

*Simo Hosio*

# LEVERAGING SOCIAL NETWORKING SERVICES ON MULTIPURPOSE PUBLIC DISPLAYS

UNIVERSITY OF OULU GRADUATE SCHOOL;  
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*SIMO HOSIO*

**LEVERAGING SOCIAL  
NETWORKING SERVICES ON  
MULTIPURPOSE PUBLIC DISPLAYS**

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### ***Abstract***

This thesis focuses on integrating multipurpose public displays with online social networking services. Modern public displays are capable of much more than the early digital billboards used for promoting brand awareness in urban areas. Currently, smaller, interactive displays are proliferating and starting to offer a variety of services for their users. A network of such displays is located in the northern City of Oulu, Finland, for example, where it is used by the general public. As such, it forms a realistic test bed for studying novel public display services in an authentic urban setting.

This thesis examines how to leverage online social networking services in creating services for interactive public displays. A key difference to most related research is that the displays simultaneously offer multiple services to their users. The thesis first provides general purpose software components, which together allow creating services that take advantage of online social networking services. These include a distributed user interface framework, a login mechanism for displays that relies on the developed framework, and a social networking service API for public displays, relying on the login mechanism. Then, the thesis presents a number of prototype services that use the developed components. The services are discussed in the contexts of user generated content, public displays for enabling communication between users, and the role of smart phones in enabling these services.

The key findings of this thesis illustrate how consuming and producing user generated content directly on public displays provide compelling use cases. Also, while leveraging online social networking services can be useful in supporting casual communication between users, the anonymity of public display users is likely to cause problems in official communications. Mobile phones are found as suitable for enabling the integration of social networking services and public displays by de-anonymizing the users. However, we are still far from a situation in which mobile phones are a natural part of the interface between humans and public displays, and more research and development towards this vision are needed.

***Keywords:*** civic engagement, communication, mobile phones, public displays, social networking services, sociality



## **Hosio, Simo, Yhteisöpalveluiden hyödyntäminen monikäyttöisissä julkisissa näytöissä.**

Oulun yliopiston tutkijakoulu; Oulun yliopisto, Tieto- ja sähkötekniikan tiedekunta, Tietotekniikan osasto; Microsoft Research Cambridge

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### ***Tiivistelmä***

Tämä väitöskirja keskittyy monikäyttöisten julkisten näyttöjen ja yhteisöpalvelujen yhdistämiseen. Uudenaikaiset julkiset näytöt kykenevät paljon muuhunkin kuin ensimmäiset suuret mainostaulut joilla mainostettiin suuria tavaramerkkejä. Pienemmät, interaktiiviset näytöt yleistyvät ja alkavat tarjoamaan uudenlaisia palveluita. Yksi verkko tällaisia näyttöjä sijaitsee Oulussa, Suomessa, missä se on yhteisön käytössä. Se muodostaa aidon ja totuudenmukaisen testialustan julkisten näyttöjen palveluille aidossa kaupunkiympäristössä.

Tämä väitöskirja tutkii Internetin yhteisöpalveluiden käyttämistä interaktiivisten julkisten näyttöjen palveluiden luomisessa. Yksi työn tärkeimmistä eroista olemassaolevaan kirjallisuuteen on se, että käytetyt näytöt tarjoavat yhtäaikaan useita palveluita. Väitöskirja esittelee ensin yleiskäyttöisiä ohjelmistokomponentteja, joiden avulla voidaan luoda näytöille palveluita, jotka käyttävät hyväkseen Internetin yhteisöpalveluita. Nämä ovat hajautettu käyttöliittymäratkaisu, sisäänkirjautumismekanismi, mikä rakentuu kehitetyn käyttöliittymäratkaisun varaan sekä yhteisöpalvelurajapinta, mikä taas rakentuu sisäänkirjautumismekanismiin varaan. Seuraavaksi väitöskirja esittelee prototyypipalveluita, mitkä rakentuvat mainittujen komponenttien varaan. Nämä palvelut analysoidaan eri viitekehyksissä: käyttäjien luoma sisältö, julkisten näyttöjen mahdollistama kommunikaatio eri käyttäjien välillä sekä älypuhelin rooli näiden palveluiden luomisessa.

Väitöskirjan löydökset havainnollistavat, kuinka käyttäjien luoma sisältö sekä sen tuottaminen suoraan julkisella näytöllä ovat mieleisiä käyttötapoja. Lisäksi, vaikka yhteisöpalvelujen hyödyntäminen julkisilla näytöillä voikin tukea arkipäiväistä kommunikaatiota käyttäjien välillä, käytön anonymiteetti voi kuitenkin aiheuttaa ongelmia virallisemmassa kommunikaatiossa. Matkapuhelimet todetaan sopiviksi yhteisöpalvelujen ja julkisten näyttöjen yhdistämisessä etenkin käyttäjien tunnistamistuen vuoksi. Olemme kuitenkin vielä kaukana tilanteesta, missä matkapuhelimet ovat osa luonnollista käyttöliittymää ihmisten ja julkisten näyttöjen välillä, ja lisäksi tutkimusta on tehtävä tämän vision suuntaan.

*Asiasanat:* julkiset näytöt, kansalaisten osallistuminen, kommunikaatio, matkapuhelimet, sosiaalisuus, yhteisöpalvelut





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## List of original articles

This thesis is based on five articles published in peer-reviewed international conferences or journals. These articles are listed below, and the Roman numerals used here will be employed to refer to the articles later in this thesis (e.g. “Article III”).

- I Hosio S, Goncalves J & Kostakos V (2013) Application discoverability on multipurpose public displays: Popularity comes at a price. Proc. The International Symposium on Pervasive Displays (PerDis 2013), Mountain View, CA, USA: 31–36.
- II Hosio S, Jurmu M, Kukka H, Riekkı J & Ojala T (2010) Supporting distributed private and public user interfaces in urban environments. Proc. Eleventh Workshop on Mobile Computing Systems and Applications (HotMobile 2010), Annapolis, MD, USA: 25–30.
- III Hosio S, Kukka H, Jurmu M, Ojala T & Riekkı J (2010) Enhancing interactive public displays with social networking services. Proc. The Ninth International Conference on Mobile and Ubiquitous Multimedia (MUM 2010), Limassol, Cyprus: Article No. 23.
- IV Hosio S, Kukka H & Riekkı J (2010) Social surroundings: Bridging the virtual and physical divide. *IEEE MultiMedia* 17(2): 26–33.
- V Hosio S, Kostakos V, Kukka H, Jurmu M, Riekkı J & Ojala T (2012) From school food to skate parks in a few clicks: Using public displays to bootstrap civic engagement of the young. Proc. 10th International Conference on Pervasive Computing (Pervasive 2012), Newcastle, UK: 425–442.



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# 1 Introduction

## 1.1 Background and motivation

After years of studies in laboratory environments, interactive public displays are finally proliferating in modern cities and increasingly in rural areas as well (13, 30, 112). Key drivers of this development are the availability of affordable display technologies and the growing interest in deploying digital signage solutions in public spaces. Often, when we think about digital displays, images of the iconic billboards of Times Square or the futuristic vibes of Tokyo cross our minds. Massive displays, situated high on the walls of skyscrapers for maximum visibility and commercial impact, have no doubt affected our perception of what digital displays are and what they are ultimately capable of.

This being the case, it is not perhaps a big surprise that public displays are often perceived as commercial mediums only, and the general public expects to find mostly “undesirable advertisements” on them (77). This, in turn, leads to lack of attention towards such displays (49). In reality, however, public displays in our everyday environments already have a plethora of different use cases, and their role in contemporary life is changing. Digital screens in office buildings and shopping malls already offer dynamic maps, navigation or category services, and displays tailored for tourists next to well-known landmarks or in hotel lobbies offer virtual postcard services.

A key characteristic making digital, network connected displays versatile is the possibility to remotely modify their content -- in real time. They can be programmed to adjust to the surrounding context and to offer different services and content to different communities and users. Especially the introduction of touch screen technologies has contributed towards the creation of novel interactive services for public displays. As these new interactive affordances of public displays become familiar to the public -- their everyday users -- the need for high quality content to interact with them increases as well.

In online environments, the quality of the offered content has always played a key role in success of any endeavour. The decades-old phrase “*content is king*” can be understood so that any media venture is most likely to fail without desirable content that people are eager to first consume and then return to. Other factors, for instance the overall service design or advertising campaigns, naturally

have a great impact on the outcome, but ultimately, it is the content itself that simply has to be appealing and of high quality.

A specific genre of content that has driven the growth of many websites today is *user generated content*. Particularly, *social networking services* (SNSs) have been successful in leveraging user generated content by hosting and distributing their users' images, videos, comments, etc. They flourish by exploiting their users' creativity and personal content. As an example, hundreds of millions of new photos are uploaded daily to the currently dominating SNS, Facebook (26). At the same time, Facebook is also one of the world's most popular websites in general, when measured by page views and daily visitors. Typical to modern online SNSs is also the fluent aggregation of content to other services; Media from different gallery services is shared in Facebook, status updates are propagated to various (micro) blogging platforms, etc. And while all this is considered "online activity", it is not just the traditional desktop computer and its web browser that are used to make all this happen, but increasingly, it is the mobile user who consumes, creates and shares content online -- on the go. However, relatively little research on leveraging SNSs outside the pure online domain has surfaced so far, and all the potential uses of SNSs have certainly not been discovered yet.

One of the ideas explored in ubicomp research has been augmenting interactive public displays with SNSs. While this enables building completely new and novel services, it can also offer potential solutions to overcome old obstacles. One of the previously identified problems on public displays is acquiring high quality content that is both fresh and interesting to the display users (34, 106). If user generated content has been proven to excel in the online domain, why not attempt to leverage it on public displays as well? Indeed, some of the early trials of utilizing user generated content from SNSs on public displays have been received well in the community, e.g. *CityWall* and *CoCollage* (27, 87).

And it is not just the content that can be introduced and studied on such displays: SNSs are an integral part of the communication culture today, and many of their features can be envisioned to find a new purpose on public displays. We believe they can be used to enrich both the display and the space where the display is situated with new fascinating opportunities, by bridging the display directly to popular online SNSs. It is these emerging opportunities and visions that acted as initial inspiration for the body of work presented in his thesis.

The thesis introduces selected features and media from popular online SNSs to multipurpose interactive public displays in authentic city settings. By conducting field trials with real, uncoached users, the citizens and visitors of our



northern city of Oulu, the thesis aims to uncover some of the unique possibilities and challenges of this research domain. The first challenge in this context has been to create the foundation, the technological enablers, for developing and deploying such services on interactive displays. Moreover, as the displays operate in the city without supervision, they needed to be realized in a way that is reusable by developers and, more importantly, usable by the general public, without constant help or support from researchers.

The developed solutions have then been verified functionally by leveraging them to create several public display services that integrate with online SNSs. These services were evaluated in field studies in Oulu, focusing on three issues: leveraging user generated content on public displays, enhancing communication of public display users, and the potential of smart phones in utilizing SNSs on public displays.

## **1.2 Thesis statement and research questions**

Summarizing the preface, the statement of this thesis is: *it is feasible and useful to leverage online social networking services in creating services for multipurpose interactive public displays.*

*Multipurpose displays* are displays that simultaneously provide several services to a user, who can then select and launch any of the offered services. By *feasible*, this thesis refers to it being possible to facilitate the proposed SNS integration in a way that is convenient to developers as well as users of such services. *Useful* refers to gaining concrete, validated benefits from such integration.

In this context, the thesis explores the following four research questions:

- RQ1. How to enable and evaluate services that utilize social networking services on interactive, multipurpose public displays?
- RQ2. Which particular concepts of online social networking services are suitable for use, and which are not, on such displays?
- RQ3. What are the key issues of public displays affecting the success or failure of the identified concepts in RQ2?
- RQ4. What is the potential role of modern smart phones in leveraging social networking services on public displays?

### 1.3 Articles, contributions and the author's role

There are five articles in total included in the thesis. Four of them are published in international, peer reviewed conferences and one in an international, peer-reviewed journal. Article I explores the effects of multipurpose displays on the use of their services. This is highly important for understanding the results of Articles II and III, which both discuss a number of services on multipurpose displays. Articles II and III also present the developed technological solutions that enable integration of the public display infrastructure with online SNSs. Articles IV and V then present detailed case studies of two public display services that both leverage the developed solutions and online SNSs in general.

It should be noted that the setup and environment was cherry-picked in the studies presented in articles IV and V. Studies in Articles I-III, however, were conducted using a grid of public displays that was simultaneously used for several other purposes and studies. Thus, making design alterations or other configurations to the already existing environment for conducting the studies of Articles I-III was never our intention, or even practically possible.

The author of the thesis is the first author in all of the five articles. However, the articles are naturally a result of collaboration with several other researchers. The articles and contributions of the author are discussed next.

**Article I** focuses on the service selection interface used on our multipurpose public displays. The main objective is to illustrate how configuring the interface differently has implications on its services' use. Article I presents three conditions that incrementally promote, with increased visibility in the interface, a selected service to the display users. The findings highlight how placing a service in different regions of the service selection interface affects its use. It also affects how the service is used: in a curious, explorative fashion or with an intention to actually do what the service is designed for. Essentially, when a service is easier to find from the interface, its absolute amount of use increases, but it is also used more without actual intention to use it for its purpose. This has implications for evaluating not just the services in Articles II and III, but all services on multipurpose displays. Thus, Article I is crucial in understanding the unique context of the thesis. The first author was responsible for designing the study together with the co-authors, implementing the service selected for the study, implementing a new launch method for the interface, and collecting all the data used for the analysis in the article.

**Article II** presents a middleware for supporting private and public user interfaces distributed across mobile devices and public displays. It enables building both single and multi-user services for the display infrastructure, and was originally implemented to be able to build more versatile services than just touch-based services that utilize public displays only, i.e. to include mobile devices in the service ecosystem. The middleware layer was verified functional by building six services on top of it and by trialling them in a 46-day long field trial. The solution was found feasible to deploy distributed services on top of it, and an information pick-up service was found as the most appealing of the trialled distributed services. The user interface solution developed in this article is still in use today and is the basis for enabling SNS integration with the displays, together with solutions introduced in Article III. The first author was responsible for designing and implementing the mobile middleware and client application for extending the user interface of the public displays. The negotiation protocol between mobile devices and public displays was designed in collaboration with the second author. The data collection and analysis of the field trial was handled by the first author.

