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Ubimedia based on Readable and Writable Memory Tags

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ABSTRACT
Ubimedia is a concept where media files are embedded in everyday objects and the environment. We propose an approach where the user can read and write those files with his/her personal mobile phone simply by touching the physical objects. This facilitates easy access and storage of, e.g., video and audio files related to the physical object in question. This paper describes our work in developing a technical solution for ubimedia and studying user acceptance of forthcoming ubimedia services. Our technical development of the ubimedia concept has been focused on a mobile phone platform with a tag reader/writer, memory tags with large storage capacity, and the communication between the phone and the tags. Currently the technical design is in test and evaluation phase. The preliminary results show that the concept works and it can be implemented technically. In parallel with the technical development we have studied usage possibilities for ubimedia and user acceptance of future ubimedia services. User acceptance has been studied in a web survey and in user evaluations of proofs-of-concept. In addition, an ethical assessment has been carried out. The users appreciated especially the simplicity, speed, low cost and reliability of ubimedia. Ethical concerns were related to control over the download with regard to viruses and other unwanted content.

1. INTRODUCTION
The increasing miniaturization of information and communication technology facilitates integrating it in the environment and different everyday objects. Ambient Intelligence (AmI) refers to invisible computing everywhere in the environment, providing versatile and contextually relevant information and services to users wherever and whenever needed. Ambient intelligence integrates physical and virtual worlds and is based on three key technologies: ubiquitous computing, ubiquitous communication and intelligent user-friendly interfaces [18].

Mobile devices are introducing a user-centric approach to Ambient Intelligence. With a mobile device as a medium of communication, the user can interact with everyday objects and surroundings. He/she can get and consume information and services from and related to his/her local environment. Mobile phone is a familiar device to the user and thus may ease adoption of AmI services. This approach is also technically lightweight as the users already carry the necessary computing power with them.

The interaction paradigm, in which the user can access digital information and services by physically selecting common objects or surroundings, is called physical browsing [22]. Thus far physical browsing research has been mainly focused on web links embedded in physical objects as will be described in section 2. The user can access web services related to physical objects by browsing tags attached to the objects. Currently available tags are visual tags read with the cameras integrated on mobile phones or NFC (Near Field Communication) tags read with phones equipped with tag readers. Current tags have a limited memory capacity; typically they can store the web address but not much more. After getting the web address from the tag, the interaction continues as ordinary mobile internet usage. In our approach, the memory capacity of the tag is sufficient to store all necessary information locally, so ubimedia does not require network connections on the mobile phone. Of course network connections can be utilized when necessary, for instance to complement ubimedia with topical elements.

This paper is focused on the physical browsing of memory tags embedded in the environment and different physical objects in the environment. We have been developing the technical enablers for ubimedia and we have studied ubimedia service concepts. Our development work has included a mobile phone platform with a tag reader/writer, memory tags with large storage capacity, and the communication between the phone and the tags. The work has taken place in a large research project, MINAmI, where two of the authors have been in charge for the mobile phone platform design and the design of the communication between tags and the phone. The other authors have been in charge of developing proofs of service concepts and they have been carrying out user studies in the project.

A memory tag may include gigabytes of memory, thus facilitating local storage of media files. The user can access this kind of ubimedia with his/her mobile phone just by touching the memory tag. The concept facilitates easy access to media related to physical objects: for instance, music files can be provided as a bonus on a concert ticket, a movie trailer can be downloaded from a movie poster, or assembly instructions can be found on furniture as a video. The user can access the content but can also take the content with him/her on the personal mobile device. This feature is beneficial and differentiates mobile approach from locally installed ubiquitous media services such as embedded large screens.

Writeable memory tags extend the application possibilities as users can themselves produce content to memory tags. This facilitates, for instance, storing information of maintenance operations on household appliances, attaching messages on digital objects as digital post-it notes or following the growth of a house plant by storing history photos of the plant on the flowerpot. A promising future application area is social ubimedia. Social media means a phenomenon where people interact with each other and share content in virtual communities. Today, this takes place in many popular web services based on user-generated content such as Facebook and Youtube. Memory tags embedded in the physical environment and physical objects will extend social media to social ubimedia. People can then interact with each other and share content via actual physical environments.

The operational ecosystem for ubimedia will require mobile devices that facilitate interacting with memory tags and tags that are easily detectable in the local environment even if embedded in the environment and different objects in the environment. Wide adoption of ubimedia services will also require easy and intuitive use of ubimedia. To understand the future ecosystem and its requirements to the technical requirements, we have studied usage possibilities for ubimedia as well as user acceptance of future ubimedia services.

Our aim has been to recognize usage and application requirements and to analyze their implications for the technical development of both the mobile terminal and the memory tags [21]. The technical development of tags is complex and the technical proofs of concept have not been feasible for user evaluations. That is why we have implemented ubimedia service proofs of concept that imitate future services with current technology. Many features of ubimedia services are not defined only in the services themselves but by the underlying tag and terminal technology solutions. Early user feedback helps in designing a technical infrastructure that supports ubimedia services that are easy to adopt, easy to use and valued by users.

In the following, we first give an overview of related research in section 2. We then describe our technical concept and the technical design of the mobile phone platform and the memory tags in section 3. Finally, in section 4 we describe the various user evaluations activities that we have carried out and the results of those studies.

2. RELATED RESEARCH

2.1 Tangible bits

Ullmer and Ishii explored the concept of tangible user interfaces in their metaDESK system and the Tangible Geospace application built on the metaDESK [16]. In Tangible Geospace, physical object resembling real buildings are used to interact with a digital map of the surrounding area of the buildings. Based on these explorations, Ishii and Ullmer [16] introduced the concept of tangible bits in 1997 as a vision of coupling bits with everyday physical objects. They define three key concepts for Tangible Bits: interactive surfaces, coupling of bits with graspable physical objects and ambient media for background awareness. Their vision of seamless coupling of bits and atoms so that everyday graspable objects are coupled to digital information that pertains to them has later been realized in various tag-based service prototypes and actual services. Holmquist et al. [14] analysed tangible user interfaces and other physical-digital interfaces and presented their taxonomy for token-based access to digital information and illustrated it with WebStickers [26], a barcode based tagging system, intended for providing physical representations for web bookmarks. Fishkin [11] developed taxonomy for tangible user interfaces, consisting of varying degree of "tangibility". He divided the tangibility to two axes, embodiment and metaphor, that is, how close the input and output are to each other, and how analogous the user interaction is to similar real-world action.

Memory tags correspond to the tokens or containers in the vocabulary of Holmquist et al. [14], depending how closely the tag content is related to the physical object to which it is attached. In Fishkin's taxonomy, memory tag interaction corresponds to embodiment of Nearby, meaning that the output (for example display of downloaded video) occurs near the input object. The metaphor degree depends again on how closely the tag content is related to the physical object, but is typically Noun, meaning that the input object is similar to the real world object, but the functionality of the objects is different.

2.2 Ubiquitous media

Current research on ubiquitous media is much focused on large screens embedded in the environment. Those public displays or situated displays are often in public places. The location of these displays in the environment often provides a context for their social usage. They can be seen as affordances for collaboration, coordination, and community building [33]. Mobile phones may also be used to interact with public displays; desired information in mobile handheld may be accessed, adapted, and exchanged with public displays [29].

