Information to Go:
Exploring In-Situ Information Pick-up "In the Wild"

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Abstract. This paper presents a case study on the iterative design of a system for delivering in-situ information services to users' mobile devices using proximity-based technologies. The design advances from a questionnaire study of the users' attitudes and needs toward such information services via several incremental prototypes evaluated in a usability lab and at a university campus to the final version subjected to longitudinal evaluation "in-the-wild" in a city center. The final prototype is a hybrid interface where the users can select from an interactive public display the information services to be downloaded to their personal mobile devices over no-cost Bluetooth connection. The results include an empirical comparison of different models for delivering such information services, and a quantitative analysis of the usage of the system by the general public over a period of 100 days. Our findings suggest that multiple environmental factors strongly affect the usage of the system. Furthermore, the usage varies distinctly between different contexts, and there is a strong correlation between location and usage patterns. Finally, we present a number of guidelines for designing and deploying this type of hybrid user interfaces.

Keywords: public interactive displays, smartphones, longitudinal study, Bluetooth, urban computing, ubiquitous computing

1 Introduction

The contemporary urban landscape is becoming increasingly saturated with new types of computational resources. Large digital displays are becoming integral parts of public spaces, and while the main use of these displays remains broadcasting of information, novel types of interaction have been developed to make such displays a two-way communication channel [e.g. 20, 33]. An important consequence of the proliferation of such public (and increasingly) interactive displays is the construction of hybrid public spaces where on-line content is increasingly merged with entities in the physical world. Hybrid public spaces allow for new possibilities in information delivery and consumption, and crucially present a new paradigm of how users can

search and find information whilst in an urban space, akin to in-situ "information pick-up".

This paper presents the iterative design of an effective interaction model for in-situ "information pick-up" utilizing Bluetooth as the main technology, and understanding users' appropriation of such technology over a long period of time.

The presented system, called BlueInfo, has evolved over a series of prototypes and user tests described in this paper. An initial questionnaire study to uncover attitudes and existing practices was conducted at bus stops, and results were used as a backbone for the prototypes. The first prototype, tested in a usability lab, utilized a pull-based interaction model of content acquisition utilizing parameterized textual commands sent from a mobile device to a Bluetooth access point. The second prototype, tested on a university campus, utilized a push-based interaction model where users could selectively request relevant content to be pushed to their devices when passing a Bluetooth access point. The third prototype, also trialed on campus, featured a proximity-based interaction model, where physical artifacts in the environment were used to push content to users who brought their device very close to the artifact, thus functioning as a hybrid push/pull interaction model. The fourth and final prototype is a hybrid interface comprising of interactive public displays and mobile devices. It was deployed for a period of 100 days "in the wild" using a network of 12 large public displays called UBI-hotspots (later: hotspots; [25], Fig. 1), situated in highly public indoor and outdoor locations around downtown Oulu, Finland. The final prototype allows users to select which content they wanted to download from a UI on an interactive public display, and continue the interaction on their mobile devices once the selected content is delivered. The displays are available for 24/7 use by the general public, and offer a number of information and entertainment services to users through their touchscreen interface. The focus of this paper is not on the public display architecture or service selection, however, but rather on the iterative design of the BlueInfo service, and, more importantly, on the longitudinal real-life deployment and evaluation of the final version of the system.

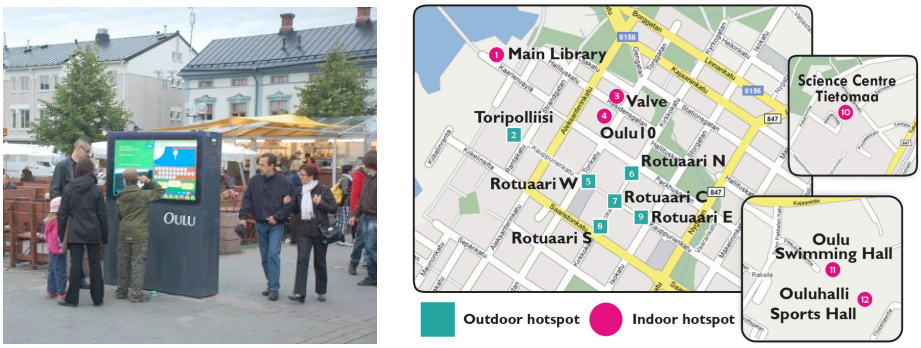


Fig. 1. Outdoor UBI-hotspot (left) and hotspot locations on map (right).

The main contributions of this paper are: i) an empirical evaluation of several incremental prototypes utilizing different interaction models for Bluetooth-based information retrieval; ii) identification of multiple environmental factors, such as the day of the week, hour of the day, and weather conditions, that strongly affect the

usage of the deployed real-world system; iii) demonstration that usage varies distinctly between indoor and outdoor hotspots set in different types of locations; iv) a number of guidelines and lessons learned for the design and deployment of such hybrid interfaces.

