARC project, is an electronic guidebook which attempts to promote a shared activity between museum visitors by allowing them to 'eavesdrop' on the descriptive audio passages that another is listening to. The system is a 'hack' in that no content is streamed – all devices have identical local content.

Bubbles [9], a Telenor R&D project, is a mobile audio player that allows users to exchange audio files with nearby peers. It functions much like a mobile file trading application: Users swap files over HTTP but there is no infrastructure to join the audio experience among those users.

Name, advertisement, and the role of representation

The name of the application, tunA, recalls the concepts of "**tun**ing in" to somebody else's music and of "**a**d-hoc" networking. We wanted to keep the name short and easy to remember mainly for "marketing" purposes. We believe that the design and development of a new application should take into consideration

the possibility for it to be easily introduced in the market and adopted by people. As tunA is mainly targeted to young people, the name and its general "look" have been adapted to this audience in particular. Apart from suggesting a particular meaning related to the concept and the technology involved, tunA represents also a "fun" name, which is directly linked to a specific graphic that includes the logo of a fish with headphones (Figure 4). The marketing aspect of a project is usually not considered in research environments, but for innovators who aim to directly contribute to technology adoption, it could be an important aspect to focus on. Of course it is something researchers cannot take care of themselves, but what they can do is to incorporate somehow into their application a direction for future advertisement of the product itself. They can also address how the idea is communicated in a way that can be appealing to users, for example through the use of websites.

Figure 4: tunA logo

It is proven that nowadays, especially for new technologies, marketing is a key aspect for the success of a new project, and it is crucial to lead the social representation of a new cultural practice. One of the best examples that is directly related to this application is the Sony Walkman, the story of which has been described in various studies. De Guy et al show how the Walkman advertisement, which is a specific marketing technique, played a major role in driving the success of the product:

> "Advertising, of course, is an economic as well as a representational practice. Its aim is to make people buy the product, to increase sales and thus maximise profits. But it is also a cultural practice because, in order to sell, it must first appeal; and in order to appeal, it must engage with the meaning which the product has accumulated and it must try to consider an identification between us – the consumers – and those meanings […] advertisement is the cultural language which speaks on behalf of the product". [15, p. 24]

Furthermore in their study of the Walkman, they highlight the relevance of the designers as "cultural intermediates". Here they refer to the design of a physical product and not of software, but even in this domain the role of designers is crucial, mainly because the choices they have to take in order to make an application appealing and useful at the same time:

> "[…] in addition to creating artefacts with a specific function, designers are also in the game of making those artefacts meaningful. In other words, design produces meaning through encoding artefacts with symbolic significance; it gives functional artefacts a symbolic form. Designers are cultural intermediaries, to use the terminology of the cultural theorist Pierre Bourbieu (1984)." [15, p. 62]

Starting from this approach Churchill and Wakeford have also stressed, particularly in relation to mobile technologies, the importance of "representation" for both the production and the consumption of products:

> " […] advertisement play a strong role in discourse of mobility, in part because so many of the technologies are new and do not have a long history of practice based stories of use" [16].

The Interface

After a long brainstorm about what the interface could look like and what features it should provide, we decided to allow a certain degree of freedom to the system by implementing a skinable interface. By

supplying a set of BMP/GIF images, and an ASCII text file describing their location, content and attributes, a user can modify the appearance of these graphical widgets. This model is similar to the one adopted by some Internet-based applications and media players, like Winamp. On one side it allows users to be creative about the interface and to personalize it their own ways; this could be appealing for young people, who are the main target of tunA, and to people who have graphic design skills. On the other side, it leaves to the developers the possibility to try different combinations in terms of graphics and features displayed. What is challenging in this system is the fact that there are almost no guidelines on how to design interfaces for PDAs, in order to fully exploit the size of the screen and the physical interaction with the device.

tunA has a default interface, which characterizes the application in terms of graphic design. We have considered various options for presenting the necessary information on the screen while keeping the interface simple and easy to use. Starting from an initial idea of having one single screen where users could both listen to their own music and access others' music, the brainstorm process led us to the inclusion of new features that were progressively added to the application, such as instant messaging and bookmark capabilities. The final decision for the default skin of tunA was to have a full screen interface with four tabs.

The first tab displays the list of users in range, each through a small icon, a nickname, and the name of the song they're playing (if there is any). By clicking on the icon people can access information about the user selected and the list of songs in their playlist. On this screen three icons are provided: one to "tune in" and listen to the user's music, one to bookmark the song he/she is listening to, and one to send messages to this user. These last options reveal two other tabs, one dedicated to the list of favourites and one to the instant messaging (IM) functionality.