Byrne & al. have analysed 15 public display systems which use mobile phone for interaction [8]. They have categorized the systems according to inputs and outputs to those systems. The concepts include haptic, presence, content and visual inputs and output. Interestingly they do not limit public displays to devices which include an electronic screen. Any processor which reacts to some stimulus, and provides an output to one or more individuals at that space will do. In their analysis several public display systems provide local content input or local content output, or both.

Many researchers have realised the interaction with public screens with mobile devices. Cheverst & al. have built a situated display, which interacts with mobile terminal via Bluetooth [9]. In evaluations most of the participants appreciated the ability of the phone to both upload and download images from the system. However Bluetooth device discovery was found problematic especially in environment with many available Bluetooth devices. Asthana [2] has reported similar findings.

Device discovery may be improved by using visual tags or infrared to establish connection between Bluetooth devices [7]. Moreover starting from Bluetooth v 2.1 specification, Bluetooth includes OOB (Out of Band) pairing utilising NFC touch to connect two Bluetooth devices [4]. These solutions ease the communication between the large screen and the mobile device.

Hardy & al. have used NFC technology both as input device and to directly exchange images between public display and mobile terminal[13]. The display is divided in several sections, each equipped with an NFC tag at the back of the display surface. Touching with the NFC mobile terminal moves over Bluetooth a picture from the terminal to the specific location of the display, or vice versa.

Public displays certainly have their role as ubimedia but our approach is based on small low-power and low-cost tags that can provide the same content as large displays but limit the viewing experience to the user's own phone. On the other hand our approach is not limited to a certain physical environment but extends everywhere where there are tagged object.

2.3 Tag-based applications

Visual tags such as barcodes and matrix codes can be used as camera-readable tags. Toye et al. [38] have developed an interaction technique for controlling and accessing local services with a camera-equipped mobile phone, visual tags and public information displays. AURA [6] is a PDA and barcode-based system for linking digital content to physical objects. Rekimoto and Nagao [35] have implemented a computer-augmented environment in which a camera-equipped PDA reads visual codes from the user's environment. Rekimoto and Ayatsuka have introduced CyberCode [34], a visual tagging system as part of their augmented interaction research.

In their work with physically-based user interfaces, Want et al. [41] have built several prototypes using RFID tags and readers with portable computers. Their prototypes include for example connecting physical books to electronic information about the books and augmenting business cards with digital information about the owner.

Riekki et al. [36] have built a system that allows requesting pervasive services by touching RFID tags. The RFID reader in their system is an external handheld device and connected via Bluetooth to a mobile phone.

Isomursu [17] reports the results of a set of field studies that explored the use of near field communication (NFC) for providing access to digital services by touching a tag with a mobile phone. The paper proposes that if NFC technology becomes common, there is a compelling need for methods and practices for tag management. If such practices are not used and available, tags can form "tag litter" that ruins the user experience by corrupting the trust towards tags and tag-based services. Isomursu also points out the chicken and egg problem with tag-based services. Device manufacturers are waiting for signals from application providers and users for a need to integrate NFC technology into devices, and the application providers and end users are waiting for the technology to become more common, allowing more uses and thus economies of scale.

2.4 Interacting with tags

The term "physical browsing" originated from CoolTown [23], for which Kindberg et al. devised the concept of web presence. The idea of web presence is to connect people, places and things to digital information about them on the Web. Kindberg et al. used active infrared beacons and passive RFID tags to bring information about real world objects and locations to a PDA.

Välkkynen et al. [40] have studied physical browsing paradigm based on reading RFID tags embedded in the environment. In their studies touching and pointing turned out to useful and complementary methods for selecting an object for interaction with a mobile device.

Anokwa et al. [1] have described a user interaction model for NFC enabled applications. In their model, the user selects a link from an augmented object with a mobile device, and the mobile device then takes on the properties and context of the selected item. They call this process a transformation; the mobile device transforms into the selected item.

Häikiö et al. [12] have carried out a field experiment where a Near Field Communication (NFC) enabled mobile phone was used as a user interaction tool with which home-dwelling elderly people could choose their meals to be delivered by a home care service. The users touched one of the four alternative tags to send their daily order. The results show that the touch-based user interaction was easy to learn and adopt. Elderly people could successfully use the system regardless of their physical or cognitive deficiencies.

In the earlier physical browsing studies described above tags have been used to store links to web services. To get to the actual information, a network connection is required. Our approach is different as memory tags facilitate storing large amount of data that can then be downloaded without a network connection. This will facilitate easier, faster and more cost-effective access to embedded media. Mäkelä et al. [27] conducted a field trial in which they studied initial user perceptions of interacting with a tagged poster. Their results showed that the users who had not had any instructions about the technology expected the tag itself to store the digital information instead of providing a link to information in a network. This finding is very interesting for the memory tag concept, and provides an added motivation for developing and studying this technology.

2.5 Ethical issues

Ethical challenges of ambient intelligence are multifaceted. Ambient intelligence can make information and communication technology invisible and thus uncontrollable. Different information of individual person and his/her behaviour can be collected without the person even noticing it. The technology should be safe and secure and human values such as privacy, self-control, trust etc. should not be violated by the technology or the applications. These ethical issues are frequently raised as ethical concerns of ambient intelligence [5, 24, 37]. Ethical issues are not just related to individual applications but they may require solutions on the infrastructure design as Wasieleski and Gal-Or [42] point out when discussing privacy issues related to RFID (Radio Frequency Identification) tags.

3. UBIMEDIA ARCHITECTURE

Our vision refers to a surrounding ambient intelligence system with which a user can interact through his/her personal mobile terminal device. To fulfil this vision, we propose a mobile-phone-based architecture, including a personal mobile terminal with access to wireless sensors and memory tags in near proximity, and Internet connectivity. The architecture is referred to as the MINAmI architecture in this paper [30].

Compared to other candidates for portable user interface devices, mobile phones have several advantages: highest market penetration and acceptance amongst users, relatively low cost and small size, both local and long-range wireless connections from everywhere to everywhere, access to a wide range of services via the Internet, data storage possibility, and local computational capacity. Today's mobile phones provide music and video players, which make it possible for consumers to enjoy entertainment while on the move. Acquiring new multimedia content, however, is hampered by the high cost and slow speed of Internet connections, as well as by the fact that commonly available physical multimedia formats, such as optical disks, cannot be read with a mobile phone. To make acquiring new content easier, cheaper and less power-consuming, we propose a new technology based on RFID memory tags readable and writable by mobile phones.

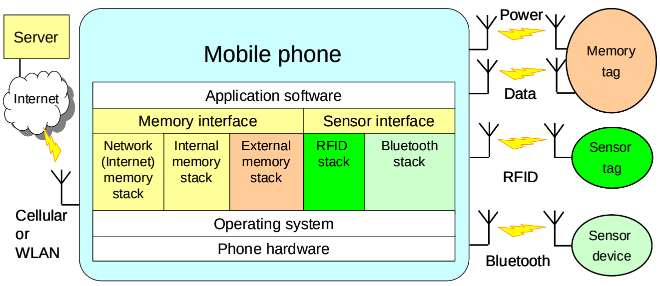

Fig. 1.Mobile-phone-centric architecture for AmI.