The rest of this paper is structured as follows: Section 2 covers related work in the field of interactive public displays, hybrid interfaces utilizing mobile devices and public displays, and Bluetooth-based information retrieval. Section 3 introduces the BlueInfo system, and briefly discusses the infrastructure on top of which it is deployed. Section 4 describes different BlueInfo prototypes and their evaluation in different settings. Section 5 presents the results and Section 6 discusses the implications of the findings. Section 7 concludes the paper.

2 Related Work

Large public displays have gained popularity in industry and research due to their reduced cost and high visual impact [33] in relation to other elements of the urban infrastructure [13]. Such displays can be categorized into *reference displays* and *interactive displays*. Reference displays are designed for unidirectional broadcasting of digital information and signage. They require relatively small setup effort, but often suffer from short attention spans [10] and so-called display blindness [21].

Interactive displays are mostly research-driven projects, although some commercial interactive display installations such as the BBC Big Screens (http://www.bbc.co.uk/bigscreens) exist. A number of important findings have been established in relation to public displays and their in-situ use. For instance, their use typically gives rise to emerging social interaction patterns, with interaction roles such as *mentoring* and *ad hoc collaboration* [28]. In addition, ongoing interaction on a public display serves as an attention incentive for attracting other users, a phenomenon known as *honeypot* [4, 11, 28]. Studies on the use of public displays during pedestrian navigation [20] have shown that displays were useful in the planning stage (due to the displays' increased capacity), as well as when straying from the planned route, suggesting that public displays support *information foraging* [27]. Furthermore, studies have shown that networks of public displays used for broadcasting [30] must emphasize the location-aware presentation of the content, thus adhering to the *calm aesthetics* principle [34].

A sub-category of public interactive displays is *information kiosks*, which usually feature certain input mechanisms in addition to touch screens, such as keyboards. Examples include the Kimono kiosk [9], and the work presented in [22]. The system presented in this paper has similarities to such information kiosks, but external input is limited to mainly that from nearby mobile devices [2].

A substantial body of work has considered how mobile devices can cooperate and interact with public displays. The increased visual capacity of a large display combined with the mobile device functioning as a private GUI and input channel has been investigated from several perspectives, including distributed multi-user access to a single public display with personal mobile phones [29], migratory user interfaces capable of traversing among different devices, maintaining the state of the application

and enabling continuous interactivity regardless of the used terminal [3]; transitioning of UI elements between heterogeneous device types through UI rendering engines and high-abstraction description languages [23]; and application composition, where architectures commonly make independent decisions on physical and logical composition of the application and its logical parts including the presentation layer during runtime rather than design-time or compile-time [26].

In addition to serving as complementary interaction spaces, mobile devices can also act as a control mechanism in conjunction with proximity-based wireless technologies. More specifically, Bluetooth has often been suggested as a suitable technology for controlling public displays, due to its high market penetration and consumer awareness: 46.7% of mobile phones in 2007 had Bluetooth transceivers, and approximately 81% of consumers are aware of Bluetooth technology [5]. Continuous scanning of Bluetooth devices has been utilized as presence information [12, 24], and along with the friendly name of a device was used to create *instant places*, which are identities of users in the same space visualized on a public display. The idea of using Bluetooth friendly names as a control channel was developed further in [8], where users could request several different services on public displays in a campus setting using command parameters in their Bluetooth friendly names.

Proximity technologies such as Bluetooth and NFC [14] have also been utilized for exchanging data with users. In [7] users were able to exchange photos with a public display, and the study's findings suggest that users react positively to the idea of being able to upload and download photos from/to a situated display. Similarly, the work in [6] describes a rule-based context-aware system that delivers information to smartphones using Bluetooth. In general, wireless proximity technologies are well suited for contextual content dissemination, defined as a process achieved either by the user's request (e.g. pull), or by the sources own initiative (e.g. push). Reportedly, the push model is more efficient when multiple clients are present, and the pull model is more appropriate for a small number of clients, however a combination of both is typically proposed [1, 32].

3 Conceptual Design and Implementation

The system presented in this paper proposes a hybrid interface for delivering contextual information to pedestrians in a city centre. This system draws inspiration from much of the work described above. Specifically, this work is partly inspired by findings which suggest that users are happy to download files from public displays [7], as well as using proximity based technologies to infer the presence of users [8, 15]. In addition, it builds on the fact that displays are well suited for information pick-up, and also attempts to capitalize on the honeypot phenomenon to entice further users to use the system. The result is a service, *BlueInfo*, where users via direct manipulation of a public display can request a small dataset to be sent directly to their phones via Bluetooth. In this model, users are initially enticed by the display's information foraging affordances [10], must physically interact with the displays (thus enticing additional users) [4, 11, 28], are able to take advantage of the display's increased visual capacity for planning purposes in preparing their dataset [10], and

can use their mobile devices as extended interaction spaces to take the information with them. This model of interaction is akin to *in-situ information pick-up*.