Existing IM tools, like MSN Messenger, could have been used and linked to the application as external functions. Instead, we decided to design our own interface for it, and to integrate it with the other internal functions. While PDAs rely on a touch screen keyboard or on a handwriting recognition system for text input, we believe that there could be better ways for entering messages easily and quickly. As in Europe SMS is massively used and many young people are used to and confident with the mobile phone input system for writing messages, we designed an interface that has touch based buttons similar to a mobile phone. Buttons are positioned on the vertical opposite sides of the screen, in order to allow for typing by using both hands at the same time; moreover we are integrating t9 for the word recognition.

The tunA default interface (Figure 5) has received good feedback thus far from potential users. Considering the relatively small size of the screen, one of the biggest challenges is to create clear icons that represents functions, without having the aid of text to explain them. We will shortly describe some findings we obtained in terms of interface improvement from the user study we conducted.

Figure 5: *tunA default interface, screens where users can see other people in range and where they can chat with each other*

The technology

The current software build is deployed on 802.11b enabled HP iPaq 4150's, and has also been tested on HP iPaq 5450's. It is however, designed to run on any Wi-Fi equipped Pocket PC device running Windows CE.Net 4.2, and could be readily extended to function over another wireless standard, such as BlueTooth, or with some modifications on another operating system such as Linux.

Some very preliminary work has begun on designing a custom hardware platform based around an Atmel MP3 decoder/microcontroller in conjunction with a Nordic VLSI 2.4 GHz RF module, and Secure Digital flash cards as a storage medium.