**Article III** presents additional technological components for flexible SNS integration: a login mechanism for our multipurpose displays and how it in conjunction with the distributed user interface allows for integrating online SNSs with the displays. The article also presents a field trial of several public display services that build on top of the developed solutions and focus especially on user generated content on public displays. A virtual postcard service was found as the most popular service on the displays at the time. Interviews with 124 study participants indicate that using interactive public displays is inherently a social event, and that playful services supporting group use have a high chance in succeeding in urban smart spaces. In addition, to our knowledge, this article is the first in public display literature that explores personalizing them by using content directly from users' personal online SNS profiles. The author of this thesis was responsible for implementing two of the presented services and collecting and analysing all data.

**Article IV** presents a case study of a service that pulls user generated content from co-located users' personal online accounts in SNSs and displays the content on a large public display. The aim was to enhance awareness of other people in the same space and attempt to make them communicate more, face-to-face. Users of the service had full control over content displayed on the display through dedicated mobile clients. In addition, users could communicate with each other

using the client. The system builds on the middleware presented in Article II. This study verified the fact that users prefer using already existing SNSs for content instead of building dedicated new ones, and that such a service is effective in “breaking the ice” in informal communication with other collocated users. This service was one of the first ever public display services that did not introduce yet another SNS, but utilized official online APIs to access already existing profiles and content from different online SNSs. The author was responsible for the implementation of the service, organizing the user trials for data collection and analysing the data.

**Article V** presents a service that utilizes public displays as a content source for online SNSs and thus reversing the content flow direction in Article IV. The service was tailored to enhance communication between the local youth and the Youth Affairs Department of Oulu, in the form of discussions happening in a Facebook gallery. Three trials for the service were conducted in three different social contexts. Majority of the service users stated that it was their first time ever to communicate to the Youth Affairs Department, indicating great success on that front. However, the online SNS part of the service was quickly left without much attention. Analysis of the submitted content revealed the youth were expressing feelings about a much wider range of topics than initially solicited by the authorities. On-site observations revealed different social contexts having a key role in how the youth were willing to use, or not to use, the service. The author of the thesis implemented the service, orchestrated and participated in running the field trials and handled data collection and analysis.

#### **1.4 Research methodology**

Much of the research carried out for this thesis aims to explore phenomena in as authentic environments as possible, as suggested by Sharp and Rehman in (103). The studies included in this thesis follow both constructive and exploratory research methodologies, depending on the case.

A key to understanding the utilized methodology and results is first understanding our experimental environment, which has a rather unique dimension. The past three decades of public displays research has been mostly concerned about bespoke displays (one service per one display at a time), essentially making the purpose of a public display identical to that of the service's that is currently deployed on it. Our displays, on the contrary, offer several

different services to their users simultaneously; thus, we call them multipurpose public displays (60, 83).

The displays, which we have dubbed *UBI-hotspots* (later: *hotspots*) (84), have been used for conducting most of the research presented in this thesis. Hotspots are large touch-enabled displays located in highly public settings, such as walking streets in downtown Oulu, a popular swimming hall, university campuses, and the main library. They are available to locals and tourists alike in a 24/7 fashion and do not appear as novel research prototypes to their users anymore as they have been already deployed for years (64). This makes them ideal for exploring new service concepts in a highly realistic and credible environment of use. The test bed environment will be presented in more detail in Chapter 4.

The participants of the presented studies were not recruited by researchers, but approached the displays by their own will. This approach was chosen to minimize any biases or influences imposed by researchers actively encouraging people to use the services. Particularly, the concept of *demand characteristics* has been identified as an undesired factor in field studies (11), referring to users' tendency to adjust their behaviour to be "good participants" and to help researchers achieve the desired results. In the studies presented in the thesis, however, motives to use the deployments were genuine, instead of researchers "telling the users what to do next".

Articles I-III focus on supporting, creating and evaluating services on multipurpose public displays. Conforming with the definition presented by Alt et al. in *How to Evaluate Public Displays* (3), they follow *deployment-based research* methodology: "*Deployment-based research is a kind of action research that introduces technology (e.g., public displays) into a social setting (e.g., a city), to address some research questions derived from theory. User feedback and involvement is then obtained, and in an iterative process, the deployment is improved. At the same time, this data is used to build and refine theory, which in turn generates new research questions that can be addressed through changes in the deployment. In contrast to field studies, deployments are really integrated into the everyday life of their users*". So, rather than presenting a single carefully planned and all the time supervised deployment, they look back in time and describe what was done to enable creating a certain set of services, and then proceed to reflect on what services were successful -- and why -- on the test bed over longer periods of time.

Articles IV and V follow a constructive approach to studying issues around public displays. They present *field studies* ("*...field studies aim at evaluating a*

*system or technique in a (semi-) public setting. In contrast to deployment-based research, they are rather short (days to months) and focussed towards a single research question”* (3)) of services that were iteratively developed for clearly defined research objectives. These studies were conducted in semi-public environments, where researchers were present and unobtrusively overseeing the use of the developed software.

We ask the reader to refer to Articles I-V for detailed accounts on how the studies and trials in question were actually conducted.

## **1.5 Research process**

The author of this thesis has been extensively involved in public display research since 2007, when the multidisciplinary *UrBan Interactions* research program (UBI Program) was launched in Oulu, Finland. The research presented in this thesis is all carried out under this program, in different projects that all were a part of the program and in which the author has been personally involved.

*UbiLife* and *UbiCity* were early projects under the UBI Program research umbrella. While *UbiCity* focused particularly on creating the hotspot network in the city centre, *Ubilife* was responsible for creating middleware and services for the network. Articles I, II and IV all document results achieved in these projects. Ideas for many of the public services were collected from the general public and in workshops that were organized for commercial stakeholders and colleagues from academia. Especially Articles II and III document a wider selection of public services and infrastructure that were all implemented to be used in the city centre by authentic end users, the citizens of Oulu. While this approach of trialling public services has proven effective in obtaining research results for us, we have also focused on smaller scale, supervised deployments and experiments over the years. Article IV focuses on one of these supervised deployments, namely a case study conducted in a local restaurant right after the end of *UbiLife* project. These kinds of semi-public deployments where researchers were actively present, interviewing and making observations, have been one of the cornerstones of evaluating and publicizing the demos developed in the UBI Program.

After *UbiLife*, the author worked in the *RealUbi* project. It practically continued the research agenda of *UbiLife*, but had a more ambitious goal of creating a permanent change in how the citizens of Oulu leverage the new urban infrastructure in their daily lives. In addition, one of the main goals of *RealUbi* was to create a set of APIs to offer open access to the data and features of the

deployed infrastructure. As a part of this more ambitious goal of having a real impact on citizens' lives, we partnered with several local officials and authorities. We started to work together with one of them, the Youth Affairs Department of Oulu, in order to improve their communications with local youth. Article V documents these joint efforts, where the idea of building "something" to connect to the local youth actually came from their side. For this, a service was built, tested and deployed on our public displays. The first case studies are presented in this publication, but also a six-month long study on the full grid of hotspots followed after these studies was conducted.

Article I is the culmination of long-term observations on the fact that the use of services on multipurpose displays, such as our hotspots, is highly dependent on their *discoverability*. We defined discoverability as how easy it is to find a service on a display. We noticed that services that are deployed as "one among many" do not get a lot of use in comparison to services that are deployed on bespoke screens. This, albeit being merely common sense, is increasingly important to acknowledge and affects, e.g. the time of how long it takes to evaluate and argue about the success or failure of a given service. The experiment described in Article I was specifically crafted to illustrate some of the issues that arise when conducting research with multipurpose public displays.

## **1.6 Structure of the thesis**

The rest of the thesis starts with presenting research on the two most closely related domains, namely public displays and social networking services in Chapters 2 and 3, respectively.

Chapter 4 discusses the experiments and contributions of the five included articles. It begins by focusing on important issues to keep in mind about the experimental environment itself and on the technical development of the displays in the environment. Next, the studies on the actual services that were implemented for the environment are discussed.

In Chapter 5, the original research of this thesis is discussed in respect to related work, and answers to the research questions set earlier are derived. The validity of findings in different environments is discussed as well. Finally, Chapter 6 concludes the thesis.





## 2 Interactive public displays

This chapter overviews past research on interactive public displays, with emphasis on studies that initially motivated much of the work in Oulu. The definition of interactive public displays is ambiguous, and it is therefore difficult to isolate any universally recognized and accepted design guidelines for them (3). This is mostly because both terms, *interactive* and *public*, can be interpreted in different ways. Here, we take the stance that interactive displays are simply displays that provide means to control the offered content or services, in-situ and in real time. Such a display is public only when everyone in its location has free access to it, without supervision or having to request permissions to use it, i.e. the display supports “walk up and use” (10). Examples of common enablers of such displays are Internet connectivity and various input and output mechanisms, such as touch panels, keyboards, cameras, and more recently, even smart phones.

A brief history of public display research is first given, followed by issues relevant to deploying displays in highly public settings. Then, typical content used in public display research is discussed, followed by research on community engagement by displays. The chapter concludes with the idea and research that has been conducted so far on the concept of multipurpose displays.

### 2.1 Three decades of public display research

The overview of public display research presented here is obviously just a glimpse to the abundant literature on the topic. The inclusion of these particular examples is motivated by their relevance to the theme of the thesis.

Research on public display systems has been conducted for over three decades now, since the 1980s. The first public display systems that sparked the interest of researchers were simple links connecting two physical spaces via video and/or audio. Perhaps, the best known installation was the "Hole-in-Space" (1980), an artistic prototype that connected public spaces in New York and Los Angeles with a two-way video and audio connection (73). Although the installation was not strictly interactive, it motivated several display systems connecting physical spaces and supporting casual interaction between them. Researchers at the influential ubicomp research laboratory Xerox PARC also explored the same idea later with similar video links in collaborative office settings (5, 36).

The seminal article by Mark Weiser, "The Computer for the 21st Century" (120), published in 1991 introduced the idea of ubiquitous computing by presenting various prototypes. The prototypes included three different types of public displays, dubbed as "tabs" (inch-size), "pads" (foot-size), and "boards" (yard-size). The boards are perhaps closest to what we regard today as public displays. Boards were large, situated networked displays employed in various use cases, such as community engagement or collaboration in the office. The idea of providing personal, user generated content on public displays was briefly mentioned as well. Further, Weiser and Brown (121) advocated deploying public displays in the periphery of attention in our everyday surroundings, and these types of installations have indeed been popular ever since in academia.

The research conducted at Xerox PARC no doubt inspired subsequent research on public displays. Archetypal use cases included, e.g. situated community news displays (47), displaying photograph content (38), or public information displays that cater generic information like weather forecasts (92). They all employed the periphery of human attention -- a concept discussed by Weiser (120) -- and perhaps best characterize the latter part of 1990s.

The new millennium saw a rapid decrease in the price of public display technologies as well as the introduction of new light weight, flat panels. As expected, this boosted public display research and deployments. One popular research direction was door displays in laboratory settings, e.g. the *Dynamic Door Display* (82) and the *Hermes* (16), published in 2000 and 2002, respectively. They both allowed two-way information sharing between the viewer and the display owner (usually the office resident).

Cheaper display technology prices also facilitated larger, wall-sized deployments. *Hello.wall* (108) was a large LED cluster that allowed users to control light patterns displayed on it. *WebAware* (104) visualized website usage statistics on a large display panel, and *Interactive Wall Map* (69) showcased the locations around the world where its users had visited on a very large (3.96m x 2.64m) grid of six off-the-shelf computer monitors.

At the same time, deployments outside the safety of laboratories emerged. One of the highly cited articles on public displays by Brignull and Rogers presented the *Opinionizer* that allowed participants in a book launch party to enter with a keyboard their opinions to be shown on a projector-based display (10). Another well-received prototype, the Notification Collage (39), was based on the simple idea of providing a blackboard where users could post media that could be of interest to other people in vicinity. In a way, this resembles a lot of today's

successful online SNSs: people post what they think others might find interesting and worthy to start discussions. Other similar prototypes that allowed for casual information displaying and dissemination for communities were highly common in the early 2000s, and often in addition to touch screen interaction input happened via online interfaces that were accessible by desktop browsers or dedicated software. Examples of these kinds of community information displays include the *Plasma Poster Network* (18), the *MessyBoard* (28), and the *Community Wall* (37).

Upon the arrival of smart phones, around 2005, researchers involved them in public display systems. Smart phones became popular devices to control public displays and provide additional control interfaces for various use cases and deployments. For example, content on public displays could be uploaded from or downloaded to phones. One of the early studies exploring this type of content transfer was conducted with the second version of Hermes office door display network (15). Prior to this, *ContentCascade* already explored offering very brief summaries of content on public displays for users to download via Bluetooth (91). For a more comprehensive overview of the early years of public display research, we refer the reader to Storz (107).

During recent years, larger and longitudinal deployments in rural and urban contexts have started to emerge. In these settings, users are often free to use the deployed systems as they wish, often leading to increased appropriation. Longitudinal deployments are seen as beneficial in technology truly becoming useful to the user community (113). Public displays have been harnessed to more societal purposes than earlier examples of socializing or examinations of technology perception among a narrowly defined user community in semi-public settings. Public screens in urban locations are envisaged to enrich and enhance public transport by offering relevant and meaningful experiences to the everyday commuters through technology interventions (32). One possible use case for such displays could be analysing the passenger's history data and displaying his/her carbon footprint to increase ecological awareness. The *Wray Photo Display*, deployed in a rural village in England, supported the local community in awareness of topical issues and creating a shared history through photographic content for several years (112). *Agora 2.0* mediated communication between citizens and their chosen political representatives by probing their opinions using a public display in authentic urban city settings (96). *Instant Places* is a large-scale installation of public displays, focused on displaying user generated content in a semi-automatic fashion (56). Studies with Instant Places highlight how

different locations have different needs for moderation and content, and how different stakeholders in a space do not always agree on what is expected from a deployment.