BlueInfo is an architecture that employs an in-situ information pickup model of interaction, allowing for multiple types of information delivery mechanisms including push, pull, and hybrid. The architecture bridges WPAN (wireless personal area network) and WAN (wide area network) connectivity in a way that allows for real-time content delivery from Internet sources to the personal mobile device of a user, with the last leg of delivery using a cost-free Bluetooth connection. Thus, the content is dynamic (i.e. not static content uploaded to the BT access point), and due to well-formed APIs, third party content can be easily integrated.

BlueInfo fetches service content in real-time from the origin servers in the Internet, and once delivered to the personal device the content is available for viewing at any time, without need of further connectivity. In our implementation we use Bluegiga's Bluetooth Access Server 2293-56-EXT, which has three Bluetooth transceivers with external antennas, runs embedded Linux, and can support up to 21 simultaneous users. This hardware is connected to the Internet via WiFi or LAN. Using the same hardware configuration multiple interaction models were developed and iterated over a number of prototypes described in the next section.

4 Iterative Design

The design of the BlueInfo has progressed as follows. First, a questionnaire study was conducted at bus stops aimed at understanding users' information needs and preferences during idle time and their preferences regarding push vs. pull modes of delivery. Then, three incremental prototypes with alternate delivery modes were developed and evaluated in different experimental settings in a usability lab and at university campus. The fourth and final prototype was deployed in real world setting in a city center for a longitudinal study "in the wild".

Questionnaire study. The study was conducted at four different public transport stops. These were selected due to the perceived idle time people experience while waiting for a bus, thus possibly being open to receiving content on their phones. The people were asked to fill in a questionnaire collecting demographic information and information about mobile device uses while at the bus stop (e.g. browse the web, call, sms). Finally, the questionnaire probed users regarding how they would prefer to access services such as those provided by BlueInfo [6].

On-campus prototypes. Three prototypes were evaluated at a university campus: BlueInfo Pull, BlueInfo Push, and "Easter egg" probe. BlueInfo Pull was tested in a usability lab to evaluate usability and user acceptance. The interaction model of this prototype required users to send text-based requests (not SMS) over Bluetooth to a BlueInfo access point, which would parse the request and subsequently respond with the requested information fetched from Internet sources. The comparative study required users to complete five information-seeking tasks using a mobile Internet

browser with a WiFi connection, and then perform the same tasks by pulling the information from BlueInfo **[**18**].**

BlueInfo Push was tested as an open trial on a university campus. Users were provided with a website to sign up and pre-create their own 'daily message', comprising of selected services, which would be then pushed to their device when passing a BlueInfo access point. Users could request the information to be sent during AM hours, PM hours, at any time, and select the number of times per day that he/she would like to receive a message, for example once in the morning and once in the afternoon, only once per day, or even every time he/she passes an access point. Seven BlueInfo access points were deployed in the restaurants, cafés, and corridors around the campus. The study was advertised on student email-lists and with posters around campus. The data collected addressed performance and user preferences. Follow-up interviews were conducted with the participants after the study.

Tests with the "Easter egg" probe were conducted just before the Easter break. An Easter egg (Fig. 2) enclosing the BlueInfo access point was built from paper maché and chicken net wrapped in a colorful paper. The egg was placed on a table at a busy cafeteria on the campus. The purpose of this study was to evaluate recognizable and fun physical user interfaces for enabling users to request content via proximity-based interaction. To do so, users had to place their mobile device very close to the egg, which used received signal strength indicator (RSSI) to detect such events. When signal strength exceeded a predetermined threshold, an image wishing "Happy Easter" was sent to the phone. Participants from this study were recruited by the sheer presence of the egg itself, as well as leaflets distributed in the cafeteria.



Fig. 2. "Easter egg" probe (left) and "Student dummy" probe (right).

We also constructed and deployed another proximity-based probe for a student party on campus. This probe was a dummy build to resemble a student (Fig. 2), and users could interact with the probe by placing their phone in the dummy's pocket. The experiment was cut short, however, as the dummy was taken to sauna by some students during the first night of the trial, and has not been seen ever since.

Longitudinal deployment in the wild. The final prototype of BlueInfo provides users with a hybrid interface for in-situ information pick-up model of interaction. In this prototype, users select from the interactive display of a hotspot the information

they wish to download to their personal device over a Bluetooth connection. To achieve this, the system continuously scans for nearby Bluetooth devices, and populates an on-screen list of discovered devices. User can browse a directory of available information services on the interactive display, including bus schedules, weather forecasts, news, TV programming, and movie listings, and indicate which services she would want to download to her phone (Fig. 3). At anytime during their use of BlueInfo, user may click the on-screen "Download to my device" button. S/he is then instructed to identify his/her phone from the list of discovered devices, which initiates an OBEX Push connection to the specified device. User is also advised that if his/her device is not present in the list of discovered devices s/he should set her Bluetooth device to discoverable mode.