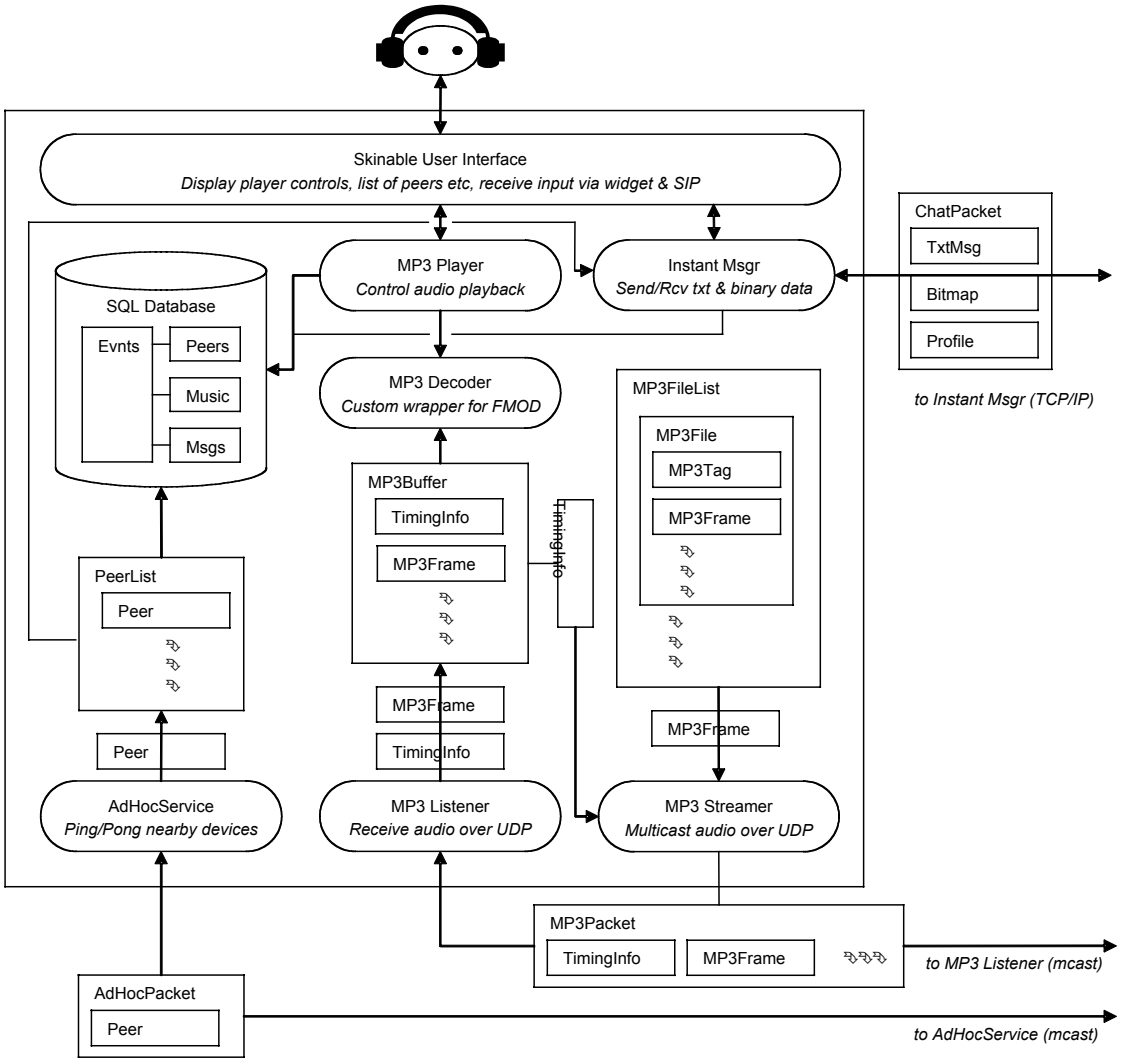

Figure 6: Overall system architecture

tunA peers discover each other by periodically multicasting packets announcing their presence to all nearby devices, and maintaining a list of those peers from whom it has detected similar packets within a specified time.

When a user selects a local audio track, the system begins to multicast packets consisting of some timing info, and frames of MP3 data to all interested peers (itself included.) A separate 'listening' process marshals this data into a buffer from which the MP3 decoder reads. The timing info is used to regulate the contents of the buffer, and the requests of the decoder to provide a synchronised audio experience between peers.

The IM component exchanges profile data, text messages, and graphical avatars over separate TCP/IP connections.

A database maintains a record all peers, events, audio, and messages encountered by the system.

1. Obtaining music

Music is stored locally on the device as a series of MP3 encoded files. More specifically for our trials we use MPEG 1.0 Layer 3, CBR[1], 112 kbps 44.1 kHz Joint-Stereo files, as we have found them a good balance between fidelity and compression levels. The only limitation of the software is in its lack of support for VBR[2] encoded audio, which would add unnecessary complexity to the streaming process.

Audio can be downloaded to the devices by copying compatible files directly to a storage card (SD/MMC) using an external card reader, or any other normal means of transferring data to the Pocket PC such as ActiveSync, a network share, or any Internet connection.

2. Peer discovery

tunA uses a 'beaconing' approach to detect other devices within range. The discovery subsystem periodically transmits custom UDP multicast packets announcing its presence and some basic peer-related information to all nearby devices, and maintains a list of those peers from whom it has detected similar packets within a specified time frame. Typically we transmit every second, and assume a peer to be out-of-range after a lack of communication for three seconds. We have also considered using RSSI[3] information or establishing and testing TCP/IP connections as alternative approaches.

The envisaged scenarios for this application (waiting in a queue, sitting on a bus etc.) require a range of approximately 20-30m. Maximum values however are heavily dependent on the 802.11 adaptor/antenna used (some reach 2700 feet), and could be extended further with Multi-Hop techniques.

3. Network protocols

Audio: The streaming service reads frames of MP3 encoded data from a locally stored file, and transmits them via specially formatted UDP multicast packets, which also include certain timing/synchronisation information (see below). When a 'tuned in' peer receives these, they are added to a buffer from which the decoding service periodically requests data.

Chat: A TCP/IP connection is formed when the discovery service detects that two peers are within range. A simple chat protocol is then used to exchange play-list information, instant messages, and other binary information.

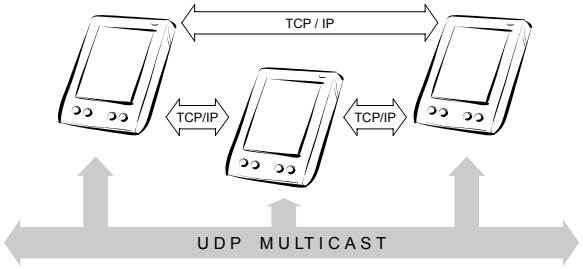

Figure 7: tunA peers interacting with each other

[1] CBR – Constant Bit Rate
[2] VBR – Variable Bit Rate
[3] RSSI – Received Signal Strength

4. Audio playback

Audio playback is achieved by decoding the MP3 frames stored in the local buffer to raw waveform data, which is fed to the O/S for reproduction via a 3.5mm headphone jack, and optionally an internal speaker. We have written a set of custom C++ classes that wrap the publicly available FMOD[4] audio library (written in C) for this purpose. These classes over-ride the default file-handling mechanism of the FMOD library, interpreting its various file open/close/seek/tell/read requests to feed it chunks of MP3 data from our separately maintained buffer instead of from a locally stored file.