The MINAmI architecture makes use of the mobile phone's capability of running software and providing several radio interfaces (see Figure 1). The architecture development has clearly benefited from the requirement of modularity, which enables faster and easier development of new technical extensions (e.g. for memory tags). As state-of-the-art hardware can be used in the technical development, modularity allows faster prototyping of possible new use cases (e.g. how memory tag implementation supports new ubimedia concept). The technical development focuses both how the actual modularity is implemented on component level (e.g. where to plug memory tag functionality) and on communication level (e.g. how mobile-phone-centric architecture can utilise memory tags). At short proximity domain, different tags are communicating locally with a mobile phone. Memory tags provide wireless storage capacity and an internal memory interface and sensor tags provide sensing data and an internal sensor interface (Figure 1). In this paper we will concentrate on the usage of memory tags. The sensor parts of the architecture (RFID sensor tags and Bluetooth sensor devices) have been studied in an earlier project [19].

3.1 Memory tag technologies

Conventional machine-readable tags, e.g. Near Field Communication (NFC) tags, normally have a very small memory in range of hundreds of bytes or kilobytes [15]. For instance popular MIFARE 1k tag has one kilobyte of memory from which the user can utilize 768 bytes [28]. With 1 or 2-dimensional optical tags (barcodes) memory limitations are even more severe. Thus, they are basically only machine-readable identification codes. Some RFID standards include possibilities for flexible-use memory, but the capacity is low compared with factory-set fixed-content memory. Tag selection is based on reading the content in a selected tag memory address (e.g. tag or manufacturer ID). The reader must know the tag memory structure – thus it has to be pre-defined for an application. As the memory capacity of these tags is small, the amount of data to be transferred is also small and power consumption of RF communication is not a very critical issue.

The aim of our research has been to develop a mobile-phone-operable memory tag suitable for consumer markets and ubimedia applications. The tag is being developed as a part of a mobile-phone-centric architecture shown in Figure 1. Our memory tag development targets improving both transfer speed and storage capacity. Communication between a phone and a tag is temporary and transactions happen faster and more efficiently compared to NFC tags. Targeted response times experienced by the user are a few seconds, even when moving tens of megabytes of data.

The targeted memory capacity of our memory tag is in the range of gigabits and the targeted mobile reader/writer transfer speed to and from memory tag is 50Mbit/s. This development, MINAmI Memory Tag (i.e. mobile reader/writer and tag) solution, is currently under test and integration phase in the MINAmI project. The preliminary technical results are promising. Targeted high speed (50Mbit/s) has been achieved in our technical demonstrations. This shows that mobile reader/writer and the high capacity memory tag are implementable and ready to be commercialised.

The same design platform can be used for both ends, for mobile phone platform reader/writer and for memory tag implementation. When designing the platform, various important design parameters, such as the selection of the radio technology, were considered carefully to provide an efficient and low-power solution for the mobile reader/writer and tags. It was important to make sure that connectivity technology is simple enough for the user, e.g., to facilitate easy content selection (see sections 3.2 and 3.3).

Table 1. The evolution of sharing the digital content in printed media, towards memory tags solution.

1st generation: Web links on paper	+	Cheap to print No extra technology needed

	–	Threshold to write the link address manually to the web browser on the computer
2nd generation: Web link readable for mobile phone (optical or NFC tag)	+	Optical tag cheap to print, cameras widely available on phones NFC available on mobile phones
	–	Price and energy consumption of data connection Slow download
3rd generation: Digital content implanted on paper (memory tag)	+	Low threshold to use Fast and free download Low energy consumption compared to wireless download from the Internet
	–	Future technology, not yet commercially available

Memory tag content selections should be based on metadata (e.g., filenames, file content types, file content keywords). Due to the large memory size, power consumption for memory access is a critical design issue, both for reading and writing the memory tag. Compared with existing technologies for providing multimedia content to customers, passive memory tags have several advantages Table 1 shows these advantages in an example use case of digital content in printed media. The memory tag technology described in this paper is applicable for this use case, but not limited to that case only.

To be successful on the market, memory tags for ubimedia should be very small in size and very simple to get them as cheap as possible. If disposed of, the tags should contain as little harmful waste as possible (preferably none). A battery would make the tags more expensive, large and less environmentally sound. Thus, memory tags for ubimedia should be passive, scavenging all the power needed for operation from the electromagnetic transmission from the reading device.

The memory on the passive tag is a read-often write-seldom memory with a very strict low power constraint (RF powered). The whole tag could be read by many users many times a day, as in the case of an advertisement poster, but written not so often – in some cases, only once. The memory unit must work reliably even with several consecutive read cycles. The limited write throughput due to power constraint seems not to be an issue, as data is rarely written by the users. Higher read/write rate during manufacturing process is achievable, as more power can be provided for this initial memory setup.

Traditionally available high capacity low-power non-volatile memories (NVM), such as NAND flash memory, are poorly usable in passive memory tags due to big energy consumption of the system especially when writing. This is because NAND needs much higher programming voltage, 20V, compared to the 3V programming voltage required by phase-change memory (PCM)[3]. The development of novel NVM like PCM has made it possible to develop a passive memory tag that would, in contrast to the conventional RFID tags, provides memory capacities comparable to USB memory sticks as well as a file system with metadata.

3.2 Radio technology

As memory tags have high storage capacity, high-speed radio is needed for communication. Currently available mobile phones contain several radio transmitters, such as UMTS/HSDPA and GSM/GPRS (cellular), WLAN (IEEE 802.11), and NFC. Most of these technologies are made for well-established communication between active devices, consuming a relatively large amount of power on both communicating parties. These technologies are also not designed for ad-hoc, possibly one-time, connection between devices that have not communicated with each other before, resulting in long latency in establishing the communications. For instance, in an environment with many unknown Bluetooth devices, the Bluetooth connection setup latency can be over 10 seconds [2]. NFC enables communications with a passive device and is more selective, as its communications range is almost touch, but has severe limitations in data transfer speed (see Figure 2).

To provide high data rates, either UHF (Ultra High Frequency) back-scattering or ultra-wideband (UWB) needs to be used. To solve the problem of providing high-speed communication (high frequency needed) while simultaneously providing power to the tag via a radio signal (low frequency better), we propose a dual radio interface. One transmitter interface, namely the NFC or 900 MHz (GSM) radio of the mobile phone, is used to power the tag and synchronize the communication, while a higher-frequency Impulse-UWB [20] or 2.4 GHz back-scattering is used for communication (see Figure 3).

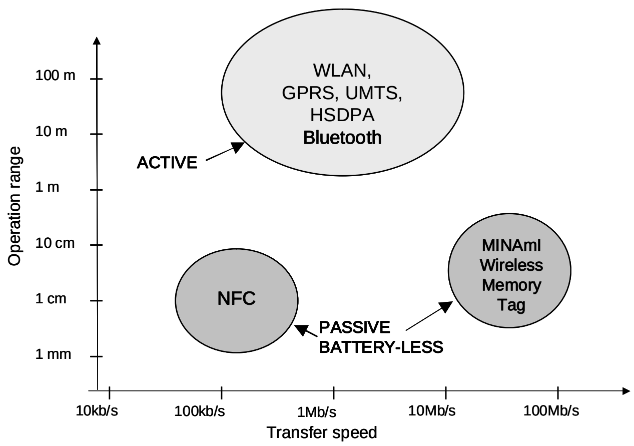

Fig. 2. Wireless communication technologies available to mobile phones.