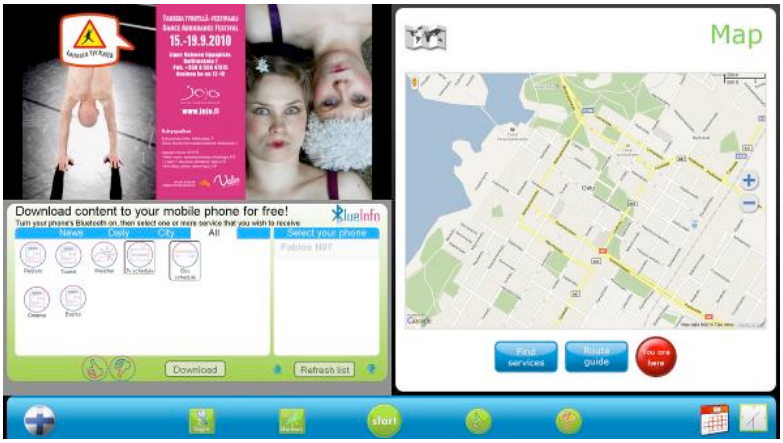


Fig. 3. Hotspot user interface (BlueInfo in lower left quadrant)

BlueInfo was deployed for 24/7 use by the general public on 12 hotspots situated in highly public locations around the downtown area of the city of Oulu (Fig. 1). The data presented in this paper was collected during a period of 100 days of usage by general public (i.e. not by recruited test users). The data reflects the types of information downloaded, along with the date, time and location of these interactions. Additionally, the BlueInfo access point in each hotspot collected traces of passing by Bluetooth devices regardless of whether they actually used the BlueInfo service. The traces allow us to explore how often each device (user) visited a hotspot in general and with respect to their BlueInfo usage. Further, three researchers individually went through the list of Bluetooth friendly names of the devices, classifying each device (user) as either male, female, unknown, or factory default based on the friendly name. Thus, devices with a friendly name such as "John's phone" were classified as male, devices with a name such as "Jane's phone" as female, devices with a name such as "Angry badger" as unknown, and devices with a name such as "Nokia N97" as factory default. While this method of identifying users is somewhat inaccurate, it can be used to gain further insight into gender specific usage patterns.

5 Results

5.1 Questionnaire study

A total of 105 respondents (51 female) completed the questionnaire, with more than half of them being 20-30 years old. Most respondents (80%) claimed to use their mobile device while waiting for the bus. Overall, 60% claimed to use their device for messaging purposes, 41% for making phone calls, 35% for entertainment (music, games), and 5% for online access. While most respondents had a Bluetooth enabled device (73%), only 11.5% had their Bluetooth turned on and set as discoverable. Of those who explicitly disabled their Bluetooth, 50% claimed security concerns and 37% power consumption concerns, while 13% gave no reason. Regarding their preferred way of receiving digital content on their mobile devices, 31% claimed they wanted to retrieve the content (i.e. pulling content), 32% claimed they wanted to be pushed information if they had explicitly registered beforehand, 4% wanted to be pushed information without prior registration, and 33% claimed that they did not care as long as the information was relevant to them.

A chi-squared analysis revealed a significant association between demographics and device usage practices. Specifically, those more likely to user their mobile phones for texting while waiting at a bus stop are women ($\chi2=6.507$, $dF=1$, $p<0.05$) and those aged between 10-20 ($\chi2=21.69$, $dF=4$, $p<0.01$). In general, participants aged 10-30 were much more likely to use their mobile device while waiting for the bus ($\chi2=11.04$,$dF=4$, $p<0.05$). Further analysis revealed a significant association between waiting time and use of mobile devices, with those waiting only between 5 and 10 minutes less likely to use their devices ($\chi2=12.83$, $dF=4$, $p<0.05$).

5.2 On-campus prototypes

BlueInfo Pull. The comparative task-based study conducted in a usability lab assessed the relative performance of a mobile web browser versus BlueInfo in five information seeking tasks such as finding a bus timetable. On average, BlueInfo Pull reduced the number of required clicks by 42% across all five tasks. Similarly, task execution times were reduced by 35% across the 5 tasks, and the success rate improved by an average of 54%. After completing the tasks, test users were asked to fill out a questionnaire with 15 statements on a 5-point Likert scale. Users indicated a strong tendency to accept the system in their questionnaire answers. The statement *the service was useful* scored an average of 4.4. The statement *learning to use the service was easy* scored an average of 4.5, and the statement *the option to use the service on a mobile phone is a good thing* an average of 4.7. Users also considered the transfer times of messages to be fast, as the average response and download time was between 20 and 30 seconds, or up to 120 seconds with video trailers. For a detailed report on the BlueInfo Pull prototype see [18].

BlueInfo Push. A total of 33 participants took part in this study for a period of one month. Overall, 336 daily messages were sent during the study. On average, each user received 10 messages during the testing period, with the most active user receiving 31 messages and the least active user receiving 4. The level of activity varied throughout the study, with the maximum number of messages sent during one day being 37, while the minimum was 5. The available information and entertainment services, along with the number of users who included these services in their preferences, are listed in Table 1.