This particular approach was chosen over several others for the efficiency of the decoding algorithms employed by the FMOD audio library, but several other decoders could be used in its place. Earlier attempts involved porting the original Fraunhofer sample C implementation to the WinCE platform, and using the Windows Media Player ActiveX control. In addition, both the MAD[5] and XAudio[6] libraries are also available for WinCE. Significantly, as the current generation of Pocket PC devices do not have hardware FPU's (Floating Point Units), integer based systems such as FMOD and MAD far outperform their floating-point based rivals.

5. Synchronization

The synchronisation method we employ is essentially a three-part process, applied for the full duration of the 'shared audio experience', the data for which we include in the header of the packets of MP3 frames we multicast as the audio stream. First, we establish a common reference logical clock or 'heartbeat' by using any of a number of algorithms - for example: Christian's, Berkeley, NTP etc. Next, we compute the track position of the remote source using information about the last frame that the decoder requested, and the time it requested it. Finally, if the local buffer is determined to be out of sync by more than a pre-determined amount, we remove frames or insert blanks to bring the local and remote players in line. We could also dynamically adjust the frequency of the local player until the peers matched.

The human ear will assume two audio signals are 'coherent' (i.e. from the same source) if they arrive within 30ms of each other. On the Pocket PC platform, this level of synchronisation is difficult to maintain over time due to variances in manufacture (audio crystals), clock skew, OEM dependent timing information, unreliable network protocols, and the lack of a real-time operating system. Despite these obstacles our algorithms are reasonably successful, and should see further improvements were they implemented on a dedicated tunA device.

THE INTERNET INTERFERENCE

While developing our case study we discovered an interesting role that feedback coming from mass media and Internet websites can play in the innovation process. This phase used to happen after a product had been launched in the market, when it could eventually be covered by mass media in terms of reviews and in advertisements. With the evolution of traditional news-making, fostered mainly by the influence of the Internet, and the growing success of weblogs, where individuals can complement to the "official" news-making process through online serial commentaries, it has been possible to create in the field of hi-tech research an ongoing "virtual" debate that allows researchers, potential users interested in ICT, and specialised journalists to brainstorm and share information about works in progress all around the world. The potentialities of this phenomenon have probably not yet been analysed, but we believe they are impossible to neglect and could eventually lead to massive changes to traditional research methods. We previously mentioned how communication and collaboration among innovation actors is crucial on a local level; nevertheless, it is also important to support this process on a global level in every field of ICT, in order to coordinate endeavours in research and development and to prevent duplication of effort.

[4] FMOD – Multiplatform music library available at: http://www.fmod.org
[5] MAD – Mpeg Audio Decoder available at: http://www.underbit.com/products/mad/
[6] XAudio – Multiplatform audio library available at http://www.xaudio.com

tunA made its first appearance on the Internet when we were about half way through its development, on a series of weblogs related to music consumption in urban settings, where people started to brainstorm about possible variations and adaptations of the concepts. We did not do anything specific to foster this process; we believe that people found out about the project after our first conference participations. During the following months various articles appeared online from "official" sources of news (i.e. Wired, MIT Technology Insider, etc.), and tunA was also covered by national mass media, television and radio. These stories fostered an Internet debate around tunA on various weblogs all around the world. The amount of feedback we collected from this process included reviews of the concept, technical suggestions, related projects, relevant theoretical issues, ideas for artistic installations and variations around the core idea. We soon realised it was important to take into consideration this external input and to try to integrate it within the ongoing tunA conceptual and technical design and development. Researchers, journalists, potential users from all around the world were unconsciously helping us in bringing forward our project and research.

A QUALITATIVE USER STUDY FOR tunA

Even if tunA had received very positive feedback through the Internet, the application had not been tested yet. User studies are in general important to validate the usability of technologies and applications, and in particular from our perspective relevant for purposes of coherence with the theoretical research methodology we exposed above. Our localised and user-centred approach to innovation implies a systematic and consistent relationship with the communities that represent the target of the new ICTs developed; in order to achieve this, different research tools and methodologies have to be considered, both existing and experimental, to test tunA within one of the local communities.