Today, it is no doubt easier to conduct research on public displays than ever before. Off the shelf digital screens are cheap, software for public displays can be developed trivially using, e.g. web-based technologies (34, 42), and the general public -- or at least the younger audiences -- are not hesitant to interact with such technologies in public.

## **2.2 Deploying public displays and services in real-world contexts**

Our research ethos regards deploying public displays and services for real users in authentic settings, in the wild, crucial for obtaining reliable and generalizable results. Urban space is a rich yet challenging environment for deploying pervasive infrastructure and applications, as pointed out in Müller et al. (78). Several considerations, including the intertwined social practices of the area, robustness of technology, vandalism, balance between the different stakeholders, and even weather conditions, have to be considered when deploying ubicomp technologies in such environments (2, 21, 31, 50). However, to gain an understanding of how technology is received and appropriated by the general public, deployments in authentic environments are considered highly beneficial (93, 103). In contexts where the users are free to engage and leave a public display when they want, and are not actively encouraged to use its services, a key challenge is to create a pleasant and fluent user experience (97). Most people are not willing to publicly spend long times in front of a display just to figure out how it works, but require interfaces that are simple and easy to just walk up and use (10).

Large-scale and long-term deployments of public displays for research purposes are still relatively rare. The *E-campus*, deployed on the Lancaster University campus, in UK, is one of the well-known deployments. Studies conducted with it highlight several issues specific to deploying displays in the wild (34, 106). First, the *role of content* and the difficulty in *obtaining high quality content* have to be acknowledged when deploying displays in authentic contexts. The general public will not settle for less than fresh and meaningful content. This is largely due to the fact that displays already tend to suffer from the lack of interest because of their traditional “advertising only” perception. In addition, after the content has been acquired, the management of it is found especially challenging. *Managing user expectations* is also important, as

discussed also in Taylor et al. (113). The public will not always realize that the deployment is still a research prototype, and that even though the displays are located in a city, they are not necessarily owned and supported by the city officials. This needs to be communicated early and clearly to the citizens. Another related issue to this is the almost unavoidable (and often negative) *public scrutiny*, which is often surprising and psychologically heavy for researchers who are not used to it.

Besides *display blindness* (77), referring to people's expectations of not seeing anything interesting on public displays in real-world contexts, *interaction blindness* plays a role in such deployments as well (83). Although the public acknowledges the presence of a public display, it is difficult to convey the message that the display is actually interactive, instead of yet another broadcast channel for passive content (66). The *mirror metaphor* has been repeatedly shown to be effective in attracting attention and making users to explore a display. It refers to displaying a web camera image, or a silhouette, of the audience in front of a display, making them essentially a dynamic part of an interface (78, 79).

The location where a display is installed has been identified to play a major role in the success of services that are deployed on it. For instance, in casual locations where enough people converge, it is possible to leverage the *honey pot* phenomenon, referring to one person first using the display and making others curious, persuading them to use the display as well (10). Only through a thorough understanding of *content*, *location*, and *people* it becomes possible to hit the *sweet spot* for a service to make the maximum impact in that location (99).

Finally, even longitudinal deployments in real-world contexts end at some point (113). If the deployment is to be handed over to the user community, instead of withdrawing completely, it is crucial to be prepared for it well ahead in time. The user community needs to be educated on maintaining, and optimally developing, the deployed technologies.

### **2.3 Content in public display services**

Although content, in theory, is anything shown on public displays, here we briefly discuss some of the most popular sources and types of content that public display research has successfully utilized to provide meaningful and engaging experiences. The intention is not to list all content sources and examples here. Rather, a handful of examples are given to illustrate how public display deployments have leveraged different means of acquiring high quality and

contextually relevant content. As we already mentioned earlier, the general public makes rapid decisions on whether the content on public displays is worth their attention or not, and therefore, display administrators and owners should always attempt to provide fresh and, when possible, dynamic content (49). It should also be contextually relevant to the location of a display (99). This poses a challenge to anyone wishing to deploy public displays that are successful long-term, i.e. when the novelty value of the deployment has diminished.

One easy way to produce such dynamic and (in this example geographically) relevant content is to tap into the abundant online news streams. RSS feeds and Twitter (117) feeds allow easy content aggregation, as they are constantly updated and easy to parse. Several public display deployments have been disseminating such news content via broadcast or by offering to download it on the go (47, 63). Supporting content takeaway is seen beneficial, especially in classifieds-style services on public displays, as digital content is highly scalable in comparison to the limited amount of space offered on traditional paper based bulletin boards for classifieds (2).

Pictures are powerful, personal, and entertaining. In the online domain, some of the most popular SNSs focus solely on images, and it is thus no surprise that photographs and images have been used widely as content in many public display studies as well. Such examples range from deployments in offices (15, 18) and casual cafes (19, 27) to highly public settings in cities (75, 87).

A key issue with all high-quality content is its availability. A common mistake is to underestimate the effort it takes to provide sufficient amounts of good content to public displays (34). It is challenging to produce interesting, topical, and fresh content (106). A potential means to obtain good quality and relevant content is, then, to turn to the community itself and let them contribute it, as successfully trialled for example in (19, 39, 99, 122). Another means of providing fresh content is naturally live video streaming. In addition to the earlier discussed prototypes connecting two separate spaces, Foth et al. recently deployed and demonstrated how camera equipped urban screens can allow citizens to collaborate in safekeeping of the city (31). The *UbiOpticon* utilized a network of screens to broadcast a matrix of video feeds from other displays in the network, including two smart phones as mobile video feed sources.

## 2.4 Engaging communities

It is envisaged that in the future digital technologies will be increasingly used for building and supporting communities and affording self-expression and identity construction for individuals in the communities they belong to (102). As public displays continue proliferating, it is likely that their role in supporting communities in the urban space grows as well, or at least provides opportunities for it. Since the popularization of the Internet, the meaning of the word "community" has changed as well: members of countless *online communities* may never have met or never will meet face to face. Public displays, however, are highly situated and accessing them is usually tightly coupled to specific locations, the spaces where they are located in. This, together with the fact that they are often "stumbled upon", used serendipitously rather than approached with a clear purpose in mind (78), offers good opportunities for reaching different kinds of highly local communities.

Supporting communities in casual spaces, such as cafes or pubs, has been a popular use case for public displays. In such locations, people from all walks of life can gather and converse, forming new friendships, connections and groups. Prototypes have been trialled in such contexts earlier for enhancing sociality and awareness, for example (71). Findings highlight the potential of public displays in acting as conversational pieces that enable discovering mutual interests among collocated people.

Academic conferences are another interesting environment where the audience shares highly similar interests. *AutoSpeakerID* and *Ticket2Talk* (72) were two early public display systems that aimed to proactively enhance the shared experience of conference visitors (in UbiComp 2003) and mesh with the social practices of the conference in general. The systems were found successful in generating awareness among conference visitors, but the proactive model of displaying users' details and information by just sensing their presence was found somewhat disturbing. Prior to those deployments, a public display service called the *PlasmaPlace* was trialled in CHI 2002 and CSCW 2002 with the goal of aggregating generic information as well as participants' profiles and content on a public display. The *PlasmaPlace* attracted considerable interest in both conferences and managed to facilitate in-situ content creation in the form of blogs and photos.

When encouraging communities to contribute content to, or even to use, a public display, it is important to make interaction as simple as possible. In this

regard, dedicated desktop software with keyboard and mouse and mobile phones have both been utilized successfully for controlling displays tailored for specific communities. For instance, the *Instant Places*, deployed in a campus bar, allowed its users to choose online content to be fetched to public displays by using an easy-to-understand naming scheme for users' Bluetooth device names (54). The simple mechanism for enabling interaction was sufficient to keep users interested to tinker with the deployment for several weeks. And the same mechanism was later adopted to empower users of the *e-Campus* display grid as well (23). The more traditional keyboard-based input mechanism has been used in many prototypes as well (10, 53).

Ultimately, it can be said safely that public displays are increasingly being used for reaching out to different communities (14, 44, 76). We believe it will be beneficial to be able to cater to many different communities with a particular display, by letting users choose the content and the services of the displays. For example, in cafeterias or pubs, audiences often consist of members from many different communities with a wide range of interests. If the purpose is to cater tailored experiences for many groups in this audience, public displays in such locations might well benefit from being able to offer multiple services. This way, the audience can choose what the display is used for, creating a democratic way to decide the purpose of the display.

## **2.5 Multipurpose displays**

Traditionally, the display or space administrator or owner decides what a display is used for. However, public displays can be envisaged to offer several different services at the same time to their users (60, 83). It has also been noted that innovation tends to occur more naturally if public displays are open to content and ideas from many contributors instead of being closed, tightly controlled systems (20, 22).

Previous research on multiple services on the same display, mainly in desktop environments, has been concerned about the effects of shortcuts on, e.g. task completion time (48) and how to create dynamic shortcuts for recently accessed items (9, 111). In the smart phone domain, research has focused on predicting application use and dynamically optimizing the user experience accordingly (123).

Several considerations motivate a public display to offer more than just one service. For example, users typically do not have a clear motive in mind when they approach and start to use a public display (78). It would then only make



sense to offer various options to maximize the chances that the display contains at least something of interest to the user. Of course, this applies to cases where we actually want to build displays that are appealing to a wide range of users instead of promoting a single pinpointed service. Also, as digital displays deployed in a city have the potential to influence vast amounts of passers-by and other audiences, sharing this potential between all the different involved stakeholders becomes a topical challenge (62). Identifying a viable financial lifecycle model of public displays, i.e. how the costs are divided between the stakeholders, is also important (118), and suggested to be done before the deployment (41). When a display offers several different services, all tailored to satisfy different stakeholders, many of these problems can be mitigated easier than using just bespoke displays with only one service.

A similar service launcher, or menu, as in desktop and mobile environments is not the only viable means to make a display multipurpose. Scheduling is another option being currently investigated. For instance, the E-campus system provided a sophisticated content scheduler to make different kinds of services and content intelligently available to consumers (34). Another scheduler interface for opening up public displays and providing multiple applications sequentially was recently demonstrated by Elhart et al. (25).

Deploying displays longitudinally in the wild solely for research purposes is a luxury that only a few can afford. The future public display networks will have to offer tangible value to many stakeholders, especially if they are to be used for much else than advertising. Satisfying a diverse audience with a single display is challenging, if not impossible, as people have very different needs and expectations towards public displays (64). We believe that these needs will speed up the development and utilization of multipurpose displays. To satisfy some of these needs, this thesis seeks to integrate online SNSs into multipurpose public displays.



### 3 Social networking services

Social networking services are broadly defined as services that enable their users to create personalized profiles with personal content, invite others to have access to their profiles, and communicate with others in the service (6, 57). SNSs, as a concept, is far too broad to be presented here in its entirety, and thus, this chapter discusses their particular aspects relevant to this thesis.

#### 3.1 The impact of social networking services

Online SNSs are a relatively new phenomenon, and arguably the earliest SNS that conforms to the definition given above is the *SixDegrees.com* launched in 1997. Despite their young age, SNSs have fundamentally changed the way we communicate and share our lives online. Today, SNSs are extremely popular: according to The Pew Research Center's Internet & American Life Project in 2013), the amount of US online adults who use at least one social networking service is as high as 73% (88). In Finland, where the thesis research was conducted, half of the adult population reported to actively follow at least one SNS in 2012 (115). Often, users choose to use many different SNSs at the same time, especially for privacy reasons: parents of teenagers, for example, might not have yet adopted a certain SNS that can then be used to communicate with friends only (7). While many of the hundreds currently operating SNSs are primarily tools to connect and correspond with peers and family, several focus on networking around mutual interests, political views or activities (6). Particularly, non-profit organizations have realized the potential and learned to harness SNSs to advance their mission, by better connecting to their stakeholders and audiences online (119).

SNSs can also be used for other purposes than communication between humans. Because of all the content people have created in them, SNSs carry a massive dataset of information about the world. For example, the content in Twitter, i.e. *tweets*, can be analysed to reveal real-world phenomena. A service leveraging tweets, The *CrisisTracker*, is an open source platform that by analysing massive amounts of content in Twitter provides situational knowledge about a disaster area or a war-zone (94). Another example is advancing linguistics by analysing the tone of communication in Facebook status updates to uncover phrases and words typical to humans with different personality traits (100). Hence,

as the popularity of SNSs continues to grow, the data and content in them can be leveraged in many different applications and research areas.

For individuals, SNSs are useful not only for cultivating existing relationships (6, 109), but also for establishing and renewing connections with people whom they have met earlier, outside the services (67). In our vision, SNSs can also be used for providing public services for their users in physical spaces, where people meet and interact even before connecting online. A particular aspect of this thesis is leveraging users' personal content from their online *social media* profiles.

### **3.2 Social media**

McCarthy defines social media websites as “*any website or service that enables users to create, modify, view, rate, or share digital objects of interest*” (68). Social media focuses on creating, discussing and viewing content, and relations between users of such services are often much weaker than within sites strongly oriented towards social networking. This is not a strict definition, however, and the terms *social media* and *social networking services* are often used interchangeably. Many websites freely adopt features from both concepts, allowing people to personalize their profile to connect with a close group of friends and at the same time create public content for anyone to consume. As such, they could easily be classified under both definitions.

One of the biggest impacts of social media has been online reporting and consumption of news. Footage from disaster areas or other emergencies is often first found from online social media services instead of the official websites of news providers or traditional television news. In fact, sites like YouTube (124) or Twitter have become sources of fresh news footage for many of the mainstream news agencies. To operate efficiently online, they have had to adapt to the prevailing social media culture (12). Some “*industry gurus*” even claim that if you do not participate in the social media phenomenon, you practically cease to exist online (58).

The key to success of social media sites is the *media*: the content hosted in them and shared across thousands of different online platforms. This drives user engagement and directs visitors to sites, especially from the social networks of users who actively share content online. A negative side-effect of free and effective distribution of content is, of course, relatively easy access to highly problematic issues, such as for example pro-self-harm content (8). There is no

practical solution to prevent such content from being created and shared in the cyberspace. It is always just a few Google searches away. Also, many online video sharing services are not moderated at all. Although many of the mainstream sites, such as Facebook, attempt to alleviate the moderation problem by eliciting signups by users' real names to introduce more accountability, it is practically impossible to guarantee that users adhere to these terms. Users always come up with different methods to protect their personal details and signing up with false names and nicknames is just one example of such methods (7).