Table 1. BlueInfo Push services and users

Category	*Service/provider*	*# users*
Word of the Day	Merriam-Webster	11
Word of the Day	Urban Dictionary	18
News	YLE	2
News	Reuters	8
News	Kaleva	20
Weather	FMI	21
TV programs	telkku.com	22
Comics	PhD Comics	3
Comics	Calvin and Hobbes	4
Comics	Viivi & Wagner	7
Other: Music charts	last.fm	10
Other: Horoscope	horoscope.com	5

During follow-up interviews participants expressed satisfaction with the service, especially noting the fact that the message would remain in the phone's inbox so that the information would be available for later reference. Participants often remarked that the news stories made for good reading during boring lectures, or on the bus ride home. One participant even mentioned that the daily message made for perfect restroom reading material.

A source of discontent was the requirement to pair the mobile phones with each individual BlueInfo access point: if the device was not paired with the access point, a confirmation prompt would be shown on the device, and the message would not be received unless the user explicitly gave permission. As the prompt does not alert the user with any audio/tactile feedback, it can be easily missed if the phone is carried in a pocket or bag. Another issue was that due to technical restrictions the system could not accurately verify if a message was successfully received - this could happen when users moved beyond the access point's range during message transmission. This resulted in the system marking the message as sent, even though the user had not received it. This issue was fixed after the first week of testing.

"Easter egg" probe. The Easter egg probe was operational for four days, during which a total of 104 messages were sent to 97 unique devices. During the study, we observed the colorful egg raising interest in passers-by, many of whom approached the egg to read the usage instructions printed on leaflets around the object. People approached the egg in company more often than alone, and preferred to interact with it while others were present. However, due to system delays, not all attempts at interaction were successful, as people withdrew their phone before the message could

be transmitted. The egg served also as a conversation piece, with people gathering around it to chat and, at times, to test the boundaries of the system by slowly inching their device closer to the egg to see when a message would be sent. Overall, the egg as an artifact appeared to encourage playful interaction, and also served as a temporary point for social behavior.

5.3 Longitudinal study in the wild

The longitudinal study in the real world setting began in February 2010 and lasted for 100 days. In total 7268 downloads, or "messages", were downloaded by 1338 unique devices, i.e. on average 73 messages per day and 5.4 messages per device. The most active user downloaded 91 messages utilizing 8 of the available 10 services, meaning that on average s/he downloaded every service 11 times. On average, a user used the system 5.4 times utilizing 3.4 distinct services.

Out of the 1338 unique devices, 74 used BlueInfo in more than one hotspot. Users using more than one hotspot were more active in downloading content than those using only a single hotspot: the 74 devices downloaded a total of 836 messages, or 11.3 messages per device on average (min 2, max 91) from an average of 2 hotspots (min 2, max 6). The most active user used the system on 10 separate days. There is a positive correlation ($r=0.5$) between the number of days used and messages downloaded. A p-test showed that the correlation is statistically significant ($r(1325)=0.5$, $p<0.0001$).

The number of unique users per each hotspot varied considerably (Table 2). The most popular hotspot located in the main swimming hall of the city attracted a total of 538 unique users (38.2 % of all users). Similarly, a hotspot at another sporting facility (Ouluhalli) had 164 users (11.7 %). Overall, indoor hotspots were more popular in terms of users, with a total of 965 users (68.6 %).

Table 2. BlueInfo usage at each hotspot (WS = Walking Street, outdoor hotspots in *italics*)

Hotspot	***# unique users (%)***	***#downloads (%)***	***Average downloads per user***
Main library	112 (8.0)	396 (5.5)	3.5
Ouluhalli	164 (11.7)	1025 (14.1)	6.3
Swimming hall	538 (38.2)	3665 (50.4)	6.8
Office building	3 (0.2)	6 (0.1)	2.0
WS: Intersection	71 (5.1)	203 (2.8)	2.9
WS: East	69 (4.9)	289 (4.0)	4.2
WS: South	90 (6.4)	370 (5.1)	4.1
WS: West	54 (3.8)	151 (2.1)	2.8
Main square	75 (5.3)	226 (3.1)	3.0
Science center	75 (5.3)	263 (3.6)	3.5
Market place	83 (5.9)	292 (4.0)	3.5
Culture center	73 (5.2)	382 (5.3)	5.2

A similar trend was observed in the number of actual downloads (Table 2). The swimming hall hotspot recorded a total of 3665 downloads (50.4 %), and Ouluhalli 1025 downloads (14.1 %). Indoor hotspots recorded 5737 downloads (78.9 %), and outdoor hotspots 1531 downloads (21.1 %). The average number of downloaded messages per user was also the highest in the two most popular hotspots, with 6.8 and 6.3 messages, respectively. The average number of messages downloaded per day across all hotspots is 74, with the maximum of 267 messages downloaded on a single day. The average number of users per day is 16, with the maximum of 38 users on a single day. Fig. 4 depicts the evolution of the number of users and downloads during the study. There is a strong positive correlation (r=0.76) between the daily number of unique users and the number of downloads. A p-test showed that the correlation is statistically significant ($r(97)=0.76$, $p<0.0001$).