From looking at current approaches to user studies in the domain of mobile applications, we realised that very little literature and empirical examples exist at this stage. Qualitative methods are usually suggested in order to facilitate the process of understanding how these technologies could be used in "real contexts". Nevertheless the aspect of "spontaneous mobility" is in general very hard to capture by "artificial tests"; laboratory experiments, while they can be adequate for Internet or desktop-based applications, present numerous limits in terms of validity when it comes to wireless mobile applications. Recent studies showed how this is anyway still the most used approach for conducting user studies even in the mobile technologies field, where we find "a lack of focus on real use contexts in relation to engineering and evaluating mobile systems as well as limited construction and use of theory. While field studies are being done, natural setting research is not prevalent. One reason for this may be that applied research and laboratory experiments are simply easier to conduct and manage than field studies, case studies and action research." [7]

We encountered few examples of "real world" experiments, which from our point of view constitute an improvement, but still there is still a lack in consistency in terms of the community of users that have been selected for them. One of the main challenges in qualitative user studies is the determination of a small number of participants that could bring value in terms of validation of the technology being tested.

For our tunA user study, we decided to conduct a field study, using an original methodology; "in relation to mobile HCI research, field studies could be applied for either informing design for or understanding of mobility by ethnographic studies of current practice or for evaluating design or theory by conducting experiments in realistic user settings." [7]

The main goals of our qualitative user studies were:

Theoretical:

- proceed with the validation of our research methodology on innovation
- contribute to the emerging field of user studies for mobile peer-to-peer applications

Practical:

- test the tunA default interface
- understand a potential use of the application within a specific community of users
- obtain qualitative feedback from participants in order to plan improvements to the application design and implementation

Various theoretical examples of usage of an application like tunA can be envisioned, partly linked to some of the scenarios we have mentioned before. In general a tunA target group of users can include everyone who already enjoys listening to music through portable music devices. At the same time this categorization is limiting in terms of future mass penetration of the tunA, because of the specific development of the software that relies on a set of technologies that is not widely-enough used nowadays: Wi-Fi-enabled PDAs. The ideal target group to research could then include everyone who already uses portable music players and owns a Wi-Fi-enabled PDA at the same time.

Nevertheless in order to be consistent with our methodology, we needed to test the application within the area analysed for the WAND user study, and to select one of the identified local communities in particular. As we mentioned before, the development of tunA was partly inspired by the "youth" community that we interviewed for our study, comprised of the students at local colleges and the skaters meeting in a specific part of the area. We decided that investigating a potential usage of tunA within a university setting was the best option. We believe that students constitute in general a realistic target group for tunA, based on the feedback from our social study, and because of assumptions we tried to confirm through the evaluation. These assumptions, which are in particular based on the analysis of the WAND region, but could probably be extended to other western societies as well, include the facts that:

- Students, as other young people, are a big audience in general for the music distributed on the market
- Music is for them also a way to represents their identities and a frequent topic of discussion
- They often make use of portable music devices
- They are curious about who is around them and willing to meet new people

Out of the two colleges situated in the area covered by WAND, Trinity College Dublin (TCD) and the National College of Art and Design (NCAD), the second seemed to better fit with both the goals of our user study and the constraints of our technology. tunA is in fact a proximity-based application, where users can "see" each other and interact only within Wi-Fi range, which is 100 or less meters. As a qualitative study focuses on a small number of users, it is necessary to find conditions to make interactions happen. Because we wanted to conduct a real world user study, trying to constrain as little as possible participants in their spontaneous actions, the size of the "natural" environment where the experiment took place needed to be relatively small. The characteristics that made NCAD look appealing for our study are the following:

- Small size of the campus. This factor can facilitate the creation of spontaneous interactions among participants, allowing the technology to be fully exploited without forcing the natural conditions of social dynamics.
- Concentration of the campus social life in only one physical place.
- Presence of people involved in art and design, who we thought could provide us with insights about possible improvements of the system better than other users could do.

Methodology and preliminary results

There are no specific guidelines for qualitative user studies yet; some of the research methods applied so far have been taken from traditional ethnography, but their validity is not entirely proven. As we wanted to test at the same time the tunA interface and a potential usage of the application in "real world" conditions, we had to combine methods suggested by different disciplines in a creative and original way. These methods included:

- Participant Observation
- Survey
- Semi-structured interviews
- Talk-aloud interface evaluation
- Field Study
- Semi-structured interviews

In order to select the local "natural" environment that could be optimal for conducting the user study, we spent, as we did for the WAND social study, significant time in the area. As we had already chosen the community of students as a target group for the study, we had to consider which campus could fit with our purposes; we finally decided to conduct the study at NCAD for the reasons we have previously listed. After this we spent time on the campus, observing the social activities happening every day and talking with some people involved in the Student Union. We noticed that the Student Union office not only coordinates the NCAD social life external to the campus's regular activities, but that it also represents a physical hub where people would gather and spend some of their spare time. We thought that meeting the people involved in the Student Union would be a good starting point to know more about the campus and to coordinate the future field trial for tunA; they in fact represented the mediators between the researchers and the students involved in the user study.