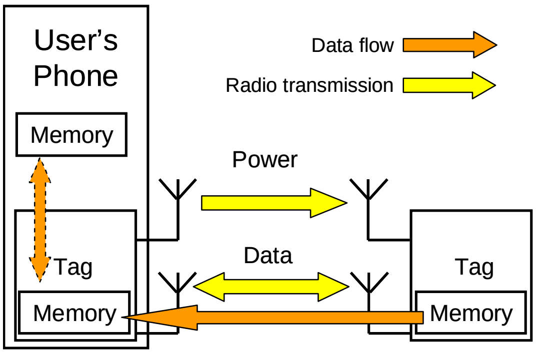

Fig. 3. Schematic view of a mobile phone using dual radio interface to read a passive memory tag.

The medium access control (MAC) of the novel dual-channel RFID interface is in passive mode (no internal power source), in active mode or in semi-passive mode (internal power source available). Tags on battery-less objects (e.g., implanted on paper) are most often passive.

Tags embedded on everyday objects, e.g., on an advertisement poster on wall, can also have their own power source. In this case, the tag works in semi-passive mode, and just synchronization is extracted from the phone transmission (no power). The signal power required by synchronization is lower than that required by powering. This would enable higher data rate or longer communication distance, or lower the power usage of the reader phone to save its battery.

The phone can write or read memory tags. The phone UHF transmission gives synchronization signal and power to the passive tags being read or written, and just the synchronization signal to the semi-passive tags.

From connectivity point of view, main objective is to find the tag and start communicating with it. There is a simple point-to-point link established between these two communicating entities, from reader/writer to tag. For normal short reading or writing operations, connection establishment time needs to be short and actual data transmission very fast.

Normally, during connection setup right interfaces need to be enabled, connection parameters need to be configured, and devices need to authenticate as well as associate before actual data transmission is possible. Practical solutions need to take into account the actual environment: what is reasonable, what tags are available, where they are located and interfaced, so that communication sequences are simple, fast and not excessively burdensome for the communication setup. Local short distance connectivity means that usually there is just one reading device and one or a few tags in the coverage area. One device selects one tag at a time.

Tags are small in physical size, and thus need to be visually distinguishable and they need to be placed in commonly known places or devices. Differentiation can be done, for example, with icons or some other visualisation effects. The icon also needs to indicate whether the tag is readable or writeable as well.

3.3 File system design

The mobile phone can read tag contents and with writeable tags the phone can write all or parts of their contents. The communication capacity between the mobile terminal and the memory tag is targeted to be up to 50 Mb/s – in contrast to, e.g. NFC, which provides speeds up to 424 kb/s. The attention span of a mobile user is about 10 seconds [31]. Within this period, the user could get a single multimedia content file – about 50 MB in size – from a memory tag (taking into account simple communication channel establishment and protocol overhead). This makes possible, e.g., a 2-minute 640x320-pixel 30-fps video trailer (3 Mb/s). We need to develop a plug-in software (External memory stack in Figure 1) to facilitate seamless use of the tag memory for mobile phone applications.

The memory tag can be used as an extension to the local file system of the reading device (e.g., mobile phone). The memory tag can be either passive, cheap one (Figure 4) or active including an own power source and thus more expensive. A plug-in in the file system of the reading device handles the connection to the memory tag. Storage space on the memory is mounted on the local file system in the same way as any detachable storage. The volatile nature of the connection causes overhead in maintaining the file system view.

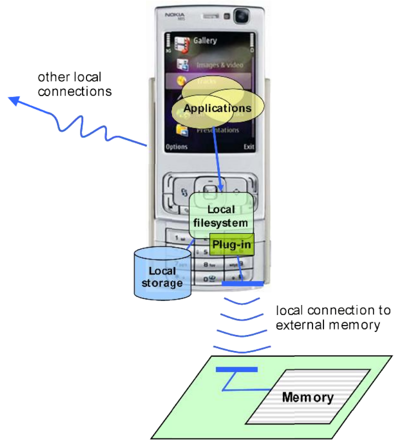

Fig. 4. Mobile phone reading a passive memory tag.

Adding a processing element to the memory simplifies the connection. The processing element can also be externally powered, so even this kind of a memory tag can be passive (Figure 5). An active memory tag can process the access requests independently and even provide some more advanced services like metadata-based queries. A service proxy relays the service interface of the memory directly to the applications running on the accessing device. The volatile nature of the connection is not a problem if the server is made stateless and transactions atomic.

Device internal modules need to support network on terminal (i.e. NoTA) open architecture [32] to get full benefit of subsystem module independency and still giving fast connection path between subsystems. This interconnect architecture structure allows future extensions for modules within one device.

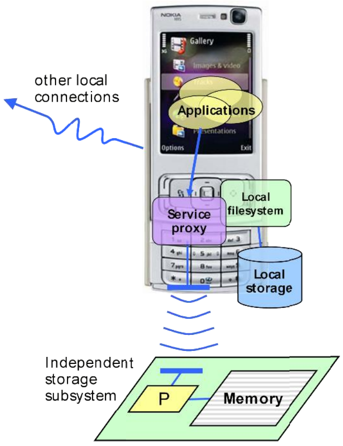

Fig. 5. Mobile phone reading a passive memory tag that has its own processor to provide USB-memory type operation, e.g. running a file system of its own.

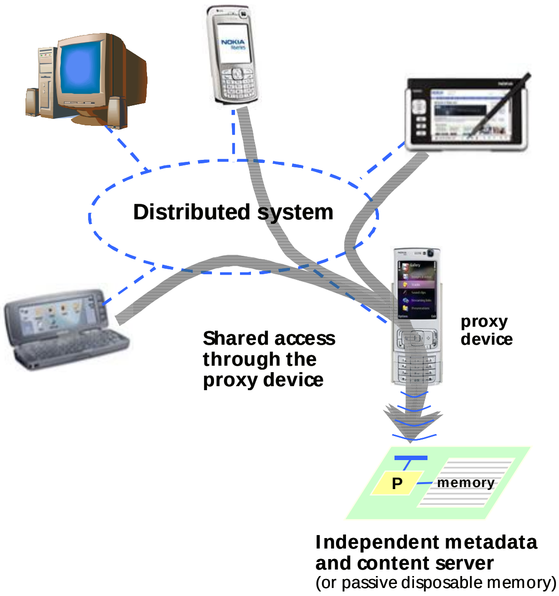

Fig. 6. Shared storage in a multi-device system. The mobile phone acts as a proxy device, connecting the passive memory tag with the network.

In a multi-device environment one device can work as a proxy for the memory tag and provide other devices with access to its services. Even a passive memory tag can be shared this way (see Figure 6). Shared access is built around multiple unicast links via a proxy device to the memory tag, where the proxy acts as a reader or writer and performs actual interactions with the tag.

4. USER EVALUATION OF UBIMEDIA CONCEPT

4.1 Human-centred design activities

Parallel to the technical development of the mobile phone platform and the memory tag we have studied application possibilities of ubimedia. Our approach can be described as human-centred design of technical infrastructures [21]. Human-centred design activities have targeted to identify for what purposes and how people would like to use memory tags. Future ubimedia services have been illustrated to users in different ways. User feedback has been analyzed to identify the implications of user requirements to the design of the technical infrastructure, i.e. the mobile phone platform with memory tag reader and writer as well as the memory tag. In this way we have been able to influence the technical developments well before actual application development will be possible. Human-centred design of the technical infrastructure will ensure that the forthcoming platform and the tags support the features and characteristics needed in future applications and facilitate implementing those features in such ways that they will be accepted by users.