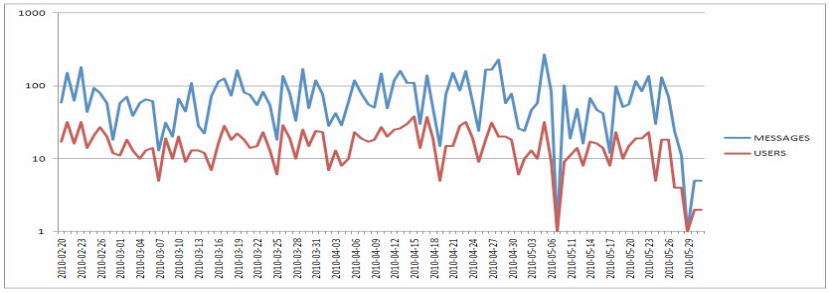


Fig. 4. Evolution of number of unique users and downloads (y-axis) over time (x-axis)

An ANOVA showed that the variation of downloads at each location was significantly affected by the day of week ($F(6,7303)=21.371$, $p<0.0001$) and hour of day ($F(23,7303)=59.192$, $p<0.0001$). The variation of downloads across weekdays (Fig. 5) shows a rising trend that peaks on Wednesdays, and declines again towards the end of the week. Further, when looking at the variation across each day, we see a rising trend towards the afternoon hours, peaking at 5 pm, and declining thereafter.

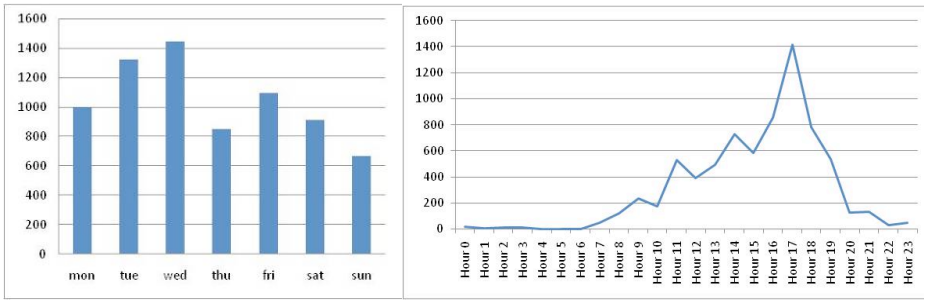


Fig. 5. Total downloads per weekday (left) and per hour of the day (right).

The number of times each service was downloaded, along with the number of users downloading it, is shown in Table 3. From the table we can see that the news service provided by Kaleva (the local main newspaper) has been by far the most popular with

1732 downloads (23.8 % of all downloads). Overall, news services (Kaleva and Reuters) have been very popular with 2397 downloads (33.0 % of all downloads).

Table 3. Downloads and users per service

Service	*#downloads (%)*	*#users*
News (Kaleva)	1732 (23.8)	1055
Weather	907 (12.5)	575
Bus schedules	866 (11.9)	555
TV programs	821 (11.3)	514
Daily message	746 (10.3)	448
News (Reuters)	665 (9.2)	395
Movie service	656 (9.0)	400
Event calendar	616 (8.5)	413
Wappu	175 (2.4)	112
City info	84 (1.2)	65

The categorization of the Bluetooth friendly names resulted in 388 (24.8 %) 'male' names, 160 (11.9 %) 'female' names, 499 (36.6 %) unknown names, and 366 (26.8 %) factory default names. Given this gender categorization, women used the outdoor hotspots more actively than men, as 27.5 % of all downloads by females occurred at outdoor hotspots, while the same number for males was 13.9 %. Both genders preferred indoor hotspots, as 86.1% of all downloads by males and 72.4 % by females occurred in indoor hotspots. When looking at the downloads of individual services, women preferred the bus service slightly more than men (12.6 % for females vs. 11.3% for males), as well as the movie service (10.5 % vs. 8.1 %), while for all other services the difference between genders was within 1 %.

6. Discussion

This paper highlights several factors related to user preferences with different models of information acquisition. The questionnaire study conducted at bus stops revealed that people are open to receive content over Bluetooth, with push and pull interaction models receiving equal support. The need for relevant data was apparent, as 33 % of respondents claimed not to care how the information was delivered as long as it was relevant to them. Interestingly, only 11.5 % of the 105 respondents reported to having Bluetooth turned on in their device, even though market reports suggest that more than 90 % of devices are Bluetooth capable. This finding highlights the inefficiency of such sampling, as shown by the fact that during the period from March 2009 to August 2010, the 12 BlueInfo access points scanned 118162 unique Bluetooth devices, which is a significant amount given that Oulu has 140000 inhabitants. This large number indicates that Bluetooth could be a feasible wireless delivery mechanism for mobile information services. With these considerations in mind, we set out to explore alternate interaction models implemented atop Bluetooth technology and evaluated in different experimental settings.

6.1 Models of in-situ information delivery

The first prototype, BlueInfo Pull, where content is pulled with textual keywords, was successful in terms of reducing task execution times and the number of clicks in comparison to a smartphone's web browser. User acceptance of the system was high, with most users claiming that information retrieval was easier and faster than using a mobile browser. The main constraint with the keyword-based interaction model, however, is the high initial cognitive load imposed on users as they have to memorize several keywords and parameters, and the somewhat unfamiliar way of sending textual messages from the phone's notepad application instead of using SMS.