The NCAD campus is mainly comprised of two parallel buildings, one for art and one for design, separated by a courtyard where students gather whenever the weather allows it (which is not very often in Ireland). A third building is mainly dedicated to administration offices, a library, and, most importantly, social activities; this is where students eat, take coffees, and spend in general their breaks from university duties. We found that the physical distribution of the spaces was optimal for a tunA field trial. The social life of the campus is in fact very "centralised", and the university activities take place mostly in "open spaces", very large rooms where students work mostly on their projects. The subjects taught at the college rely more on the development of practical projects rather than theoretical and classroom-based learning activity. This aspect seemed to facilitate more interactions happening among the students, and allowed them to listen to music even while working and studying.

Once we had confirmed the choice of the setting where the trial could take place, we had to prove that our assumptions about students being a potential target community for tunA were well-founded. We decided to conduct a survey among students, by distributing a questionnaire divided into three sections:

Music
Through these questions we tried to understand at what level the students were involved with music, how often they used portable music devices, and other related issues.

Technology
With this section we wanted to investigate what types of technologies the students used and owned in general, and how often they worked with computers.

Social issues
Here we researched the willingness of students to meet new people who happen to be nearby, their feelings toward their existing social networks, and their level of satisfaction about how human connections are established and maintained in a urban environment.

We collected a total of 76 completed questionnaires. Through the answers given, our initial assumptions were shown in general to be valid:

- A substantial percentage of the respondents said they were very much interested in music (54% responded 7 on a scale from 1 to 7).
- The respondents said they use portable stereos to a substantial degree (78% own one, 31% responded that they use it "always") and listen to the radio often (25% said "always").
- In general, the respondents appear to be curious about meeting new people nearby (31% responded 7 on a scale from 1 to 7).

- The respondents said they are quite comfortable about sharing their music with other people nearby, even strangers (33% responded 7 on a scale from 1 to 7).

Nevertheless, as we expected, there are also aspects of this target group that make it difficult to be reached in terms of future penetration of the technologies, and characteristics of the community that could prevent the adoption of a social application as tunA:

- The respondents said they don't invest much in technologies (43% responded 1 on a scale from 1 to 7).
- None of the respondents said they owned a PDA.
- Most of the respondents reported feeling happy about their social network (43% responded 7 on a scale from 1 to 7).

This last result could suggest that students are not willing to meet new people because they are already satisfied about their circle of friends. This is, on the other hand, partly compensated with the fact that they are curious about people who they see nearby everyday. We believe that the aspect of "curiosity" is very important to make an application like tunA effective in creating social connections.

The positive results of our survey supported the direction that we were taking with our user study. The next step consisted of selecting a small number of users to participate in the field trial; usually a number between 5 and 15 is suggested for qualitative analysis. Because of a technological constraint – students didn't own PDAs and we had to provide them – we were able to assemble a group of only six participants. The students we selected, among the ones who had expressed interest in the application through the Student Union or during the survey, were four males and two females, of which four were studying art and two industrial design. We selected them without knowing if they knew each other or not; nevertheless, we were aware of the fact that NCAD is a small environment where almost everybody has seen each other nearby. We later discovered that the two guys from the art department were really good friends and knew one of the girls, and the two guys in design were good friends as well. This was in fact a very good combination of participants, as interactions between friends and between people who did not know each other before could be observed at the same time.

We conducted semi-structured interviews, in order to understand more in depth their perspective on some of the issues considered with the survey. The questions we asked depended on their answers in the questionnaire. The aspects of mobile music consumption, social network satisfaction, and use of new technologies were analysed through these interviews, which were recorded and later transcribed. We were surprised about how much enthusiasm they showed toward music, and about the high level of interest that they showed in being able to listen to other users' music and to meet new people nearby.

The subjects then participated in an interface test, where we applied a talk-aloud protocol in a laboratory setting. Usability engineering guidelines [17] suggest that five users is generally enough to discover the main problems with a system. Nevertheless in this field still little research has been done on the evaluation of PDA-based interfaces, so it is still challenging to design a meaningful procedure for this kind of evaluation. We asked the students to perform specific tasks with tunA, and we asked them to verbalize their thoughts, feelings and opinions. For the debrief session of the test they were then asked to fill in a satisfaction questionnaire.