We started the human-centred design activities by describing application possibilities as scenarios. The scenarios were written in cooperation with the project team consisting of platform and tag designers, human factors experts and application field experts. The main scenario, downloading video from a newspaper ad, was illustrated as an animated movie (Figure 7).

Mary (25 years) is relaxing on her sofa and reading a magazine covering the latest movies from Hollywood and elsewhere. After spotting an advertisement in the magazine she touches the page and a movie trailer and additional info how to book tickets are downloaded to her mobile phone. After pressing the start button the trailer is played on the mobile. The trailer ends with a possibility to order tickets.

Fig. 7. Scenario of downloading video from a newspaper ad.

We studied user acceptance of the ubimedia concept with web surveys in Finland, France and Spain, involving altogether 250 respondents. The survey gave feedback on features that attracted people in the scenario as well as issues that required improvements. We also identified potential user groups and got new application ideas.

Ethical issues were studied from user point of view in the user evaluations. In addition, we carried out ethical assessment of the scenarios with 11 external experts representing different fields of ethics. The Ethical Advisory Board (EAB) in MINAmI project consists of eleven ethics experts from eight European countries. The experts represent different fields of ethics, e.g. ethics of e-health, social-ethical issues, legal issues and e-Inclusion. The work of the experts is voluntary and based on personal or professional interest in ethical issues related to novel technologies and ambient intelligence in society. Ethical issues related to tag technology have been discussed and studied quite a lot [42]. In our work we wanted to study and foresee ethical risks as a part of the human-centred design. We aimed to analyze the ethical requirements and identify implications on the mobile phone platform design and the tag design so that the resulting architecture would encourage, support and even force ethically acceptable solutions.

The main user evaluation method has been building proofs-of-concept and evaluating them with users. Proofs-of-concept facilitated the study and evaluation of user interaction with memory tags in practice. We first built and evaluated a proof-of-concept of readable memory tag. The proof-of-concept was evaluated with 8 users in laboratory conditions. The feedback from the evaluation revealed many issues that indicated implications to the technical infrastructures, e.g. the need for setting touch mode on and off, user confirmations needed before launching default actions and preferred reading distances. An important issue is designing tag appearance so that it would indicate clearly to the user what kind of content and functions it is offering and how these offerings can be accessed.

The feedback from the web survey as well as from the proof-of-concept evaluation encouraged us to enhance the memory tag concept to include also the possibility to write content to the tag. With the project group we defined new scenarios that illustrated the possibilities of writeable tags as social ubimedia. With writeable tags embedded in the environments people can extend social media from the web to physical places. Figure 8 illustrates one of the anticipated usages: a poster where people can contribute with topical and interesting local content.

Fig. 8. Illustration of social ubimedia on a poster.

The writeable tag proof-of-concept was implemented as a photo frame that was used as a virtual quest book in a media museum. The users could store their comments with photos on the frame and view the comments left by other users. The proof-of-concept was evaluated with 8 users in the media museum. The results again revealed several implications to the design of the technical infrastructure, e.g. related to the feedback that users would need during the interaction and reversing from touch-based interaction to interaction with the phone user interface and vice versa while interacting with the service. We also identified practical problems that the users faced when keeping the phone close to the tag and at the same time trying to see the phone screen.

In the next sub sections we will describe in more details all the evaluation activities and the results of them.

4.2 User evaluation of the proofs-of-concept

We studied user experience of ubimedia with two proofs-of-concept. The first of them, Readable memory tag, demonstrated reading or downloading contents (video) from the memory tag to the mobile phone of the user. The second, Writable memory tag, illustrated writing or uploading contents (photos) to the tag in addition to reading.

The proofs-of-concept were both built based on existing technology: Nokia 6131 NFC mobile phone and common (small storage) NFC tag emulating the memory tag. The data that is supposedly stored in the memory tag is, in these prototypes, stored in the mobile phone itself. The downloading and uploading times were simulated to correspond to estimated reading and writing speeds with real ubimedia applications. Reading speed was 10 Mbps and writing speed ten times slower. For example:

- downloading a photo from a tag: < 2 s
- uploading a photo to a tag: 17 s
- downloading a small video from a tag: 6 s
- downloading a large video from a tag: 30 s

The long download and upload times were simulated by requiring the user to keep the mobile phone close to the tag for the assumed duration of the data transfer. The mobile phone continuously senses the presence/absence of the selected tag, thus the data transfer proceeds only when the tag is present close by. The user experience was planned to be very similar to the proposed user experience with memory tags.

In both evaluations, the most important research questions were 1) is the user interaction concept feasible, 2) what is the user experience in terms of easiness, usefulness, fun, and effectiveness, 3) what kinds of user interface and ergonomic issues arise from the requirement of keeping the mobile phone in close contact with the tag for the duration of the entire download or upload.

4.2.1 Readable memory tag – Downloading videos

Eight adult users of different ages, 3 male and 5 female, participated individually in the evaluation. They used the system for downloading movie trailer videos from memory tags to the mobile phone. The tags were attached to a movie poster and on six magazine advertisements (Figure 9). The download times from the tags varied between one and thirty seconds. The evaluation took place in a usability laboratory, where the users carried out predefined test tasks. The users were observed and interviewed.

From the users' perspective, the application supported downloading videos from a memory tag by first selecting the tag by touching it with the mobile phone, and then keeping the phone in contact with the tag until the download was completed. At that point the media player was displayed with the video loaded into it. The memory tag also contained a link to a video download from the WWW over cellular network (roughly 300 kbps) so that the users could compare the download speeds, and a phone number link to call the local box office. These links were displayed as a menu after the selection of the tag.

Overall, the concept was found interesting and easy to use. When asked to compare downloading videos from the memory tag to downloading from internet over cellular networks, the users clearly preferred the ubimedia download. The main reasons told were the speed, user-estimated cost, reliability and simplicity of downloading from tags. Downloading videos was not error-free in the sense that 27% of downloads was interrupted by the user once or more. The main error source was that the user took the phone too far away from the tag. All the users were however able to accomplish all the download tasks because the download continued immediately when the mobile phone was again in the reading range.

Fig. 9. The user is downloading a movie trailer from a memory tag attached to a poster. The mobile phone screen shows a progress bar displaying how much of the video clip has already been downloaded.

4.2.2 Writeable memory tag – uploading photos

Eight adult users, 3 male and 5 female, participated in the evaluation. Two of them had been test users also in the evaluation of the readable tag. The user evaluation was carried out in a media museum. The proof of concept was implemented as a social ubimedia application. A photo frame with an embedded memory tag acted as a virtual quest book at the museum (Figure 10). The test user first viewed photos and comments by previous visitors. Then the user could take a photo of a point of interest in the museum with the mobile phone camera. Finally the photo was uploaded to the memory tag with an optional caption. The users were observed and interviewed during the test session. In the end of the test session, the users filled in a questionnaire where they assessed easiness, usefulness, fun and effectiveness of the interaction.