### **3.3 User generated content**

So, while there is no doubt that user generated content introduces issues with, e.g. moderation, it can also be argued that it fuels much of the popularity of the web as we know it. An everyday example of user generated content, outside the already discussed SNSs domain, is comments in online news articles or magazines. Sites allowing visitors to leave comments are abundant, and many of the reputed online media publishers leverage user generated content as a core part of their online strategies (43). For example, in the UK, The *Guardian* started to provide *messageboards* for its readers to contribute content already back in 1999 (114). Podcasts, photo galleries, consumer product review sites, question-and-answer sites, even advertising, etc. are all driven by user generated content. Curiously, the *Time* magazine's 2006 "Person of the Year", was *you*, referring to all people contributing to the creation of the online experience of today.

The benefits of user generated content to the online hosts, the site owners, are quite obvious in that it drives users to participate and return. However, for the contributors, i.e. the users, the benefits are not that direct. Their motivations for contributing content are diverse and vary a lot between different individuals. The identified motives for contributing online include building reputation in a community, creating connections to others with similar interests, informing others, self-expression, archiving ideas, or just simply passing time (105).

The ubicomp community has always found user generated content resourceful in creating new experiences with technology. Allowing people to create content can be a good way to entice users to participate. Focusing just on public displays, it is easy to identify a number of earlier well-received deployments that can be argued to owe their success largely to the content contributed by their users.

The *CityWall* and the *CoCollage* both thrived because of the contextually meaningful pictures, submitted by the visitors in the deployment locations (27, 87). The *Opinionizer* successfully elicited discussions and engagement by using text based feedback from its audience (10). *TexTales* encouraged people to contribute to text-based discussions on projected screens (4).

Another interesting domain where technology has enabled creating interesting experiences with user generated content is public arts, where the audience can actively take part in the creation together and in collaboration. *MobiSpray* (95), for instance, consists of a powerful mobile projector and smart phone clients that can be used together as a digital spray can to paint large canvases, such as buildings. Among the buildings that have been painted with *MobiSpray*, are such as the Guggenheim Museum in New York and the Sydney Opera House. *I in the Sky*, introduced in (61), utilized a massive public screen at Times Square, New York, to showcase artistically enhanced photos that people could take in a special photo booth, located in a nearby art gallery. Similarly, *Manhattan Story Mashup* utilized mobile phones and massive public displays in creating user generated stories via gameplay (116). The players were able to use their phones and creativity to come up with bits and pieces of stories that were then showcased on screens. These installations illustrate how user generated content can be used for reaching large audiences in highly public locations.

The approach taken in this thesis aims to flexibly leverage user generated content on public displays, not only by allowing the creation of new content, but also by providing access to already existing content. There are many social networking services, image repositories, blogs, etc. to obtain meaningful user generated content from, to be used on public displays. Technically, this can be easily achieved by building, e.g. scrapers to fetch the content, but fortunately, most big online content sources provide application programming interfaces for easier access.

A good centralized resource for exploring the publicly available APIs of online content sources is *ProgrammableWeb* (90). It lists thousands of different online APIs from different providers. Not surprisingly, many of the popular APIs listed there are from such user generated content sources as Facebook, Twitter, or Flickr (26, 29, 117).

In summary, consuming and sharing user generated content in one form or another has traditionally been the key driving force behind the success of social networking services. Recently, however, the entire online SNSs ecosystem has been shaken by the avalanche of mobile Internet users.

### 3.4 Mobile social networking

Mobile social networking has become popular during the last few years. Practically all dominant SNSs offer web interfaces tailored for mobile phones, dedicated mobile client applications, or both. The main reason behind this development is the rapidly increasing technical capabilities of modern smart phones (52), not only their improved communication capabilities, but also context-aware features, particularly positioning. For example, a specific genre of social networking services that has radically benefited from the popularity of smart phones is location-based social networks. Mobile phones are easy to geo-locate and practically always carried along with their owners, making it possible to implement functionalities that relate well to the surrounding context. For example, FourSquare (33) offers advertisements of the particular place where the user is in, or notifications of contacts being in the same place at the same time. It also implements a social ranking mechanism for any place registered in it. In addition to tailoring services by users' physical locations, it is also possible to match different users who are near to each other (24).

The mobile phone is (practically) always with its owner, at hands and ready to be used when queuing in the grocery store, waiting for a bus, at lunch, etc. With our mobile phones, we are constantly online, more than ever before, and this has led several of the new and rising social networks targeting mobile devices as their primary platforms. Based on the current trends and figures, it is widely forecasted that soon most of the traditional social networking services will be used more on mobile than on desktop. The future seems inevitably mobile.

A particularly interesting characteristic of the mobile phone is its capability to create and share content. Full-fledged QWERTY keyboards for typing, integrated cameras for taking pictures and videos, microphones, applications that make content editing possible, etc. make them versatile tools for creating high quality user generated media and other content. Often, this content is about documenting the daily life on the go. Especially the integrated cameras are used for activities such as sharing experiences with friends and family, personal reflection, or documenting mutual experiences with close ones (59). Together with powerful networking capabilities and APIs, that allow the phones to be constantly connected to online SNSs, this makes the smart phone a great source of personal, high quality user generated content that can be distributed with ease. With this in mind, and considering how flexible it is to implement custom software on mobile

platforms, it was logical to consider the smart phone also as one of the possible user interfaces in our goal of merging public displays with SNSs.

### **3.5 Social networking services on public displays**

The public display research community has also leveraged of SNSs for creating novel services. CoCollage (27) allowed users to create a profile and contribute content to public displays in a cafe, practically creating a new, highly situated SNS focused on cultivating a local community. Already existing online SNSs can also be high-quality content sources for displays (25). The *Context Community & Community Collage (C3C)* (70) showed users' photos from their personal Flickr accounts on large touch-screen displays deployed in laboratory settings. C3C used Bluetooth to detect and show content only from users in close proximity to the displays, much similarly to Instant Places discussed earlier (54). CityWall (87) is another example showing Flickr content on a large touch-enabled display. Deployed in downtown Helsinki, Finland, it showed photos tagged "helsinki" and highlighted how such a large interactive display can act as a "stage" in the urban space.

SNSs can also be used as a direct input mechanism for public displays. Particularly Twitter has been utilized for this. The *Discussions In Space* (98) was deployed on eight different large urban screens in Brisbane, Australia, for collective expression and public discourse on urban planning and city design. Discussions In Space provided citizens opportunities to voice their opinions through direct input via SMS and Twitter. The *Thanks and Tweets* prototype (80), deployed on a university campus, elicited feedback and comments on public displays via Twitter. One benefit of utilizing SNSs for input in such services is automatic logging and backlog of the provided content.

More recently, SNSs have also been utilized in hosting content created in-situ on public displays. The *Moment Machine* (75) is a public display photo service that allows people to take a snapshot, which is then distributed across a network of public displays to be viewed in a public gallery. Another version of Moment Machine creates the public gallery in Facebook, consisting of all photos sent from the displays running it.



## 4 Research contributions

This chapter presents the research contributions of Articles I-V that are relevant to this thesis. The chapter begins by discussing the experimental environment in which the majority of the research in the thesis has been conducted. Then, the developed middleware components that enable integration of SNSs to public displays are described. These are a distributed user **interface**, a login mechanism, and an API for accessing online SNSs directly from public displays. Case studies of services leveraging online SNSs on public displays are presented, and finally, the chapter presents a summary of the relevant contributions in each of the five articles.

Figure 1 provides an overview of the middleware components that were developed for the experimental environment, as well as the services that were built utilizing at least one of those components.

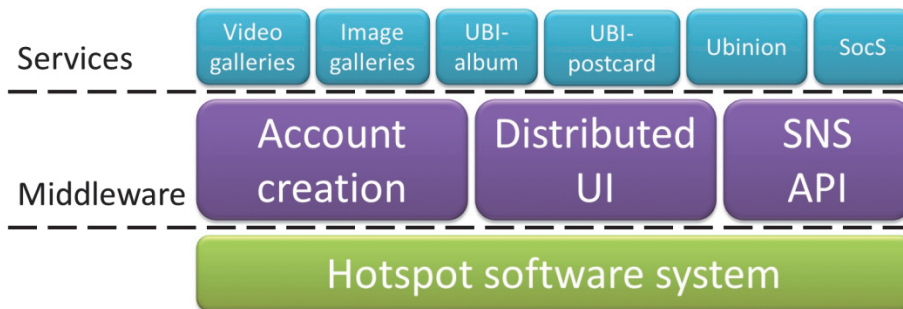


Figure 1. The middleware components and services developed in Articles I-V.

### 4.1 The experimental environment

In late 2007, we started to design, develop and eventually deploy (summer 2009) a network of large interactive public displays in Oulu, Finland. This network is a part of a much larger effort to provide a range of technologies, interfaces, and resources for conducting ubicomp research in an authentic urban city setting and with uncoached end users (85). We named the public displays *UBI-hotspots* (84).

The initial design process of hotspots included a thorough planning phase in collaboration with citizens, City of Oulu officials, and related stakeholders from the local industry (65). The hotspots are multipurpose, i.e. they offer several

different services to their users. While most of the services are developed by researchers from University of Oulu, we allow -- and in fact encourage -- third parties to contribute content and services to them as well. Our goal is to maintain the hotspots as an open infrastructure that is genuinely accessible for many different purposes and uses. The deployment process has been accomplished with constant strong support from City of Oulu, and one of the core ideas behind the whole infrastructure is to offer joy and concrete benefits in the form of useful services to the citizens, visitors and tourists of Oulu.

The hotspots feature 57" or 65" full-HD LCD screens with capacitive touch screen foils, and there are different versions of hotspots for indoor and outdoor uses. The outdoor versions are all double-sided, offering two identical screens to their users, whereas the indoor versions have only one screen and are naturally deployed so that the back sides of them are facing walls. A hotspot, depicted in Figure 2, is equipped with WLAN access point, Bluetooth Base Stations, and RFID readers for versatile wireless connectivity. They also feature two embedded web cameras, microphones, and loudspeakers, providing rich interaction possibilities for services. For a more detailed description of the hotspots and the whole infrastructure, we refer the reader to Ojala et al. (83, 84).



**Figure 1. Components of an indoor hotspot.**

The amount of hotspots has varied slightly during the time span of the research presented in this thesis (2009-2013), but at all times, there have been 12-18 screens available in the city for the general public to use. All hotspots have always been and are currently located in pivotal, highly public locations in Oulu, where they can be used freely by anyone. Several factors have influenced the set

of operational hotspots available at a particular time, such as renovations in the deployment locations, differing stakeholder interests, opportunities to relocate a hotspot to a better location, etc. The current setup includes locations such as the main library, swimming hall, University of Oulu, Oulu University of Applied Sciences, several hotspots in the main walking streets in downtown Oulu, and a sports arena. Figure 3 depicts real-life examples of hotspots in their deployment locations. For research purposes, it is naturally most beneficial to have hotspots in as diverse a set of locations as possible, as it allows us to reach different audiences and observe how new services and concepts fair in different social and physical environments.



**Figure 3. Examples of UBI-hotspots in their authentic deployment locations. Top row from left: the local main library, swimming hall, market square of Oulu. Bottom row from left: a pedestrian street in downtown Oulu, a sports arena and university campus.**

Typically, when no services have been launched by users, the hotspot is in so called *broadcast mode*. In this mode, the hotspot simply broadcasts full-screen videos. These videos consist of both commercial advertisements and non-commercial content from various partners and collaborators. When a user is detected in front of a hotspot by one of the embedded web cameras, using face detection algorithms, or when a user touches the screen, the hotspot enters into *interactive mode*. In the interactive mode, the video player is minimized to the upper left quadrant of the screen, and a service selection menu is revealed to invite users to interact with the hotspot and to explore and launch the offered services. It occupies the remaining three quadrants of the hotspot’s screen. There is also a bottom-bar on the screen, much similar to, e.g. to the “taskbar” in

“Windows operating systems”, that offers miscellaneous functionality (discussed later).

It is also important to note that due to contractual reasons, most of the time services on the hotspots are not unfortunately allowed to be launched fullscreen. Thus, the video player is usually always visible as fullscreen or as minimized to the upper left quadrant. This is not a technical requirement, but just one of the external issues that we have to deal with in our environment.

A service on the hotspots can be configured to use any arbitrary combinations of the four equally-sized quadrants, allowing also “L-shaped” configurations for services. This interaction model has also been slightly changing over the years as we have introduced new versions of the hotspot. We have also trialled different approaches, such as not minimizing the video player and showing a “page peel” animation in the upper right corner of the hotspot as invitation to interact. All hotspot activity, such as service launches, transitions between states, etc., are logged to a centralized log server. This makes gathering quantitative data of studies conducted in the environment effortless. For an overview of the evolution and different approaches we have explored with hotspots, we refer the reader to Ojala et al. (83). For details about the underlying in-house web-based screen real estate management, responsible for the layouts and their transitions, see Heikkinen et al. (42). Generally speaking, everything visible on the hotspots' screens, i.e. the service selection interface and all services, is web-based and runs in a standard web browser.

Access to the services is naturally the most important task of the selection interface. However, through the bottom-bar, it also offers additional functionality such as changing the locale of the hotspot with Finnish and English supported at the moment), displaying a clock, providing surveys to users, or inviting the user to login to the hotspot (explained in more detail later). This interface has evolved during the years and it has consisted of various different types of service menus and directories. Detailed information about major iterations of the interface is found in (60, 83, 84). After a user chooses a service to launch from the service selection interface, the chosen service is rendered to the areas of the hotspot that it was configured to employ. Figure 4 illustrates this by an example of a hotspot's screen in interactive mode: a service has been launched to occupy the right half of the screen, videos are being played in the upper left quadrant, and a service menu is visible in the lower right quadrant. The buttons in the bar in the lower part of the screen belong to the service selection interface of the hotspot.