Data from this phase, which was entirely video-recorded, is currently in the process of being analyzed and needs to be combined with the actual usage of the system during the field study. This "hybrid" approach to interface testing turned out to add value to what could have been a more "traditional" one. In fact, participants had initial small problems in understanding the functions of certain icons, like those for "bookmark" and "tune in", but after the field test they were commenting very positively about the ease of use of the interface in general. They all said that buttons turned out to be very clear and straightforward once they discovered what their function was.

Even if for the field study the IM was not operating, the students gave good feedback about the interface we designed for it. Something that was very important for them seemed to be the possibility to access the

information about the songs contained in the playlists of other users, which was a feature that we were not entirely sure about implementing, because another option could have been to be able to connect directly without browsing through others' songs. The optimal way to organise the list of favourites still remains the main design issue in terms of the interface, as how it is handled now was not very satisfying from a user point of view. In general participants were happy to use a touch-screen graphical interface, even though few of them said they would prefer physical buttons. This aspect became evident during the field trial, as the subjects were very cautious about using the PDAs and afraid of breaking them. Something that emerged from the experience of almost all of them was the necessity to have a device that could be not too expensive and not so delicate as a PDA. In terms of interfacing with the screen of the PDA, some of them enjoyed using the stylus while the majority discovered late but preferred to use their fingers to interact with it. This could support the necessity to have icons and buttons of a certain size so they can be easily pressed by fingers.

The interface evaluation allowed the participants, none of whom had used a PDA before, to be prepared for the trial and almost confident with the use of the application. Concerning the planning of the field study, we wanted to let the students perform their everyday usual activities in the campus, integrating them with the use of tunA. We believed this could be possible, as all of them said during the pre-test interviews that they spend a lot of time using their portable music player while at the campus. Nevertheless, in order for the software to perform its features people needed to be in range, and the small number of participants made this condition very difficult to achieve in "normal" everyday campus life. As we decided to conduct the study during a single day from about 11 o'clock in the morning to 6 o'clock in the afternoon, we asked the students to be around the "social area" of the campus around lunchtime for about an hour and half, trying to use tunA as much as they could both for listening to their own music and for connecting to others. We thought that this could be more or less the time they dedicate to lunch and coffee break. We provided the six subjects with the tunA device. Each user had an icon and a name identifying them and a list of their favourite MP3s in their device. They were also asked to recharge the PDA at some stage during the day, as battery duration is still not optimal to run an application like tunA for more than about three hours. Apart from this small set of specific conditions the students were asked to behave as spontaneously as they could, because we wanted to explore how tunA could be quite "realistically" integrated with traditional campus life. As we mentioned this is only one of the potential scenarios for using tunA, but interesting enough to be researched through a qualitative user study. During the day of the trial, one researcher stayed at the campus, observing the interactions and usage of the application and capturing with video some moments of the trial. The researcher acted for one part of the test in a detached way toward the activities that were going on among the participants, and for another part she tried to have a "participatory" behaviour, interacting with the users and taking an active role in the test. We believe this approach was important to make sure the researcher did not interfere with the spontaneous social dynamics but also that she could experience first-hand the usage of the device within that natural context, with the aim of better understanding the experience of the other participants.

Unfortunately some technical problems encountered during the test left the six participants with only four fully working PDAs, but the cooperation among them in terms of sharing the devices when needed was remarkable. Two other important "external" variables that affected the test were:

- The good weather outside
- The Irish smoking ban

People would already gather outside every time the weather allowed them. As the test took place in May on a sunny day, participants preferred to have their lunch and social interactions outside rather than in the inside social area. This was also due to the recent smoking ban that involved all of Ireland not more than a couple of months before. The fact that students cannot anymore smoke inside is drastically changing the way their interactions take place in the physical space, and the way they make use of the social spaces assigned to them. As we observed the campus social life over the winter and conducted the trial in spring, when students spend a good part of they spare time outside anyway, it would be interesting to see next winter how the social life will change after the introduction of the smoking ban. These dynamics demonstrate how difficult it can be to study aspects of a society, because of the constant changes that affect it.