To study the feasibility of touching a tag as a part of the interaction, the application was implemented so that on each screen there was a sensible default action that would progress the interaction. For example, when the user had taken a photo, the default action was to add a caption to it. The default action was accessible by 1) touching a tag, or 2) pressing the middle navigation button of the phone. A side effect of this was that the command label of the middle button was always showing to the user what would happen if they touched a tag. The screen flow was based on a few basic ideas:

1. if user-generated content was being displayed, touching a tag would write it into the tag;
2. if the table of contents of the tag was being displayed, touching the tag would read and display the photo, which was currently highlighted on the list;
3. if reading or writing was interrupted by removing the phone from the proximity of the tag, touching the tag again would continue the read/write operation;
4. in other cases, the table of contents of the tag in question was displayed when the tag was touched.

Fig. 10. The mobile phone for downloading and uploading photos, and the photo frame with the tag.

The goal was to provide the user the "path of least astonishment", that is, the default action was selected so that it would follow the natural flow of work and the presumed user expectations.

In general, all test participants found the concept of writable memory tag a positive experience. They highlighted novelty, easiness and fun of use of the application, both when interviewed and in filling in the questionnaire (Figure 11). In the test setup, uploading a photo took around 17 seconds, including the internal operations on the phone. Three users thought that uploading was too slow. Downloading took a few seconds, and all but one user considered it fast enough.

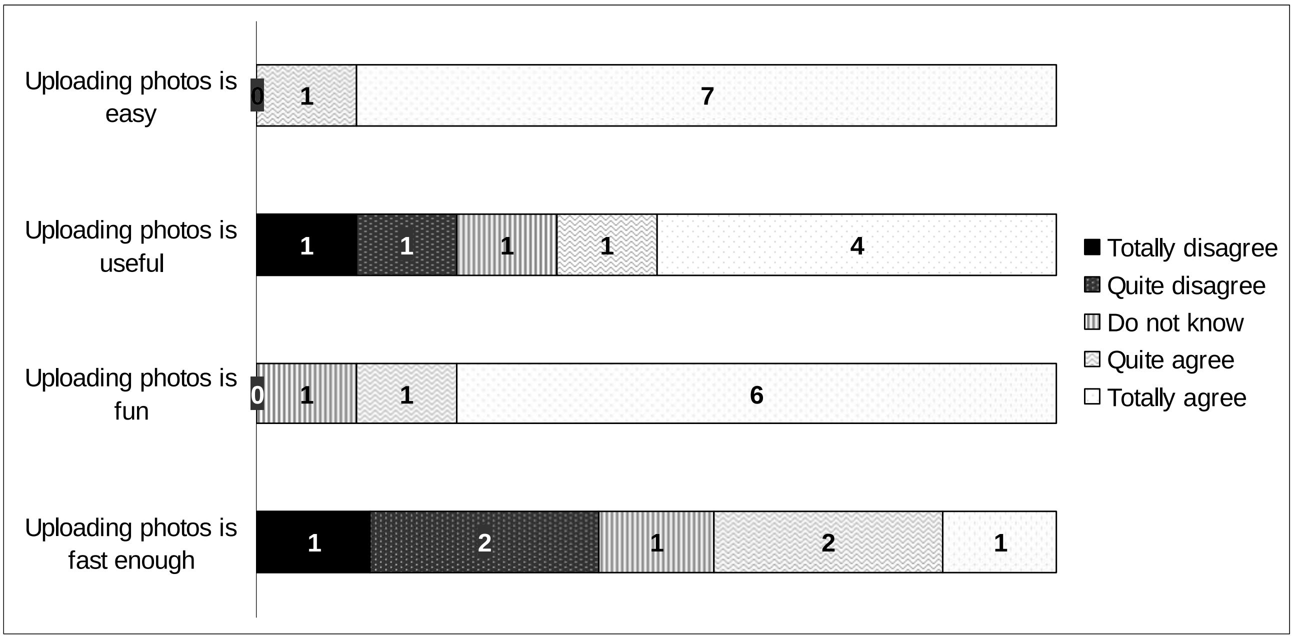

Fig. 11. User experience of uploading photos.

The main difficulty with the system was the correct distance between the phone and the tag. Of all download tasks, even 79 % were interrupted due to the user taking the mobile phone out of the reading range too early. It was not clear to the users how close the phone should be to activate and maintain the interaction with the tag. In upload tasks, the users had better learnt to hold the phone still, thus only 16 % of the uploads were interrupted.

4.2.3 Memory Tag Interaction

In general, the users liked the speed and ease of memory tag downloads and uploads, because a) the touch-based selection was simple, easy, and reliable to perform, and b) no possibly troublesome network connections were required.

In both evaluations, several interruptions to the content reading or writing occurred due to the user accidentally moving the phone too far from the tag. However, the users did not consider these interruptions as severe problems, because as soon as they brought the phone back to the reading range, the operation continued immediately from where it was interrupted. Avoiding connection cuts turned out to be a good design decision and indicates that the memory tag, when it is actually implemented, should support continuing reading and writing from the point where it was previously interrupted.

Other suggested improvements were:

- longer communication distance between the phone and the tag to prevent accidental interruptions in the data transfer during time-consuming downloads or uploads
- better feedback to the user of what is happening when the phone is close to the tag. Users had difficulties in seeing the phone screen while downloading or uploading content.

Because the users liked the accuracy of the selection, which was caused by the short reading distance, but at the same time would have liked a longer distance for the download part of the interaction, we can suggest that a "rubber band" effect would be beneficial in the usage of the memory tag. Detecting the tags from a short range, but then extending the actual data transfer range would improve the usability of the memory tag. This result also lead to a direct implication to the memory tag and reader design.

In the uploading tasks, some users deliberately took the phone away from the tag to check how far the progress bar had advanced. This was due to the long upload times and the users not seeing the phone screen from the angle that the phone had to be held while keeping it in contact with the tag. The physical design of the phone might help with this, but also multimodal feedback could be used to achieve a better user experience. Sounds and haptic responses would probably help keeping the user informed about the progress of the uploading.

4.2.4 *Memory Tag Usage*

In addition to the experimental part in the evaluation, the participants were also interviewed about their opinions about the memory tag concept. The users considered the memory tag concept most useful in situations in which they have to wait for something, such as while travelling or in stations and airports. They also suggested linking items in stores to digital contents, such as linking movie trailers to DVDs in a rental store, and music clips in a music store to get a preview of the music before purchase. Common to both of these ideas is that currently it is possible to download the content from the Internet, and access to the Internet could be eased with NFC tags attached to the items, but the size of the content is rather large. The users said they would prefer in these kinds of cases the quick memory tag download compared to downloading over the Internet.

The participants were asked about the maximum download time they would be willing to wait for the content to transfer. The estimates varied greatly, from a few seconds to up to a minute. The time also naturally depends on the importance of the content to the user. As shown in section 2, for example a 2-minute 640x320-pixel 30-fps video trailer (3 Mb/s) would fit in 50 MB and download in approximately ten seconds from the proposed memory tag. In the writeable tag evaluation, the users considered the photo upload time (17 s) rather long. A reasonable target in this case would also be approximately ten seconds.