**Figure 4. Screen area of a UBI-hotspot in interactive mode.**

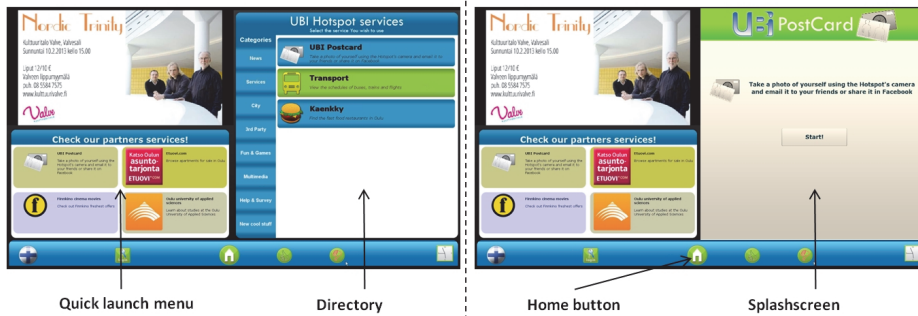
The fact that our hotspots are multipurpose, i.e. host multiple services at the same time, has certain implications on deploying and evaluating services on them. This applies to many of the services presented in this thesis. Therefore, it is necessary to elaborate on this topic, to better understand the context of the experiments.

In the trial reported in Article III, we noticed that the services deployed on the hotspots often were used only for a few seconds. In fact, of the tens of thousands of sessions logged in the trial, 79% lasted less than 30 seconds. Moreover, from our preceding observations, we already knew that it is typical for a user to use multiple services sequentially. We concluded that many of the service launches on multipurpose public displays are motivated more by curiosity than strong intention to use the service for its actual purpose. So, having multiple services on a display has network effects on a single service's use in general. Most importantly, this alluded that evaluating a single service deployed as one of many on a multipurpose display is certainly not the same as evaluating a single service deployed on a bespoke public display. This is something that affects not only evaluating services leveraging SNSs, but indeed all services on such multipurpose public displays.

Article I explored the effects of the multipurpose display on the use of its services. A service deployed on a hotspot was represented by an icon, title, and a textual description in service selection interface. Thus, users already could get a

clue of what a given service is and what can be done with it. The interface had three areas in which a service can be placed, for subsequent discovery and launch by a hotspot user. These were *directory*, *quick launch menu* and *splashscreen*, as illustrated in Figure 5.

The directory occupies the right-hand side of the screen, and it could always be invoked also by touching a home button in the bottom bar. It provided categorized listing of all services that were available on that hotspot. The quick launch menu was located in the lower left quadrant of the screen and was used to promote a set of services, by giving constant visibility in a prominent location. Finally, the splashscreen yielded a service the most visibility. It took over the right half of the hotspot, thus overriding the directory that by default would be rendered there, and promoted a single service to the user.



**Figure 5. The hotspot's service selection interface. Copyright ACM Press, 2013, Article 1.**

Together these three areas defined different discoverability conditions for a service. Discoverability governs how easy it is to find a service in the service selection interface. Article I explored the usage of a particular service on a hotspot in three incremental discovery conditions. In our definition, when a service had *low discoverability*, it was placed only in the directory. To launch it in low discoverability condition, hotspot users first had to choose a category in the directory and then the service in the category. In *medium discoverability* condition a service was placed also in the quick launch menu, located in the lower left quadrant of the screen. Thus, it could be found and launched much easier, without necessarily accessing the directory at all. Finally, in *high discoverability* condition, a service was placed in all of the three placements, including also the splashscreen that replaced the directory by default.

We computed statistics to evaluate service usage on multipurpose public displays: *relative utility* and *conversion ratio*. Relative utility is the frequency that a service is launched relative to the frequency of all service launches on that same display (60). Conversion ratio refers to the percentage of service launches that led to the service being used for its actual intended purpose of all the launches of the same service. In this study, we used a service that allowed users to send postcards in-situ from the hotspot. This allowed calculating the conversion ratio by just logging if a postcard was sent or not during a service session.

The statistics in Table 1 show that the differences between the three conditions are surprisingly drastic. As expected, increased discoverability leads to increased relative utility. However, our most important finding for conducting field trials in multipurpose display environments is that increased discoverability leads to a decreased conversion ratio.

**Table 1. Postcard service launch statistics for each condition.**

Condition	Launches with no cards sent	Launches with cards sent	Conversion Ratio	Relative Utility
Low	72	21	0.23	0.012
Medium	191	38	0.17	0.038
High	488	63	0.11	0.075

The key takeaway point is that a service selection menu providing many services has a role in the overall use of an individual service being evaluated. The different discoverability conditions greatly affect how a service is used on the display. Services displayed prominently on the screens tend to get launched out of curiosity much more than ones placed in the directory only, for example. In our study, the very same service attracted considerably different amounts of use and conversion ratios in different conditions. It is still the same service, providing the same functionality in every condition. In much of the related literature, studies are conducted with just one service on a dedicated public display (highest imaginable discoverability), and for the aforementioned reasons, a direct comparison to those kinds of studies is quite misleading.

The findings from Article I confirm that a multipurpose public display is a much different environment than a bespoke one. This framing is highly important to keep in mind when considering deployments on multipurpose display environments such as in studies that Articles II and III report. Equally important is to acknowledge that the earlier described experimental environment was not



specifically designed for the articles in the thesis. The hotspot setup, screen layout and the set of available services in Articles II and III were carefully defined earlier, to form the grid of identical hotspots for the public. Thus, we could not alter them just for the studies in this thesis. Naturally, altering the design was never even the purpose, as we wanted to study services deployed in the grid, in their native environment. In Articles IV and V, the displays were deployed in custom locations for specifically organized case studies, and the contextual setup could be altered specifically for the studies.

## **4.2 Integrating public displays with online social networking services**

The software platform of the hotspots offers high level APIs and middleware components for implementing and deploying service. This thesis contributed components that enable integrating SNSs into hotspot services.

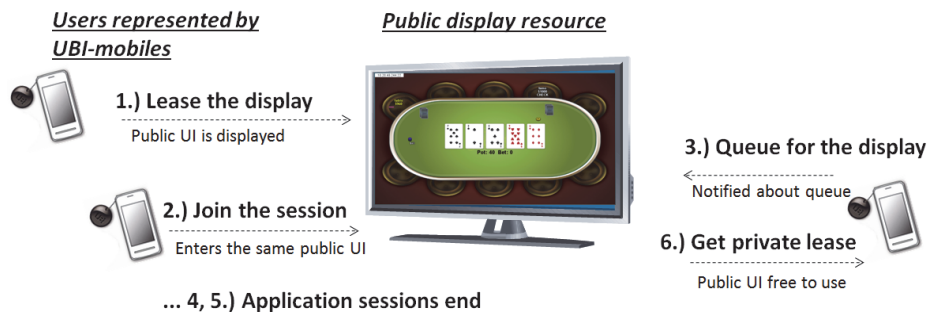
### **4.2.1 Extending the user interface**

As we pursued for more advanced services for the hotspots, the public touch-based UI alone was simply not sufficient anymore. Various use cases, such as accessing the user's personal data in online SNSs or uploading and downloading content, called for a more private user interface than the highly public screen of the hotspots.

Mobile phones had already been used successfully in conjunction with public displays in other public display deployments, so we chose to start exploring them as an alternative interaction mechanism for our displays as well. A Distributed User Interface (DUI) middleware component that enables services comprising of several (private) UIs on mobile devices (phones) and a public UI on a hotspot was developed in Article II. Such a distributed service can be single-user (one phone, one hotspot), or multiuser (many phones, one hotspot). A distributed service can be launched by simply associating a mobile device to a hotspot by touch. This is realized using RFID technology. RFID tags were distributed to users' *mobile phone jewels* from a dedicated field trial office at downtown Oulu. The tags inside the jewels were read by the RFID readers in the hotspots. Once the unique code in the tag identifying the user was read, the distributed services available on that hotspot were displayed to the user. If there was already an ongoing multiuser session running on the hotspot, the user was offered an opportunity to join it. If

someone was already using the hotspot for a service that did not support multiple users, the arriving user was put on hold in a first-in-first-out queue, to wait for a notification (sound + vibration) indicating that the hotspot was free to use again. This negotiation process is illustrated in Fig 6.

The negotiation between a mobile device and a hotspot was handled by a mobile phone application called *UBI-Mobile*. It acted as a *personal service selection menu*, to discover and launch available services. This should not be confused with the *public service selection interface* on the hotspot's UI. The service discovery interface provided by the UBI-Mobile offered only services that required a mobile phone UI to be used. Thus, there was a clear separation between services that can be used by anyone in the public and the ones that can be used only by users with a smart phone with the UBI-Mobile installed.



**Figure 6. The distributed user interface mechanism for hotspots. Copyright ACM Press, 2010, Article II.**

The functionality of the distributed user interface solution was validated by implementing several services that were evaluated in a longitudinal field trial. The services had varying user interface configurations, comprising of hotspots and users' personal mobile phones. Article II offers further details on the DUI component, the services, and the field trials.

The DUI component proved versatile for not only implementing distributed services, but also for integrating SNSs to the hotspots. However, empowering the users' mobile interfaces was not sufficient alone, but specific support for that purpose needed to be added to the hotspot middleware.

#### **4.2.2 De-anonymizing the public display user**

A well-known and often problematic issue in public display research is the inability to reliably identify the users. It is often impossible to distinguish between new users and returning users, which prevents capturing potentially interesting data about user-specific usage patterns. Obviously, methods such as face recognition could be used, but it makes errors and is guaranteed to face heavy public resistance due to privacy issues. In our case, we wanted to reliably identify users in order to be able to offer them services that access their personal, online SNSs. Also, we wanted this to be a feature of the hotspot middleware, instead of individual services, to make the overall user experience more fluent.

An *account creation / login mechanism* was developed for the hotspots, to allow users to create an account and identify themselves. Article III provides details about the mechanism. The bottom-bar of the service selection interface provides a button to create an account or to login to the hotspot. Clicking the button opens a pop up on the screen, as illustrated in Figure 7. An account can be created in-situ by completing three steps. The created account can then be used on any of the hotspots.

An account is created and associated with the user's mobile phone as follows: The user is first asked to select his/her Bluetooth enabled smart phone from a list of all detected devices in close proximity. A security code is then sent to the selected phone over Bluetooth. The user is then prompted to choose a personal PIN code, after which she will have to verify the phone's ownership by inserting the security code received earlier from the hotspot. After the phone's ownership is confirmed, the account is created and associated with the phone's Bluetooth device address. This process is also illustrated in Figure 7. Login to the hotspots happens by again choosing the user's mobile phone from the list and then inserting the personal PIN code. Login is not required to use the public services of the hotspot. However, together with the DUI component, the account and login mechanism allowed leveraging personalized services such as online SNSs.

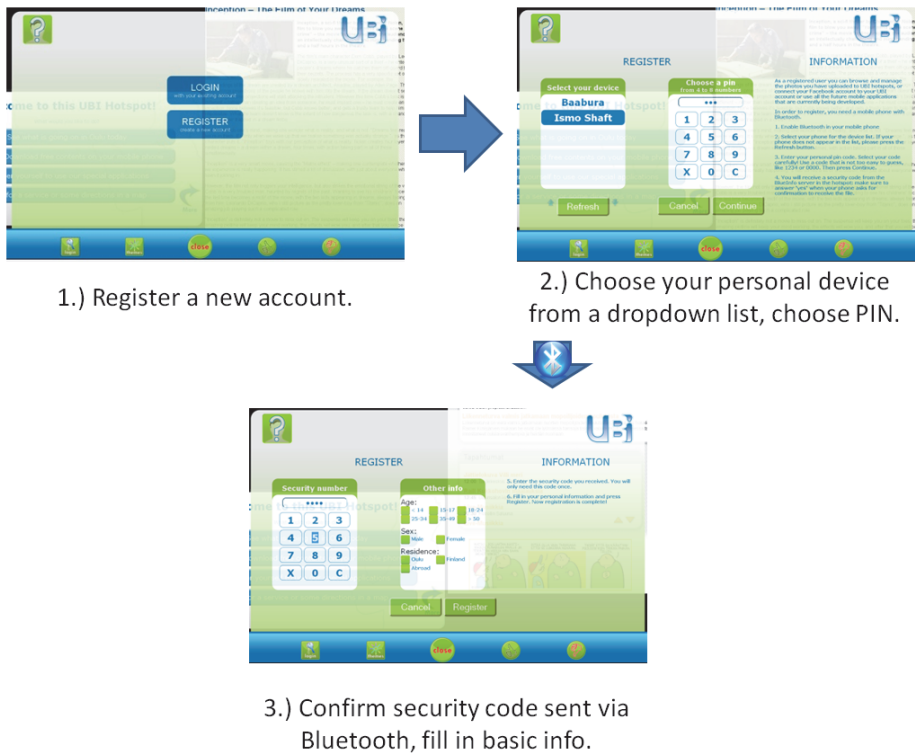


Figure 7. Account creation on a hotspot. Copyright ACM Press, 2010, Article III.

#### 4.2.3 Integrating social networking services with the hotspots

To bridge online SNSs to the hotspots, we developed an *SNS API* for them. With this API, we chose to first support the globally most popular SNS, Facebook. For the API to function as we wanted to, we also had to develop a Facebook application: *UBIOulu*. If a hotspot user wishes to use any of the supported features from online SNSs, this application has to be granted permissions to read from and write to the user's Facebook profile. To install the application and grant it the needed permissions, the user can choose to receive over Bluetooth a URL in the end of the account creation process as discussed earlier. The link redirects the mobile phone's browser to the *UBIOulu* Facebook application, which prompts the user about the required permissions. This happens inside Facebook's native interface, without concerns about security issues on our side. This way, the user

never has to use the public interface of the hotspot to type sensitive data such as Facebook username or password.

The UBIOulu application enables the SNS API to use Facebook's native APIs to access users' content and feeds. The interface of the SNS API resides on a server in the experimental environment and is protected by access control. It can fetch content from any registered user's online Facebook profile, including friend connections, first name, last name, profile image URL, and the user's recent activity feed in its entirety. It can also publish updates, with or without an image, to the user's wall feed. The SNS API is available for third party developers as a part of the open API set offered by *Open UBI Oulu* (86). Facebook integration and the SNS API are discussed in more detail in Article III.