To address this issue, the next prototype, BlueInfo Push, employed *push-based* interaction model, which was evaluated in a month-long study on a university campus. The relatively small number of participants (33) in this study is due to the requirement for a high-end mobile device with a browser that supports the composite HTML format used to create the daily messages. The penetration of such high end models among university students was still low. However, participants who did use the system were mostly happy with it. The follow-up interviews showed that users appreciate the push-based model as it is a very low-effort way of receiving up-to-date information and entertainment content. However, users expressed discontent with the fact that the access points were not visible in the environment, and there was no way of telling when they were within range to receive a message. Users explained that they had only paired their device with one or two access points, usually those situated within their favorite restaurant or cafeteria, and would always go to those places when they wanted to receive a message. Moreover, users expressed the desire of being able to change their preferences even when they could not directly connect to the configuration page of the system's website. The idea of a simple interactive interface in proximity of some access point was very appealing to them. With this emergent behavior push-based information delivery can begin to actually take on characteristics of pull-based interaction, where users explicitly go to a certain location to get content.

The Easter egg probe provided a middle ground between the two previous prototypes. Users did need to register before using the system, removing keyword-based messages reduced interaction time, and the system employed proximity-based mode of interaction by requiring the user to explicitly place her device very close to the egg, thus clearly marking the area where content could be downloaded. The downside was that only a single message could be made available at a time, i.e. users were not able to select which content they want to receive. However, we considered the Easter egg to be a successful experiment given the number of sent messages and unique devices. Since the message was a simple animated GIF, even older devices were capable of showing it. Also, the physical user interface seemed to be a strong incentive for people to try the system as it encouraged playful and social interaction.

6.2 In-situ information delivery in the wild

The final prototype utilized the 12 hotspots located in indoor and outdoor locations in a city center. In this study users were able to select which information services would be sent to their devices using the touch screen interface of the hotspot. This added feature addresses the finding from the pull experiment, where users wished to select

services while on the move, and not have to have access to the configuration webpage to do so. After deployment the system was left "in-the-wild" for the general public to use, without researchers' intervention or supervision. The point of this type of study is to see if a deployed system can survive on its own in a highly public setting, and whether or not it will entice people to start using it. Additionally, because BlueInfo was offered as a part of a large set of different applications, it was interesting to see if people would find and use this service, as it was among the more technically challenging applications in the hotspots (users were required to begin the interaction sequence on the hotspot, and continue it on their mobile device).

Over the course of the 100-day study, 1338 unique devices were used to interact with BlueInfo. We consider this to be a highly encouraging number, as it shows real users' willingness to adopt such a service. The number of users utilizing the service on several hotspots was rather low, however, indicating a high amount of 'curiosity usage' where people try the system once, and never return to it, which is to be expected in a real-life setting. The group of lead users who did use the service on several hotspots became very active in downloading content, indicating that they had adopted the service as part of their everyday information seeking behavior.

The number of users and downloads illustrates that people do have a need for easily accessible information services that they can take with them. Observations from the use of the hotspots indicate that the proportion of people utilizing their mobile phones for on-line information access (i.e. web browsing), or even owning suitable smart phones, is still rather low, especially with older people. In many studies mobile on-line services are offered as a the solution for information acquisition while on the move, but the longitudinal observations and data from this study shows that alternative ways of content delivery need to be explored. Marketing research shows that high-end smartphones with large touch screens suitable for extended on-line access are still somewhat rare among the general population. According to a recent report [35], only 19 % of mobile phones globally are smartphones. Furthermore, people still often quote cost as a major reason for not doing mobile browsing. Bluetooth-based services are a viable option, as WPAN connectivity is free of charge, and browsing the downloaded content does not require further (IP-based) connectivity.

6.3 Towards understanding users' in-situ behaviour

Over the course of the longitudinal study, 965 (72.1 %) of the 1338 devices used BlueInfo at indoor hotspots to execute 78.9 % of all downloads. This may be explained by the time of year the data gathering took place. The arctic winter conditions in Northern Europe do not encourage outdoor use of mobile devices, which often requires the user to remove his/her gloves to operate the keypad. There is a (somewhat low) correlation between the mean temperature each day, and the number of users in outdoor hotspots ($r=0.3$). A p-test shows that this correlation is statistically significant ($r(91)=0.3$, $p<0.004$). The highly public nature of the outdoor hotspots may also discourage first-time users from attempting to use the system, as they may be afraid of failing in front of a lot of people.

Regarding the most active days and hours of use, Wednesdays, Tuesdays, and Fridays stand out as usage peaks. Similarly, usage peaked around afternoon hours

between 5 pm and 7 pm, and other times of high activity were 2 pm and 11 am. This cycle reflects the daily and weekly rhythm of the city, where there is high activity at lunchtime (around 11 am), when youngsters get out of school (around 2 pm), and when people leave work (around 5 pm). The lower number of users during weekends is partially explained by the fact that some of the indoor locations are closed and thus not accessible during weekends.