After the writeable tag evaluation the participants had more insight into the possibilities of the memory tags and suggested more usage ideas for the memory tags. Some of the application and usage ideas could easily be implemented with current NFC or visual tags containing just an identifier or a link to online data, but the following ideas would clearly benefit from the writeability or storage capacity of memory tags:

- storing backup of the mobile phone data
- downloading voice information for blind users
- multimedia guest book at home or in a museum
- message book for family members
- maintenance operations history stored directly on the physical object, for example a car or at home
- pet medication history
- customer feedback for example on a restaurant menu
- downloading maps, for example in museums and golf courses
- downloading information about museum exhibition objects; because static textual or image information can be easily embedded directly in the environment, the most useful use for memory tags in this would be adding videos or audio guides to the objects

4.3 Web Survey

The survey sample consisted of 250 participants and was picked from three countries: Finland, Spain and France with 120, 100 and 30 respondents, respectively. The respondents were 18-60 years old mobile phone owners and they represented both genders equally. The questionnaire was Web-based and self applied. It first included two sections that determined the respondent's general profile and his/her mobile phone usage habits, especially regarding content download. The last section presented our memory tag scenario (Figure 7) as a flash animation. After watching the animation, the respondent assessed the scenario regarding ethical, usage and consumption topics. Different measures were adopted in order to assure the validity of the survey avoiding bias as social desirability, repeated responders, etc. ESOMAR ethical codes and guidelines for conducting research using the internet (2007) were followed all along the survey process [10].

Regarding current mobile phone usage profile of the respondents, results showed that 85% of the participants used the phone daily and never turn it off. Phone calls and SMS represented the main use of the phone and Internet surfing the less, with just 15% of the respondents. Age differences were found between two groups. Adults (aged 31-60) tended to use less both the phone and the functions of it. Young people (aged 18-30) seemed to have more regular usage habits, keeping the phone always online and exploiting more extensively different capabilities that it offers.

We found that people from 18 to 30 years old were the most active in downloading contents to their mobile phones. 32% of them used regularly their phones for managing files while the percentage was 19% of the 31-45-year-old respondents and 12% of the 46-60-year-old respondents.

The kinds of contents the respondents stored in their phones were mostly multimedia (pictures, music and video) then games and finally other applications. Within multimedia content there were also differences: 90% of respondents stored photos, 74% stored music and 40% video files.

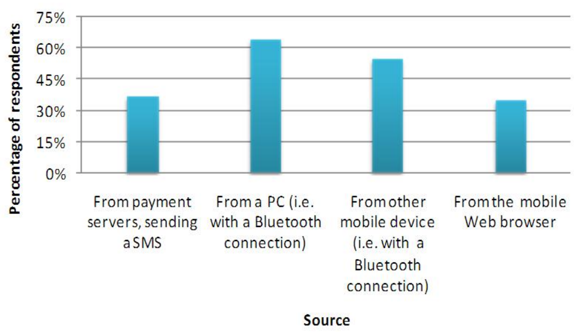

Fig. 12. Current data downloading sources of the respondents

Sources from where people download contents tended to be overlapped and stratified. Personal computers and other mobile devices were the most frequent sources of downloads while mobile phone browser and SMS-based services subject to charge scored lower in frequency of use (see Figure 12). Bluetooth seemed to be the predominant way of connection with the source of downloaded content.

From these results people that tend to download data to their mobile phone could be sketched as young adults that manage mostly multimedia content (pictures and music overall) and do it through a Bluetooth connection.

According to our survey, people's interest in ubimedia seems to be quite high. 82% of survey respondents were curious or clearly interested in ubimedia based on memory tags. We found a significant difference regarding estimated future use (defined as frequency of use) of memory tag between people who were already familiar with mobile data storage media (such as mobile phone memory cards) and those who were not. 62% of the respondents who were familiar with mobile data storage devices thought that they would use memory tags regularly, compared with 40% of the respondents who were unfamiliar with them. As the interest shown in memory tags was the same in both groups, the estimated frequency of use should not be mistaken as an interest measure but, maybe, as a sign of the existence of different user profiles in the interaction with memory tags.

There were differences in interest and estimated usage frequency with different age groups. Interest in memory tags was reported by 89% of the 18-30 year old respondents, compared with 78% of respondents aged 31-45 and 79% of those aged 46 and over.

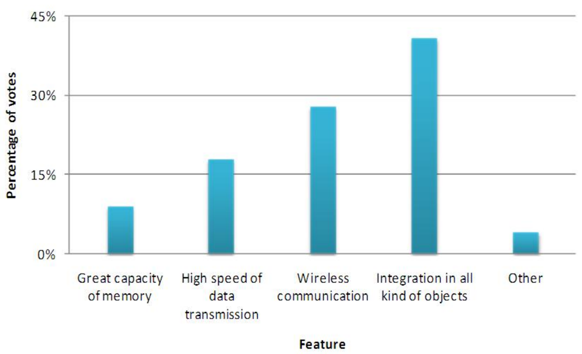

Fig. 13. Most valued features of ubimedia concept.

The most appealing characteristics of the ubimedia concept were the possibility to integrate media into different everyday objects as an interesting alternative to content downloaded from the Internet and the easy access to multimedia content via wireless communication (Figure 13). Participants commented repeatedly that the possibility of integrating memory tag with diverse everyday objects was really attractive and may allow a stimulating new level of interaction, being in itself an added value for these objects.

It is noticeable that memory size and speed of data transmission scored lower than wireless communication and integration capability features. From these results it seems that, once respondents knew what the memory tag was about, they were attracted mostly by characteristics related to interaction design rather than technical capacities.

We found some cultural differences in preferred ubimedia characteristics. French respondents seemed to value ubimedia as an interesting alternative to content downloaded from the Internet over other features, while Spanish and Finnish participants gave more importance to the possibility of integrating ubimedia into all kinds of objects.

52% of the respondents were willing to pay for using memory tag based services. However, the respondents were very sensitive about paying for any advertisement-related material as it seemed logical to them that in this case the advertiser should be the payer.

French respondents seemed to be more willing to pay, with 60% of them answering 'yes' to several kinds of fee alternatives. The willingness to pay was quite high also with the Spanish respondents (55%) and Finnish respondents (49%).

The main user concerns were related to control over the interaction between the mobile phone and the memory tag and issues regarding security and reliability. The users were concerned about knowing exactly what was being downloaded and also about protection against viruses and unwanted content. Typical statements by the respondents were for instance: *"How can the user become assured about the reliability of the source?"*, *"I need to be informed about the content even before I start to load it, so I can make the decision about it"* and *"What other equipment is needed?"*

Other studies confirm our findings of the sensitiveness of user acceptance regarding mobile phone advertisement, security and reliability. Tsang, Ho and Liang [39] carried out a survey evaluating attitudes toward SMS mobile advertising. They found that consumers generally have negative attitudes toward mobile advertising unless they have specifically consented to it. Leppäniemi and Karjaluoto [25] have built a conceptual model of consumers' willingness to accept mobile advertising. Among other conclusions they settle some principles that this kind of advertising should fulfil: guarantee of privacy, providing relevant information, being delivered by trusted organizations, allowing total control over messages by the receiver, providing rewards, etc.

Other worries included possible compatibility problems with older phone models and ease of use for elderly and disabled people.