### **4.3 Experiences from the field**

Over the years, dozens of services have been developed for the hotspots. This thesis focuses on services that either utilize online SNSs directly as a building block or contain features mimicking online SNSs. Next, prototypes exploiting three aspects of SNSs are discussed: user generated content, communication between users, and role of smart phones in bridging SNSs and public displays.

#### **4.3.1 Leveraging user generated content**

User generated content, as discussed earlier, has been harnessed to empower numerous highly successful ventures online. Our approach is exploiting it on hotspot services initially focused both on using existing content online on hotspots and allowing users to upload content using hotspots.

Four distinct gallery services are reported in Article III: *Photos*, *Videos*, *UBI-videos*, and *UBI-photos*. Photos service, depicted in Figure 8, allows browsing Oulu-related images downloaded from Flickr using a tailored version of Tag Galaxy (110). The set of displayed images can be refined by choosing from a set of related image tags, as suggested by Flickr's own image API. The images can be then browsed in an "orb" style interface. New images can be uploaded or a selected image can be downloaded, chosen as favourite, or flagged as offensive for temporary removal and later inspection. Videos allows users to watch videos contributed by our research partners and other non-profits. Videos are hosted in YouTube and played using an embedded, custom YouTube player (Figure 9, left).

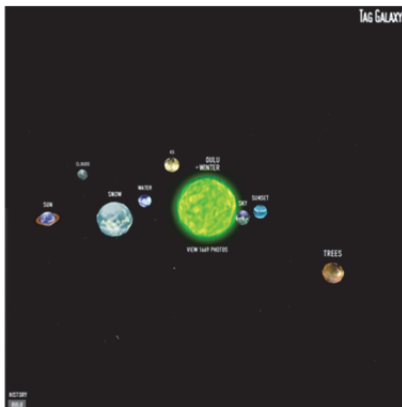
The UBI-versions of the services are identical software-wise, but contain only content that hotspot users, the “UBI community” in Oulu, have uploaded.

Uploading content from users' personal mobile phones takes place via Bluetooth. A content item, a video or an image, can be uploaded at any hotspot. The hotspot then relays the content to the SNS hosting it, and it becomes available on all hotspots, yielding an efficient content propagation and hosting concept. Besides utilizing content from online SNSs and allowing user generated content, the services also adopted other familiar features from online SNSs. It is possible to select content items as "favourites" (equivalent to “likes” in Facebook) and flag inappropriate content for temporary removal and later inspection by moderators. Downloading content to users' mobile phones was also allowed, again using Bluetooth.

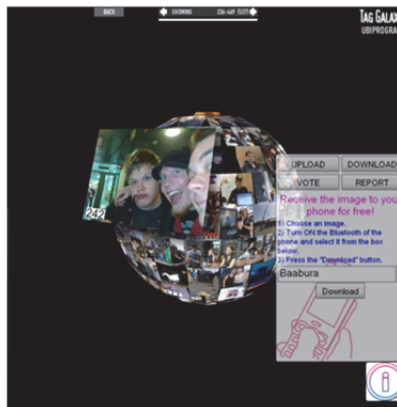
## Browse and select images



## Selection of filter tags



## Extra actions for images



**Figure 8. Photos service on hotspots. Copyright ACM Press, 2010, Article III.**

The uploaded content could also be deleted in-situ at the hotspots, by using UBI-album service, but only by the user who had uploaded the content. (Figure 9, right). To use UBI-album, the user had to first create an account for subsequent login as discussed earlier. Besides just managing content, UBI-album provides a handy interface for showcasing all uploads to other people.



**Figure 9. A) Video player (custom YouTube player) with a selection of videos uploaded by hotspot users. B) UBI-Album showing a gallery of content uploaded by the currently logged in user. Copyright ACM Press, 2010, Article III.**

User generated content is also utilized to personalize the look and feel of the hotspot just like in various online SNSs users can personalize their profile. Myspace (81) was the pioneer in allowing its users to customize their profiles, which was a much liked feature. In our case, when a user logs in to a hotspot, the service selection interface uses the SNS API to fetch her profile image from Facebook along with her real name. These are then used to customize the interface and to display a personalized greeting to the user. This only happens if the user has completed the optional SNS integration step when creating the account.

Finally, we explored content creation in-situ with the *UBI-postcard* service at a hotspot. There, first a user takes a photo with the embedded web camera, then adds a textual greetings to it, and finally enters email address(es) to receive the post card via email. It also allows for decorating the postcard with a custom frame, much like in certain photo sharing services and SNSs. The service can publish the photo directly to the user's Facebook feed using the SNS API. The UBI-postcard was later used in Article I to explore the effects of multipurpose displays on service usage. Figure 10 depicts the current version of the service UI. Naturally, the service has been updated a few times over the years.



A



B



**Figure 10. The user interface of UBI-postcard. A) The user can take a snapshot and enter destination email addresses. B) The user can type a message, choose a frame and send the photo and/or publish it in Facebook. Copyright ACM Press, 2010, Article III.**

Article III reports on a ten-month data collection period that verifies UBI-postcard as the most appealing service among all the presented services that were given equal visibility on all hotspots. UBI-postcard attracted 38.9% of 61,779 total service launches. A qualitative user study with 23 self-proclaimed power users, recruited from Facebook and local mailing lists, indicated that creating and sending postcards at hotspots is highly fun and social, and that people wish to do that, especially in groups. Fifteen participants liked the possibility to publish photos directly to Facebook, while only five did not. UBI-Postcard is still a very popular service among hotspot users, and more than 18,000 postcards have been sent since its introduction in late 2009. At times, we have observed groups of up to twenty people joyfully taking a photo together several times before being happy with the result, and sending it forward via email. The results presented in Article III show that user generated content -- photos in particular -- are an avenue worth exploring on public displays.

However, in retrospect, when discussing the value of UBI-postcard to its users, we found out that it was perhaps more about communication than just the photo content itself. People send postcards as invitations, for instance, or just inform their friends that they are back in town after a long trip. In a way, the

content in the postcards takes a back seat and the underlying message becomes more important to its users. We have developed several other communication services for the hotspots as well, including services utilizing online SNSs.

#### **4.3.2 Enhancing communication between public display users**

From a philosophical standpoint, everything that users do with a public display is communication in one way or another. *One cannot not communicate*. However, in this thesis, communication services refer to services that allow users to meaningfully send messages to other users, friends, or strangers. Two such services, *Social Surroundings* and *Ubinion*, are presented here. Both services expand the simple idea of user generated photographs towards more complex communication patterns.

##### *Social Surroundings*

The concept of Social Surroundings explores the idea of leveraging personal and socially meaningful, user generated content on displays located in casual places where people spend free time and have time for serendipitous interactions. The content shown on displays could then be used as a conversational piece to spark and enrich communication between the collocated users, to enhance awareness and sociality among them. The Social Surroundings prototype (SocS), introduced in Article IV, was developed for this purpose.

SocS displays content from users' online SNS profiles on a public display. The content may encourage people to socialize and network with each other more. Pictures are often used as "ice-breakers", to support small-talk between people who are not well acquainted with each other. This has certainly been noticed in academia as well, and some early installations allowing users to contribute personal content to large displays already existed before SocS. However, SocS took the idea a bit further, in a novel way.

SocS does not create yet another social networking service to handle the content and displays. Instead, it accesses the user's public content via the official APIs of SNSs, SNS API developed for our hotspot infrastructure, or via custom Web crawlers if no APIs were available. SocS supported five popular online SNSs: *Facebook*, *MySpace*, *Flickr*, *Picasa*, and a Finnish SNS popular at the time, *IRC-Galleria* (26, 29, 51, 81, 89). SocS uses only content that is defined completely public in these services and thus accessible to anyone online.

SocS consists of a centralized server, a full-screen user interface on public displays, and dedicated mobile clients. The distribution of the user interface is managed by the DUI component. Besides serving the web-based UI on the public displays, the server fetches content from online SNSs and manages the mobile clients. The client offers the following functionality:

- Choosing the place where the user is currently located from a list of places supporting SocS;
- Providing a nickname as the local user identity;
- Providing account details of SNSs that the user wants to utilize as content sources;
- Setting a short status message / checking status messages of other users who are in the same space;
- Sending instant messages to other users in the same SocS space.

Once the user had configured her content sources, SocS started periodically pushing images from the sources to the display. The images were shown together with the local nickname of the author and captions, if they had been provided for the images. A list of current SocS users in the same space was also on the public display. The client supported only simple text-based status messages and instant messages. Specifically, trendy features, such as "nudges", smileys, camera functionality, etc. were omitted, as the goal was to make people socialize face to face instead of playing with the client. The SocS client and the public display are depicted in Figure 11.

SocS was deployed for one night in a local bar and for one day in a lecture hall waiting area on our campus. In both cases, we used large, interactive public displays that were similar to our hotspots (35). We also handed out mobile phones with the SocS client already installed to avoid delays and unexpected technical issues.

During the trials, 31 participants used the service. Data was collected by surveys and interviews. While SocS was found to be fun and entertaining, not all users liked the idea of displaying their public online content on a public display. Half of the participants were not willing to contribute content from their online accounts, but they still judged SocS as a fun and welcome service in the space. They were still able to peek at other people's photos and lives, and communicate with them using SocS.

Most respondents agreed on SocS being a good way to connect people to each other, by providing opportunities for discussions. This verifies that

photographs obtained from SNSs can act as conversational pieces also outside the online environment, on public displays. Curiously, one user was enthusiastically displaying photos from his girlfriend's accounts, stating that he would never use his own photos with SocS, but using hers is perfectly fine. Finally, the idea to use already existing online SNSs instead of creating a dedicated one was deemed as a good choice. In addition, users wanted to have a possibility to contribute photos directly from their mobile clients.



Figure 11. The private and public user interfaces of the Social Surroundings prototype. A) The user is setting up her credentials in online social networking services. B) Sending an instant message. C) Setting a status message. The bottom image depicts the user interface on a public display. Copyright IEEE, 2010, Article IV.

In terms of communication, user generated content on public displays can be harnessed to invite people to interact with each other. Encouraging comments

such as "I feel it can be entertaining in bars, especially if people are shy" and "I think it could be deployed in restaurants, as, for example, a public service for messaging" speak clearly for its potential role in connecting collocated people.

### *Ubinion*

Over the years, we have noticed that hotspots appeal particularly to younger citizens. They play games or just spend time tinkering and toying with the hotspots, as can be seen in Figure 12. This behaviour was exploited in the Ubinion service designed in collaboration with the officials of the local Youth Affairs Department (later: YAD). Ubinion was set to enhance their communication with the youth by enabling discussions using public displays and online SNSs. Ubinion is reported in Article V.

The reasoning behind Ubinion was promising: hotspots were already highly popular among the youth, as were online SNSs. In addition, the YAD had identified several shortcomings in their online presence and wanted to try something new. Partnership with the YAD was mutually beneficial: the hotspots would get a new service relevant to the research themes of this thesis, and the YAD would get a new medium to communicate with the youth.

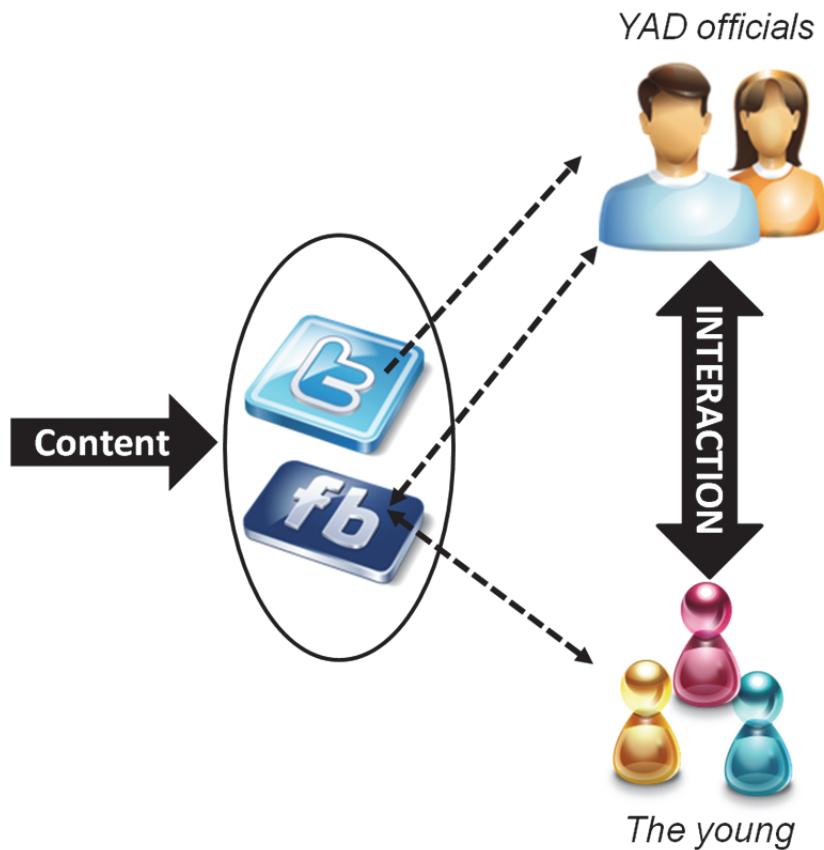


**Figure 12. Young public display users at downtown Oulu. Both screens of the double-sided hotspot are being used simultaneously.**

From the very beginning, Ubinion was developed in close collaboration with the YAD to gain a thorough understanding of their operational models and identify ways how to complement their ongoing communication practices with the youth using public displays. The idea was to utilize public displays to bootstrap an online community (image gallery) in Facebook. This gallery was projected to act as a new hub for ideas and feedback, a novel communication medium between the youth and the YAD officials. While the YAD already was present in Facebook, it was not seen particularly efficient in engaging the local youth so far. Ubinion was seen as a good way to let the youth contribute content and opinions “offline” and then later discuss online with the YAD officials.

The Ubinion's user interface occupies the right half of a display. It first presents the current topic that users are encouraged to leave feedback on. The feedback is left in the form of a photo that is taken by using the embedded web camera. The photo is complemented with a movable “speech bubble”. A textual comment is then typed to the bubble by using an on-screen soft keyboard. Finally, the resulting image is uploaded to the Ubinion's gallery page in Facebook. This

page was made accessible via an easy-to-remember domain name (www.ubinion.com). There, the YAD officials could then engage with the youth by discussing the community contributed content, the photos, and comments. To explore integration with online SNSs further, Ubinion also relayed all the textual comments to a dedicated Twitter account. This allowed easier skimming of the comments, without the visual clutter of Facebook. The content flow of Ubinion is illustrated in Figure 13.