During the test the interactions took place in groups of three students, who converged in two different locations of the campus, outside, at two different times of the day. They were also using the application for a certain amount of time while working on their projects in the studio, but apparently they were not able to spot each other online and they were using tunA like a normal MP3 player, with headphones. Around and after lunchtime these two groups were almost spontaneously formed, and each of them consisted of two men who were already good friends and a woman who they both did not know well before. Again this was ideal for research purposes, as we could observe tunA being used among friends and to interact with strangers. As the subjects were all in physical proximity while doing the test, sitting around with other friends of theirs, they decided to use their tunA PDAs more like stereos rather than with headphones. Something we did not consider before was the opportunity to take advantage of the built-in speaker provided by the device. In this way the students (and the researcher) could check that the application was working, and at the same time they could let other people around enjoy the music as well. Some small technical problems related to the applications occurred at various times, but the participants were able to learn very fast how to fix them and to restart the application when needed; fortunately, this factor didn't seemed to influence the success of the test much. The students decided themselves when to end the test and to go back to their studies and activities, but this happened after a few hours of constant interaction with the application and with the other users.

After the field trial we conducted again semi-structured interviews with the students, in order to gather their comments and thoughts about the use of the PDA and the software, about the social interactions mediated through it, and the whole experience in general. Again these interviews were recorded and have still to be analysed in detail. We do not have at this stage a coherent framework of results, but we can say the experiment was in general successful and can be iterated on a larger scale. Such a larger scale study is already in preparation in collaboration with another istitution. Therefore, a second tunA field trial should be happening over the next couple of months. The details and planning of it, and its relationship with our general methodology, have still to be defined, but we believe this is a logical next step to take in our research process.

From the final interviews with participants we received very good feedback about the application. Students felt that even though the experiments interfered a bit with their usual everyday activities in the campus, the application could be integrated with their lives very well in case it becomes a product available on the market. All of them enjoyed very much using the application and had no major criticisms of the system except for the technical problems that we were already aware of and that will be addressed in future versions of the software. The subjects also showed a willingness to replace their current portable music players with tunA, except that the high cost of the technology could constitute a barrier for them. In general their approach toward PDAs was not very enthusiastic; they didn't seem to understand a use that they could make out of them except for something similar to tunA. They would rather prefer to have a device only dedicated to tunA, instead of having to carry around a small delicate computer like an iPaq. This fact could lead to radical changes in the way the application is designed and implemented, possibly on its own purpose-built hardware device.

Regarding social interaction, they subjects all agreed that it was a fun activity to share their music with their usual friends at the campus, and also that this helped them in breaking the ice with people they did not know well before. Interesting comments were made about the fact that music really constitutes a topic of discussion that is important in their everyday lives, and which is much more appealing than other types of conversation to get to know new people.

Something that we did not expect before the trial was the incredible enthusiasm and interest that the participants showed toward the opportunity to send messages to each other via the devices. They were all very disappointed that this feature, which is currently being implemented, was not working on the day of the trial; they all said that they thought about sending messages around at several points during the study. This confirmed our assumptions that having an IM tool integrated in the application could add more value to the social interactions.

One of the limits of the technology turned out to be the wireless communication range. It appeared that the students needed to always be in sight of each other in order to be "visible" to each other on tunA and to share music. Further work needs to be done on integrating ad-hoc routing protocols into the applications, in order to allow the creation of multi-hop networks with more spread in terms of physical coverage. Nevertheless this might be not necessary if wireless technology improved or if the application reached a mass penetration; the students commented that this would allow them to have access to a bigger selection of music files to share and listen to. As they did have quite different music taste, they said that sometimes they did not want to connect to others during the day of the trial because they did not like the song that these users were currently listening to. At the same time, they all said that ideally they would browse the music of everybody who is around them before connecting to any of the existing FM radio stations.

As we already mentioned, these are only preliminary results from our qualitative user study, which was founded on a customized hybrid methodology that seemed to be appropriate given our initial goals.

TESTING tunA ON WAND

Apart from bringing forward the software development of tunA and the analysis of the user study, future plans for our research include the opportunity to integrate the application in some way within the WAND network discussed earlier. The implementation of this testbed is close to completion, and new opportunities for testing various applications might arise from it. From our perspective, to be once again coherent with our research methodology, we are planning to find a way to adapt tunA to the characteristics of this network, maybe by including the possibility to use the WAND nodes to enable the upload or download of songs among users, creating some sort of local radio system accessible with tunA and linked to specific locations in Dublin. The details of this next iteration have not been planned yet. But despite the fact that we have only engaged thus far in a single case study which is far from complete, we feel encouraged that we may be making progress toward confirming the validity of our methodology.

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