Alternative usages were proposed to the concept, e.g. integrating operating manuals into household machines and giving installation guidance in video format. The respondents also proposed that they could reuse the tag to store and share their own contents there, *"I would try to find out some real use to the system. For instance integrating the manual to household appliances, checking the type and serial number of the appliance and updating the software of the appliance"* one participant commented.

To conclude, the results of the survey were quite promising and indicated high interest towards memory tag concept, especially among younger (18-30) people. The most attractive features were the possibility to integrate memory tags in all kinds of everyday objects providing possibilities for different applications and the multimedia content in itself. Development needs were seen in friendly advertisement use, spam control and protection for viruses and unwanted information.

4.4 Ethical assessment

The external experts of the Ethical Advisory Board (EAB) of our project have supported our project with ethical considerations throughout the project. Their work was started by the ethical assessment of our usage scenarios. The ethical assessment of memory tag scenarios revealed concerns related to autonomy of the users, trust, security, privacy and e-inclusion.

The EAB identified three main ethical problems with ubimedia, and proposed solutions to those problems:

Problem: User autonomy and trust may come under threat if the system could send spam information to the user's mobile phone (e.g., if the reading takes place automatically at a distance close enough to a tag), or if the system somehow allows involuntary or accidental buying of products. Furthermore, tags can contain harmware, trojans, viruses, and tracking software.

Proposed solution: "Opt-in" should be used, meaning that the user must actively request for the service. To prevent involuntary buying, perhaps there should be contract requirement to avoid others from using the device to these kinds of purchases. Opt-in to some extent protects also from harm ware.

Problem: User privacy is at risk if collecting information on the user is possible (through the further functions, such as a ticketing service), and if others have access to the device and the downloaded material (e.g. politically, sexually or otherwise sensitive content). Also profiling issues can arise, preparing the ground for the deployment of targeted advertising and discrimination practices.

Proposed solution: There should be security protocols in place, and perhaps encryption of data should be offered.

Problem: The application *may exclude the disabled* if the content is provided only in one format.

Proposed solution: The content should be offered in multiple formats, and "design for all" approach should be used in implementing the applications.

The EAB defined ethical principles for mobile phone based AmI solutions. Those principles were used as the framework in assessing ethical issues in user evaluations. The findings by the EAB were complemented with findings from the user evaluations. We then analysed the results and identified implications on the design of ubimedia technology and future services. In the following we describe the conclusions from this analysis.

Although touching is an easy way to access the memory tag, it can not always be interpreted as user consent. If the reading takes place automatically at a distance close enough to a tag, the user may end up downloading content that he/she did not intend to access. User-initiated actions such as writing to a tag should be secured so that the user clearly confirms the action. The user should have feedback of the actions initiated and he/she should have ways to cancel and undo actions.

Tags may contain hardware, Trojans, viruses, or tracking software. The users should have ways to ensure the trustworthiness of the tags and the security of the data transfers.

Ethical issues concerning privacy raise the question of whether information about the user can be collected in connection with accessing tags. This may take place through the further functions such as buying tickets in the scenario case. Privacy issues may also rise if others have access to the mobile device and can see what kind of material the user has downloaded. Privacy issues are related to the services that utilize memory tags. The memory tag concept in itself does not include collecting information about the user.

User privacy should be protected when using writeable tags. The user should not be obliged to reveal publicly his/her personality when writing to the tags, even if identification may be needed for moderation purposes. The information written to the tags should be moderated to ensure that it does not include elements that would threat the privacy of other people, or insult them.

The accessibility of tag-based solutions should be ensured for people with disabilities. Content should be offered in alternative formats, and the tags should be recognizable not only visually but also by touch. Memory tags have good potential to adapt to user abilities by providing information in alternative forms.

5. CONCLUSIONS

We have been developing the technical infrastructure for ubimedia: high-speed low-power memory tags and a mobile phone platform architecture that facilitates interacting with the tags. This technical infrastructure enables many different applications of ubimedia that utilize media embedded in everyday objects in our environment. Parallel to the technical development we have been studying usage possibilities of ubimedia and user acceptance of future ubimedia services.

Our approach to ubimedia is close to the original definition of tangible bits by Ishii and Ullmer [15]. In our approach the digital information actually resides on the physical objects and can even be updated by the users.

With proofs-of-concept we have been able to study in details how users could best interact with readable and writeable tags in their environment. Usability evaluations in laboratory conditions have given a lot of concrete feedback to the technical development of the memory tags and the mobile platform. We have been able to define what kind of user experience with memory tags would be successful and we have been able to identify what implications the targeted user experience has on the design and implementation of the mobile platform and the tags.

With a web survey we have got cues of market potential in different countries and revealed issues that people value and on the other hand issues that people are doubtful with. The thorough ethical assessment of the memory tag concept has guided the design of memory tags by pointing out issues that should be taken care of to support ethically acceptable usage of memory tags. As a result of the ethics work we have also generated guidelines that can be utilized when designing forthcoming commercial ubimedia applications.

The survey results indicate that the type of content that will first be provided on memory tags may have crucial effect on memory tag usage and commercial success. Positive user experience with first services will encourage using memory tags more.

The user evaluation results look promising. Mobile devices form a natural platform and user interface for reading and writing tags. The interaction can be made effortless and easy to the users. Future work is needed in designing the appearance of tags such that users can easily identity tags and understand what kind of functionality each tag will offer. Ethical issues need to be studied further. Too effortless interaction may lead to involuntary or accidental actions such as buying products. It should be carefully considered which actions should require user confirmation and whether interactions should be started by the user actively requesting the service or the service proactively offering itself for use. Users should have ways to ensure the trustworthiness of tag contents and user-generated content may require moderation. Design for all approach should be followed in implementing individual services and applications to take advantage of the potential of memory tags and the personal mobile device in providing content and services adapted to the abilities of the user.

We believe that our approach of parallel technical development and usage studies with scenarios and proofs-of-concept has been beneficial. We have been able to illustrate concretely usage possibilities and we have gathered user feedback to future ubimedia services. Early user feedback has influenced the development of the technical infrastructure, thus ensuring that it will support and even force ubimedia applications that will be ethically solid and accepted by users.

6. FUTURE VISIONS

We can foresee that wireless network connections will continue to become cheaper and faster thus easing Internet access everywhere. The benefits of memory tags will be in the area of local storage of static information where updates are not needed. Usage can also be found in areas with more limited or slower connections, or in events with thousands of simultaneous users where wireless network capacity may not be sufficient. Local writeable memory tags have several application possibilities both for personal storage and social ubimedia.

A complete business ecosystem is needed to justify the inclusion of memory tag interaction in mobile phones. Component manufacturers need to see the business benefits that give reasons to manufacture chips and tags. Content providers should find value in using the new type of media, e.g., for advertising. The users will need a comprehensive set of services – worth the cost – or considerable savings to motivate them to get a mobile phone capable to interact with memory tags.

To put ubimedia into practice, there should be an extensive set of services available to choose from. To make it affordable to set up those services there should be enough potential users, e.g. users who have mobile phones equipped with tag readers. Setting up this infrastructure requires encouraging examples of ubimedia so that device manufacturers start including tag readers on their phones and service providers start designing tag-based services. Thus, there needs to be several high-profile use-cases to motivate the users and all the actors in the business network. Our work in studying usage possibilities for ubimedia as well as user acceptance of future ubimedia services has helped to understand the future ecosystem and its requirements to the technical enablers for ubimedia.

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