**Figure 13. Content flow in Ubinion: text and images are relayed from public displays to Facebook and Twitter. The officials access the content in Twitter and Facebook. The communication between the youth and officials happens via discussions in Facebook.**

Ubinion was evaluated in three different social contexts. The first trial was conducted during a two-day sports fair, featuring sporty activities and



contraptions, such as skateboarding, bouncy castles, and BMX cycles. The second trial, lasting one day, took place at a university open days event that was organized for informing potential future students about study possibilities in the University of Oulu. Finally, the third trial lasted for only two hours and took place during the breaks of an ordinary day in a local high-school.

During the field trials, 262 feedback entries to the YAD were provided via Ubinion (for examples, see Figure 14). Feedback from users about Ubinion was collected via questionnaires (N=195). The questionnaires focused on usability, users' trust in the YAD and in the potential impact of their feedback. In addition, we observed the use of Ubinion at each location. After the field trials, we analysed the feedback entries and collected usage data from Facebook analytics for five months after the last field trial ended.

The data revealed Ubinion to be an easy to use, entertaining service that is especially fun to use in groups. Respondents were not convinced about their feedback having any impact, indicating a lack of trust in the communication between the youth and local authorities. However, prior familiarity with the YAD had a significant positive effect on this. Respondents who already knew about the YAD and its operations trusted Ubinion much more. Semantic analysis of the feedback entries revealed that the youth were most concerned about public services, sports and education. While group size did not affect the feedback category, sports-related feedback was much more common among males than females.

An interview with the YAD officials revealed that they regarded Facebook gallery as a good tool for facilitating communication with the youth, whereas twitter feed was preferred for quickly getting an overview of submitted feedback. The usage of Ubinion differed heavily between the three different trials, underlining the importance of the social setting on the effectiveness of such a communication channel. Overall, communication beyond the initial one-way submission of feedback via displays did not really take off in the magnitude we hoped for.



**Figure 14. Examples of feedback given via Ubinion. Top row: “cheaper bus tickets and more training facilities for local bands”, “It would be nice if there was more physical exercise possibilities tailored for high school students – cheap, of course”. Bottom row: “more soda to Oulu”, “Oulu is a violent place”.**

Despite the slight disappointment in terms of achieving the original, rather ambitious goal, we nevertheless learned a lot about public displays and SNSs as a communication medium between the younger generations and City officials. Most importantly, Ubinion trials proved that it was feasible to enable our users to communicate with local authorities using public displays and online SNSs. We have since designed and deployed several services with similar technologies and goals, leveraging the lessons learned with Ubinion experiments.

#### **4.4 Summary**

This thesis contributed a body of research that has focused on leveraging SNSs to create new functionalities and services for a network of displays deployed in the

city of Oulu, Finland. Table II summarizes the research objective, the experimental setup and the findings of the five original articles.

**Table 2. Summary of research contributions**

Article	Research objective	Experimental setup	Findings
I	To investigate the effects of discoverability on multipurpose public display services on two aspects: amount of use and seriousness of use	Six weeks long deployment on three selected displays of the public displays of the test bed.	As the discoverability of a service on public display rises, it is used more but in a less serious fashion, having implications especially on evaluating services in multipurpose environments.
II	To provide a user interface framework that supports public UIs on large interactive displays and private UIs on mobile phones.	Three months long deployment on the test bed with hundreds of end users.	Building distributed services using the developed framework is technically feasible.
III	To study sharing, creating and consuming user generated content on public displays.	Ten months long deployment on the test bed with hundreds of real end users.	Social and playful experiences are important factors for the success of services on public displays. Sharing and especially creating user generated content is appealing also on public displays.
IV	Investigate the use of already existing SNSs as source of user generated content for public displays for enhancing awareness and sociality.	One night deployment in a local bar, one day deployment on university campus.	Using content from personal accounts in online SNSs on public displays can be used to entertain and encourage people to socialize in casual settings. Users prefer more to use content from already existing services or personal mobile phones than from a new, dedicated SNS.
V	To enhance the communication of the youth with by using public displays and SNSs together.	Five days of supervised deployments in three different locations.	Playfulness is a highly effective way to engage the younger audiences to create content in-situ using public displays. Social settings of display locations and anonymity of users play a key role in the effectiveness of such a communication medium.



## 5 Discussion

### 5.1 On conducting research on multipurpose public displays

When we started sketching the blueprint for the hotspots and their deployment in Oulu, it became quickly obvious that they would have to be multipurpose, to support many use cases. The amount of stakeholders in the planned stages of the deployment was large, consisting of authorities, academic institutions, and businesses. It would have been impossible to satisfy everyone's interests with content scheduling (25, 34) or by dedicating different displays to different stakeholders. So, we opted for our hotspots to provide multiple services via a service directory similar to desktop environments. The resulting network of multipurpose public displays deployed in a city centre for research purposes did not yet exist anywhere else, giving us a unique opportunity to pioneer this field.

The hotspots allowed for deploying and trialling multiple services at the same time and offering generic solutions like the SNS integration as middleware components. However, the uncontrolled public experimental setting also has its downsides. Curiosity drives much of the use of services on a multipurpose public display, just like it does when using any public display in general (78). The key difference is that on multipurpose public displays *users have a choice*. They can, and based on our data they really do, “surf” between the services, just like one surfs the TV channels in an attempt to find something interesting among the options. On multipurpose public displays, the services placed more prominently get launched more often, simply because they are more visible to users. Thus, they attract lots of users who were never interested in using the service in the first place.

To illustrate this with an example, in a recent study we deployed a service that allows users to use SNSs to communicate with local officials, similarly to Ubinion (45). We placed it on the service selection interface of all hotspots prominently to promote it by giving it strong visibility. As expected, it was launched a lot. However, only a really small portion of these users actually proceeded to give feedback via it. While there are of course several reasons to this, users' tendency to launch several services sequentially, out of curiosity, is certainly one of them.

The curiosity aspect in service use has to be taken into consideration in assessing studies conducted on multipurpose public displays. Many users do not

right away know what they can or want to do with a display, so they explore and launch different services, just because it is possible. The strongest criticism from the research community towards our studies conducted on multipurpose displays has often been the "low" ratio between all service launches and the desired actions, i.e. the *conversion ratio*. When using multipurpose displays, users can quit using a service and rapidly start using another one, just out of curiosity. This is not possible when using traditional bespoke displays. This obviously produces different results, and we have found this very difficult to communicate to the research community. The findings reported in Article I are not yet publicly acknowledged, and cause misunderstandings in interpreting quantitative data on multipurpose displays.

The effect of the multipurpose displays is particularly unfortunate for studying novel concepts on such displays. It is tempting to criticize an idea, for example using SNSs on multipurpose public displays, as a "failure", due to its low conversion ratio. Our takeaway message here is that numbers from studies on multipurpose displays are not directly comparable to those of studies conducted using dedicated displays. In the latter case, users do not have a choice and are forced to either use the provided service or just walk away from the display, whereas on multipurpose displays, all services compete for attention with any other content available on the same display (60). Obviously, this leads into very different usage data even when an identical application is used on both kinds of displays, as also indicated by our results in Article I.

Another interesting topic is the effect of display location, which has been discussed often in public display literature (99, 101). As Article V reported, location had big impact on the usage of the Ubinion service. Multipurpose public displays can be used to explore the context rapidly by analysing the use of all available services, followed by removing services that were not used in a location. Using bespoke displays, there is no means to find out if the users actually wanted to use the deployed service, or did they use it simply because they did not have an alternative. In our case, we certainly have learned a lot about the display locations by just studying how services (do not) get used in particular locations. Over time, when enough data is logged about service use, the service selection interface of the hotspots could be customized to show only those services that are successful at that location. With only a few services deployed on a display, arguably the effect of curiosity use would be lower. The trade-off in this case would be that the hotspots would no longer provide the same user interface across the board.

Considering the main focus of this thesis, integrating SNSs with public displays, it has certainly been beneficial to be able to trial multiple services in parallel. This way, it has been possible to find out how several services perform with respect to each other, instead of evaluating them as standalone entities. Besides exploring a wide array of services in a relatively short time, we believe that it makes perfect sense to provide general purpose components like the SNS API to empower services. It can be reused by all services, reducing implementation overhead and simplifying service development on public displays.

## **5.2 Integrating social networking services on public displays**

Many of our everyday activities rely on ubiquitous Internet access (65). Computing, in its many forms, largely dictates the functions of the modern society, and with it, also many parts of our lives. However, we do not always even recognize this, as interfaces between humans and computers are becoming integrated into our environment (102). We consider the hotspots in Oulu as an interface that offers access to the digital in the physical by tangibly merging online services to the urban infrastructure.

Articles III, IV and V discuss offering online SNSs, residing in the digital domain, in the physical space via hotspots. As online SNSs play increasingly large roles in our communications and lives in general (68), we envision that their reach will sooner or later be extended to our physical surroundings. Online SNSs already aggregate content between hundreds of networks, so it is only a matter of time that networked, public displays are harnessed as one distribution channel for this great network of networks.

The studies presented in this thesis on utilizing public displays as content source and sink largely agree with prior findings on the persuasiveness of user generated content on such displays (27, 34, 70). As content acquisition and production are key challenges on public displays (34, 106), online SNSs are potential sources for high-quality and compelling content (25). The services presented in this thesis utilized user generated content from a wide selection of sources, such as online SNS and personal mobile devices. In addition, users were able to create content in-situ on the displays and share their content online. We feel that enabling the community to reuse already existing content can alleviate content production challenges and help in creating constantly fresh experiences on public displays.

While public display research has typically exploited SNSs as content source, recent experiments have also utilized SNSs as a sink for user generated content created on the displays. The *Moment Machine* (74, 75) allows its users to take photos and upload them to a dedicated public gallery in Facebook. The experiments with *Ubinion* showed how civic feedback, submitted directly at public displays, can be shared via Facebook and Twitter (text only). *UBI-photos* and *UBI-videos* relayed content from users' mobile phones to online SNSs. These examples create community contributed media repositories directly from public displays and benefit from the handy features of SNSs, such as sharing and content management. Particularly, storing and serving content via SNSs is a great benefit, as the management of high-quality media is an identified problem with public displays (106).

Merging public displays and online SNSs for content distribution has also challenges. For example, in the context of human communication, it is challenging to stay ahead of the curve and understand the evolution of technology and specific user needs. Our study on communication between the younger demographics and local officials in Article V is a good example of this. The youth are increasingly turning towards channels such as SNSs. However, reaching the youth there can be difficult and calls for new approaches.

We cannot say that Ubinion succeeded in bridging the youth and the authorities, but the potential seems to be there nevertheless. 67% of all Ubinion users had never before communicated with the local youth officials. This demonstrates how public displays can be used with SNSs to reach out to these previously unreachable citizens. This has not gone unnoticed, and researchers and practitioners are interested in utilizing SNSs in domains such as civic participation and urban planning (98, 122). As public displays are seen as accepted parts of the urban infrastructure, like they already are in Oulu (64), we envision them together with popular online SNSs to be capable of providing a new communication medium between the city and its citizens (45).

The most interesting characteristic of public displays is their situatedness, i.e. their capability to cater to a tightly knitted community and context at a particular location. While mobile social networking has enabled us to communicate virtually anywhere, a public display can tie our communication to a specific location. In this location, the display can then offer a conversational piece for socializing and communicating, just like SocS in Article IV and Ubinion in Article V. A display deployed at a particular location is appropriated in a manner suitable for the location and the dwellers. Thus, some locations will fit better for a



given purpose, while others will lead to a lot of appropriation and “noise” in the use.

So, while in terms of technology, everything is in place, one of the key issues causing problems in our deployments was content moderation, preceded by people appropriating the displays to their own purposes. In online SNSs, content can be often uploaded by registered and identifiable individuals only. This being the case, it can be traced back to the owners’ profiles and their digital identities. This puts pressure on “keeping it clean”, to refrain from uploading offending content that may lead to a prompt ban and deletion of the account. Allowing users to post content to online SNSs anonymously using a public display, however, is a different case. The users are not accountable for the content, and the barrier to upload perhaps unorthodox content is much lower. Also, when harmful content is then propagated back to public displays, it has the potential to offend other passers-by, or city officials, who certainly do not expect to stumble upon such unwanted content on a public medium.

It was only a few months after the publication of Article III when we had to terminate several of the multimedia-oriented services that were reported in it from the displays, due to complaints about content that was regarded inappropriate by members of the public. The same happened in a longer deployment of Ubinion on the hotspots. We had to terminate the deployment, as Ubinion was used to distribute racist content. In online environments, users are already used to the model that offending content is quickly removed and the hosting service continues to operate normally. Public displays, however, seem to be a much more sensitive platform as the content is openly visible to everyone, everywhere, so the same model will simply not work.

Our experience is that services allowing anonymous content submissions directly from public displays to public repositories should always adopt a *pre-moderation* strategy. A good working example of such can be found in (98). Discussions in Space, a public display deployment curating user generated content on public displays, offers moderation through an online chat-style interface. With enough manpower, this can lead to a near real time experience in publishing content on public displays. Other types of moderation strategies for posting user generated content on public displays are discussed in-depth in (40).

### **5.3 The ever-increasing utility of the smart phone**

Today, smart phones are considered intimate and highly personal devices to their users (97) and used for a variety of things in our everyday lives. It is also the de facto means for communicating with our friends and family, while others find it handy for email, banking, time management, etc. The smart phone empowers us to do things on the go that just few years ago still required a desktop PC. Especially, mobile social networking and gaming are popular among younger generations. We use it as a tool to link users to public displays.

Coupling mobile phones with the hotspots has offered opportunities that would not have been possible otherwise, or at least would have been difficult to realize. Field trials reported in Articles II and III verified Bluetooth as a viable solution for direct content transfer between phones and hotspots. In addition, smart phones can be functional in de-anonymizing public display users. However, it is not straightforward to handle this association of a phone to a display in a user-friendly way, and several solutions have been trialled for it (55). Our approach, RFID readers in the displays and RFID tags to identify users' smart phones, received a mixed reception from citizens.