When looking at the usage of individual hotspots, the hotspot at the municipal swimming hall clearly stands out. This hotspot attracted 38.2% of all users, and 50.4% of all downloads. Similarly, the hotspot located in another large sporting facility (Ouluhalli) attracted substantial use. From this data we can draw the conclusion that sporting facilities work well as settings for interactive displays. This may be due to several factors, such as a high number of children and teenagers, but also the extent to which the physical environment instills trust in users, as shown in [17]. From our empirical evidence we have found that youngsters often have an open view on new technology, and are willing to try it out without encouragement or external reward. In fact, emerging technologies are often a driver of younger users behaviour, shaping multiple aspects of their everyday life [16]. Older people, on the other hand, often have a more reserved view, and require explicit training or encouragement before starting to interact with a device/service. This was confirmed during another study utilizing the hotspots, where public events were arranged to educate people on the use of the hotspots and services. A majority of participants in these training events were middle-aged or elderly (45% over 50 years of age), while teenagers and young adults often declined participating, claiming to already be familiar with the technology. Further, people in sporting facilities often have idle time, when either waiting for their training shift to begin, or parents waiting for their children to finish practice. This perceivably attracts people to experiment with new technology.

There is correlation between the number of distinct days people visited a hotspot (as determined by the number of times their device was scanned by a Bluetooth access point) and on how many of those days they actually used BlueInfo. Overall, we find a regression of how many visits people made to a location with a hotspot and how many times they used BlueInfo with a=0.15, suggesting that people use the service once every 7 days. People who did not use BlueInfo at all on average visited the hotspot on 5 separate days during the study. This shows that they did not "make the threshold" of 7 days which would likely cause them to use BlueInfo at least once. For the swimming hall hotspot we find a similar pattern with a=0.2, suggesting people use the hotspot every 5 days. The people who did not use the hotspot visited it on average 2.8 separate days, hence again not "making the threshold".

6.4 Implications for design

Different locations attract different types of use. Outdoor locations, usually characterized by their highly public context, do not necessarily attract first-time users if the offered service is perceived as technically challenging. Further, weather conditions have a considerable effect on outdoor usage. Indoor displays, on the other hand, seem to attract heavy usage, especially with hotspots situated in locations geared towards leisure such as the two sporting facilities used in this study. This

would suggest that other projects planning on deploying public displays should look into the possibility to have at least one in such a context. Related to this, there appears to be a 'threshold' of how many times a person has to visit a hotspot before becoming an active user: in our case of the swimming hall hotspot this threshold was 5 days. This is an interesting phenomenon that requires further study before explicit implications for design can be drawn.

Bluetooth is a viable but underused channel for delivering in-situ information. The very large number of Bluetooth devices scanned by the hotspots, the high number of downloads using BlueInfo, along with the results from the different studies presented here, suggest that a substantial number of people a) own Bluetooth capable devices, b) have the Bluetooth radio turned on and set to discoverable, c) do not care how information is transferred to their devices, as long as the information is relevant to them, and d) appreciate the option to select information services from a public display for immediate pick-up. This implies that low-effort, fast-to-use interaction models, such as the one presented here, work well because people do not have to install additional client software on their devices prior to using a system, which in turn encourages a lot of curiosity usage which, eventually, turns into continued use for some proportion of users.

In-situ information pick-up demonstrates strong daily, weekly and seasonal patterns. These patterns intuitively appear to reflect the rhythm of the city. For design, this implies that users are more willing to interact with systems found in the environment during these times. Context-aware services supporting activities normally found around these times would have the potential to become highly used and valuable to people. Interestingly, similar usage patterns were found in a recent study on Twitter usage [31]. The highest number of 'tweets' is found on Tuesdays, Thursdays and Fridays. Further, the number of 'tweets' peaks at 5 pm, and between 10 pm and 11 pm. This further confirms the fact that these are optimal times for offering services, and the correlation provides fascinating possibilities for further research.

Push-based services seem to be well received by people. However, users need to be made aware of the location and range of access points offering push-based content. Otherwise, users may begin to re-appropriate their interaction model by always going to a place where they know information will be pushed to them, thus shifting the interaction paradigm more towards pull-based interaction. Related to this, a physical artifact such as the Easter egg probe functions well in communicating interaction possibilities to users. These types of artifacts could be employed to make users aware of access points, which could push content to them.

7. Conclusion

We presented a set of prototypes for in-situ information delivery over Bluetooth. Given our findings, we conclude that Bluetooth is a viable option for delivering mobile information services, and that the general public is willing to utilize such services together with interactive public displays. We showed that usage differs between hotspots placed in varying contexts and that several environmental factors affect the usage of services. We explored the relationship between how many times a

person visits a space augmented with the hotspots and how likely they are to become active users. Finally, we presented a set of design and deployment guidelines that should be useful for anyone planning similar installations.

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