While for example downloading and uploading content was something that people did enjoy and tried also alone, the overall message from the trials presented in this thesis is clear: The concept of controlling displays with mobile phones was quite cumbersome for many other than the tech-savvy ones. Interviews revealed that the process of launching services on the public displays using personal mobile phones was found confusing.

We are optimistic, however. Especially today, there is no other as prevalent and flexible technology that can be used for research like this. Associating the users with displays, accessing their online SNSs, enabling content transfer, etc. is technologically trivial with smart phones. They have become much more common since these trials and it is likely that users are accustomed to leverage their phones better than few years ago. In this space, two or three years can make a big difference. App stores have made installing new software components and client applications to smart phones trivial. In our case, the required effort was much bigger than what it would require today, and of course, modern mobile user interfaces are also easier to use than what was possible back then.

Naturally, it can be argued that the smart phone is not the only device that can be used as the link between users and public displays. In the future, users will likely carry many types of wearable computing resources capable of wireless

communications. Gesture based association mechanisms, even brain-computer interfaces, etc. can be considered for enabling the identification of display users. However, this is future work, and for the moment, we feel that the smart phone is the only feasible and sufficiently ubiquitous tool in the push towards the vision we laid out in this thesis.

In regards to mobile phones and their utility as shown in this thesis, the key takeaway is the fully functional implementation and demonstration of how mobile phones can be used as "keys to the environment". While the source code is perhaps not directly applicable to existing all public displays, the concept and design certainly are. We feel that this is a promising direction to develop public display environments in general, and especially multipurpose public displays that can offer a host of different services for audiences with different needs and skill sets. Of course, further research is needed to unlock the full potential of the modern smart phone in this context.

And it is not just research that enables the development of things, the mental models of smart phone users need to mature as well. If we wish to see the kind of development envisioned in the thesis, general public needs to eventually regard the smart phone as a kind of remote controller. While the actual role of phones in controlling our surroundings remains to be seen, this thesis provides a strong, fully functional proof of concept. In this vision, smart phones act as our proxies not only towards online services, but to other computing resources around us as well.

## **5.4 Revisiting the thesis statement and the research questions**

### **5.4.1 Validity of the thesis statement**

The original thesis statement was: "*It is feasible and useful to leverage online social networking services in creating services for multipurpose interactive public displays*".

The thesis provided a set of middleware components that facilitated leveraging SNSs on public displays in a way that is fully functional for service developers as well as users. This was validated by field trials of services utilizing the components as their building blocks. Thus, the proposed integration is *feasible*.

Further, as the trialled services were deemed compelling, successfully leveraged personal online user generated content, and enhanced users'

communication capabilities, the integration is also shown *useful* in the context of the thesis.

#### **5.4.2 RQ1: how to enable and evaluate services that utilize social networking services on multipurpose public displays?**

The thesis highlights three key points for enabling and better understanding services that leverage online SNSs on multipurpose public displays. First, *the displays need to offer a login or identification mechanism that can be reused across all the deployed services*. Articles II and III elaborate how this was achieved using a DUI component that combines public displays and smart phones. Using this mechanism, it is also possible to identify users, and therefore, implement an API that can access the users' personal accounts in online SNSs. Second, *it is useful to offer a generic API providing access to online SNSs, so that services on public displays do not need to handle user identification and logging in to the SNSs*. This makes developing services that access online SNSs easier. Finally, when evaluating such services, or any other services, for that matter, on multipurpose public displays *researchers have to acknowledge the effects of offering multiple services on the usage and conversion ratio of individual services*. It has direct consequences in the amount and motivations of the use of a single service. One should be careful in comparing the usage statistics of such multipurpose displays to the ones obtained with dedicated displays.

#### **5.4.3 RQ2: which particular concepts of online social networking services are suitable for use, and which are not, on such displays in urban settings?**

The studies conducted in this thesis have shown that *functionalities based on user generated content are highly appealing on public displays*. Creating, consuming, and sharing such content on public displays seem to drive user engagement and deliver meaningful experiences to the public. Especially *creating content in situ* using the hotspots has proven to be a delightful and social activity: the users of Ubinion and UBI-postcard utilized the web camera of the screens to capture and share joyful poses taken in large groups, years after the services were first deployed. This verifies that their popularity was not just due to novelty of introducing such services in the city, but due to their authentic and long-term appeal among the everyday users of hotspots.

Hosting and serving high-quality media is always challenging. So, one beneficial use case is *leveraging the content storing and sharing capabilities of online SNSs*. This can be achieved using their official APIs. The near-perfect uptime of online SNSs and their high-quality content delivery networks can be utilized in creating robust multimedia services for public displays.

On the other hand, enhancing the communication between locals and authorities in online SNS by utilizing public displays failed. Users created a lot of content that could have been used as conversation starters online, but they did not go online and pick up the conversation. While more studies on public displays as a communication channel to SNSs are needed, we have shown that *utilizing public displays for bootstrapping formal discussions in SNSs is not very feasible*. Hardier moderation and accountability to the created content suggest that perhaps this kind of communications would be best to perform using the SNSs only. This, in fact, has already been proven popular in Finland. The Finnish Police has a presence in SNSs, where especially the youth are encouraged to approach them in matters such as bullying or, more recently, cyber-bullying.

#### **5.4.4 RQ3: what are the key issues of public displays affecting the success of the identified concepts in RQ2?**

This thesis shows that *the anonymity of public display users has a great impact on how the displays are used*. The anonymity allows users to create and share content without feeling strong ownership to it, making it fun and enjoyable to create and publish content. It also goes to explain why in the Ubinion study, for example, the obtained feedback towards city officials was unfortunately very much different from requested: posing, funny faces, profanities, etc. If users would have had to leave feedback face-to-face or even using the same medium, Facebook, by using their own accounts there, this would probably not have happened. Supporting this, almost half of the interviewees in the SocS study indicated that they would not like to show their own personal content from online SNSs on public display.

#### **5.4.5 RQ4: what is the potential role of modern smart phones in leveraging social networking services on public displays?**

This thesis demonstrated a means of integrating online SNSs with public displays by *utilizing smart phones to represent and identify their users*. Identification of users is the single most important thing in integrating SNSs with public displays,

and as the smart phone is highly personal and typically used by its owner only, we argue that the smart phone is a logical choice for this.

Besides just acting as access tokens and identifiers, *smart phones can also be used for controlling the displays*. By utilizing distributed user interface solutions, phones can offer a private interface to users, enabling them to, e.g. choose content from online SNSs to be displayed on the screens. The middleware component developed in this thesis enables offering services employing a public UI on a hotspot, and one or more private UIs on smart phones associated to the hotspot. Using the component, access and control of the public UI can be distributed to several clients simultaneously.

If we were capable of controlling displays in our environments with phones constantly connected to online SNSs, it would be trivial to develop novel services for public displays that are empowered by the content, social connection information, and other data already available in online SNSs. Leisure services utilizing user generated content, as demonstrated in this thesis, are examples of what can be achieved by leveraging personal smart phones in conjunction with public displays.

## **5.5 Validity of findings**

Many of the findings documented in Articles I-V generalize well to other contexts. First, the software components that we developed for creating services that integrate online SNSs can be ported to other public display environments with ease. The problem of providing distributed user interfaces is still topical, although the introduction of HTML5 has introduced other options for this as well. Google, for instance, has utilized QR codes and HTML5 to pair mobile phone web browsers to desktop browsers, to create distributed user interfaces in *Chrome Experiments* (17). A similar mechanism could naturally work for public displays as well in the future, when people are more accustomed to using such technologies. In addition, while the login mechanism of hotspots never gained sustained use, a mechanism to identify users of public displays will be required for example for personalization. The solution demonstrated in this thesis is not the only way to authenticate users, and further research to discover the best practices is welcome. Once the problem of authentication is solved, SNSs with their comprehensive online APIs can be integrated with public displays using the methods laid out in this thesis, as long as the terms and conditions of the SNSs permit it.

The thesis, of course, assumes that public displays are going to be personalized in the first place, and be used by individual users in a personal fashion in public settings. To be brutally honest, it is far too early to tell. Interactive public displays are not available at a sufficiently large scale, and most of the deployed interactive displays offer simple directory services, maps, or advertising that do not require authentication. The findings of this thesis nevertheless help to identify services that could be entertaining and appealing to the users of the public displays, and why perhaps some institutions or business owners would be willing to invest such displays to attract customers.

We also strongly believe that future large-scale public display installations will be multipurpose. Why would displays, apart from maybe advertising-only displays, be dedicated to a single service? Mobile phone, TV, many kitchen appliances, and countless other consumer electronics have over time developed to provide several related functionalities instead of the "main purpose". The author of this thesis feels that public displays will eventually see the same development. This suggests that a general purpose public display platform offering general high-level functionalities for service developers will be useful. Thus, the findings on supporting and studying services in this kind of multipurpose environment will be relevant and applicable to a much larger body of research than currently. The unfamiliarity of the idea of multipurpose displays, such as ours here in Oulu, is still, in a way, hindering the real value of the findings on the network effects this new paradigm has on the use of services. Although the mechanisms of how content on public displays will be discovered will surely evolve and differ from ours, they will still compete for attention with multipurpose environments.

The appeal of user generated content is a global phenomenon. The mechanisms for how content is created and displayed will, however, always be closely tied to the prevailing culture and accepted social norms. In our environment, users are happy to pose and play in groups, as exemplified by UBI-postcard users in Figure 15, but obviously, that might not be the case everywhere. The environment has a great effect on the use of services, not only locally (for instance, different setups yielded very differing results for Ubinion), but also in different countries, continents and cultures. This affects how the services get appropriated, the need for moderation and overseeing deployments in general.

Simply put, what works in Oulu might not work somewhere else. This is not to be taken as a negative thing, however, and similar issues have naturally been voiced out earlier as well: It is difficult to reproduce ubicomp trials conducted in public environments even with the greatest efforts by researchers (11). The same

holds naturally true for the need for moderation, or how people might use public displays for official communications.



**Figure 15. UBI-postcard users posing to the public display.**

Finally, we wish to note that the audiences of the studies in the included articles were not identical. This does not hinder the validity of the results per se, but it certainly impacts their direct comparison to each other. While Articles I-III report studies conducted using hotspots in their authentic deployment locations in multipurpose service mode, Articles IV and V report on case studies situated in cherry-picked spaces and focus on only one deployed service. The very purpose of those articles was to probe the suitability of the trialed services in specific contexts and thus specific audiences. It should be kept in mind that such services will likely perform differently when deployed on an unsupervised grid of multipurpose public displays in the urban city with all its challenges, highly heterogeneous user base, and emerging social phenomena (45).



## 6 Conclusion

This thesis explored utilizing online SNSs for creating services for multipurpose public displays. Public displays should no longer be regarded as novel and isolated artefacts that offer "bleeding edge" prototypes to their users. Instead, they should blend to the environment and offer services to their users without constant supervision from and promotion by researchers. This also resonates well with the early visions of what ubicomp could eventually really be. Such an environment has been deployed in Oulu, offering the experimental setting for the thesis.

This thesis first contributed general purpose software components for building distributed user interfaces (DUI) and integrating SNSs to the experimental environment. Then, several services leveraging user generated content and communication capabilities of modern online SNSs were described. The services allow consumption of user generated content, obtained from online SNSs, directly on public displays. Services allowing generating content directly on screens, or from users' personal mobile phones, were also introduced. Many of these services are essentially communication tools, allowing for example sending greetings in the form of a postcard, leaving feedback to city officials, or just chatting in a shared space via a dedicated mobile client.

The diverse set of services and trials yielded findings on a fairly broad scale, within the overall concept of exploiting SNSs on public displays. Although the development discussed here is still largely conceptual and in the hands of researchers, it is claimed that interactive displays will inevitably be increasingly common in urban environments. Their actual, sustainable roles outside the commercial domain are yet to be seen. The research community is actively seeking optimal new use cases for such displays. Urban planners and officials need to be educated of the possibilities and affordances of public displays, to make sure that the future role of displays is not just about big brands and their marketing budgets. There is much work to be done, as arguably the current killer application on public displays is advertising, and researchers are already looking into *pervasive advertising* to make ads more personal and even more effective in the urban space (1).

We provide a few suggestions to creating similar multipurpose public display networks in the future. First, results and findings from studies conducted with single-use displays do not directly transfer over to multipurpose environments. The users can, and will, browse through the offered services of the displays, not always choosing the one the display designers would like them to. Simply put,

services trialled on single-use displays do not always live up to the expectations when it faces all the competition on multipurpose ones. Second, the very nature of multipurpose displays calls for the involvement of multiple stakeholders. These parties will have a very different understanding of what is success and what the displays exist for. The administrators of the displays will need to be ready to negotiate and make compromises that satisfy all the stakeholders (46). This is often problematic, especially when the display administrators have mainly research interests in mind, such as in our case. By including the stakeholders in the actual research cases from the very beginning, many of these problems can be alleviated. Finally, the displays are only as good as their content is. We have witnessed first-hand how users use the displays as only toys if they offer nothing interesting. And there is no such thing as universally interesting content. So providing a rich variety of different experiences is crucial. By allowing the creation and presence of user generated content, can help users feel ownership to the displays and make them more appealing to different communities. Online SNSs are an excellent source of high-quality, personally meaningful content.

Online SNSs and their content are the greatest open digital databank humans have created online thus far. They contain the stories of our lives and digital traces of real world phenomena in a magnitude never seen before. This can be leveraged to make public displays more appealing, by making them more personal and allowing them to leverage the data. Are the means suggested in this thesis for integrating social networking services into public displays the best ones? Not necessarily. Technologies evolve, SNSs die and new ones with completely different usage paradigms will emerge. Public displays will change as well. But for the time being, this thesis demonstrated a coherent push towards this vision, along with a fully functional solution to allow public display services to tap into, and benefit from, online SNSs and the personal profiles of their users.

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- I Hosio S, Goncalves J & Kostakos V (2013) Application discoverability on multipurpose public displays: Popularity comes at a price. Proc. The International Symposium on Pervasive Displays (PerDis 2013), Mountain View, CA, USA: 31–36.
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