Bluetooth and WAP Push Based Location-Aware Mobile Advertising System

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ABSTRACT
Advertising on mobile devices has large potential due to the very personal and intimate nature of the devices and high targeting possibilities. We introduce a novel B-MAD system for delivering permission-based location-aware mobile advertisements to mobile phones using Bluetooth positioning and Wireless Application Protocol (WAP) Push. We present a thorough quantitative evaluation of the system in a laboratory environment and qualitative user evaluation in form of a field trial in the real environment of use. Experimental results show that the system provides a viable solution for realizing permission-based mobile advertising.

Categories and Subject Descriptors
C.2.1 [**Network Architecture and Design**]: Wireless communication;
H.1.2 [**User/Machine Systems**]: Human factors;
K.4.4 [**Electronic Commerce**].

General Terms
Performance, Design, Experimentation, Human Factors.

Keywords
Location-based services; location-aware; context-aware; Bluetooth positioning; mobile advertising; wireless advertising.

1. INTRODUCTION
In marketing, mobile advertising has two distinct meanings: advertisements moving from place to place, e.g. displayed on the sides of trucks and buses, and advertisements delivered to mobile devices, e.g. mobile phones and personal digital assistants (PDAs). In this paper we study the latter, and focus on permission-based advertising, ruling out unsolicited advertising (i.e. spamming). Sometimes, wireless advertising is used to refer to mobile advertising.

A location-aware or location-based service is a service the behavior of which is mostly driven by location information. Proximity-triggered mobile advertising is a special case of location-based notification services [10]. Usually, notification services are user-driven, e.g. getting a notification when a set of conditions is met. Advertising, on the other hand, is typically not user-driven, i.e. the recipient does not request or pull the advertisements from a server, but they are pushed to him/her instead. [15]

The novel contribution of this paper is the introduction and implementation of a new location-aware mobile advertising system, which is based on Bluetooth positioning and WAP Push. We call this system B-MAD (for Bluetooth Mobile Advertising). Further, we present a thorough quantitative and qualitative empirical evaluation of the system. The former is carried out in a laboratory, while the qualitative assessment is realized in the real environment of use in a form of a field trial involving eight local companies as advertisers and 35 test users. Engaging with a real application and real users provides valuable experience and insights that are often missed with laboratory prototypes. In this paper, we focus purely on the technical aspects of the system. We do not address the validity of the candidate business models of the proposed advertising service.

Earlier we have developed and deployed the SmartRotuaari service system for provisioning general-purpose context-aware mobile multimedia services, including location-aware mobile advertisements [13]. The system relies on wireless local area network (WLAN) for connectivity and positioning, while PDAs are employed as mobile devices. The work presented in this paper reflects our ongoing work for incorporating smartphones and the connectivity and positioning technologies applicable to them, such as Bluetooth and GPRS (General Packet Radio Service). The advertising system presented in this paper is not a part of the service system; rather it is used to evaluate these technologies to be incorporated.

This paper is organized as follows. In Section 2 we briefly review related work on location-aware mobile advertising. The developed system is introduced in Section 3. Quantitative evaluation of the system in a laboratory environment is described in Section 4. Qualitative user evaluation via a field trial in the real environment

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of use is presented in Section 5. Section 6 provides discussion on various aspects of the system and future work and concludes the paper.

2. RELATED WORK

Barwise and Strong [3] explored the effectiveness of SMS (Short Message Service) advertising in the United Kingdom. They identified six types of mobile advertisements: brand building, special offers, timely media teasers, service or information requests, competitions and polls.

Kaasinen [8] analyzed user needs for mobile location-aware services. In her interviews, most users did not mind being pushed information, as long as they really needed the information. Thus, location itself is not enough to trigger pushed advertisements, but it has to be complemented with personalization. This need for personalization is recognized in a number of other studies as well.

Yunos *et al.* [21] addressed the challenges and opportunities of wireless advertising. They surveyed existing advertisers like Vindigo, SkyGo and AvantGo, and approaches and technologies currently in use. They also presented five business models applicable to mobile advertising.

A number of location-aware service studies list the mobile advertising as one of the future possibilities in the application area. Barnes [2] introduced the concept of tempting nearby users into the stores and delivering geographic messaging related e.g. to security in particular area of a city. Varshney and Vetter [17] suggested mobile advertising to be a very important class of mobile commerce. They augmented location information with the personalization of the delivery by obtaining the history of the user's purchases or consulting the user at an earlier stage. In addition, the users might be able to either receive push advertisements or actively pull the messages.

Ranganathan *et al.* [15] discussed mobile advertising in the context of pervasive computing environments. They presented a list of challenges and possibilities as well some ideas of solutions for advertising in pervasive environments. The challenges include: reaching the people with the right ads, delivering ads at the right time, serendipitous advertising, means for users to follow up on the ad, and how to collect revenue for ads.

Randell and Muller [14] presented the Shopping Jacket infrastructure, which used GPS and local pingers in stores for positioning. Wearers were alerted when passing an interesting shop. The system could also be used to guide the user around a shopping mall. The system presented in this paper has some similar characteristics.

WideRay's Jack Service Point [20] is a product for delivering local content, such as advertisements, using Bluetooth or infrared. A number of these devices have already been deployed at mass events such as sports and conferences for distributing event related information. We are not aware of any published research papers that would involve Jacks.

Two different positioning methods are applicable with Bluetooth: either measure received signal power levels to obtain distance estimates to multiple known-location Bluetooth devices and triangulate the user device position [9], or do cell identity based positioning by mapping known Bluetooth device addresses to location information [1]. Further, these two methods can be combined into a hybrid system [6].

Oiso *et al.* [12] presented the architecture for a museum guidance system based on Bluetooth positioning. They also proposed a concept for improving the accuracy of the cell identity based positioning by placing several fixed Bluetooth devices with different reachable distances into a given location and excluding paths that are not physically possible.

3. B-MAD SYSTEM DESCRIPTION

The main components and operation sequence of the proposed B-MAD system are illustrated in Figure 1:

1. Bluetooth Sensor discovers the globally unique Bluetooth device addresses (BD_ADDRs) of nearby end user devices.
2. Bluetooth Sensor sends the addresses over a WAP connection to the Ad Server, together with a location identifier.
3. Ad Server maps the addresses to the user phone numbers (MSISDNs) and checks from the database if there are any undelivered advertisements associated with the location that have not been delivered to the end user.
4. The undelivered advertisements are sent to Push Sender for delivery.
5. Push Sender delivers the advertisements as WAP Push SI (Service Indication) messages.

Our requirements for Sensor and end user devices were that they be commercially available models with GPRS capability, a programming interface to Bluetooth stack for the Sensor and XHTML (eXtensible Hypertext Markup Language) browser for the end user device. These requirements led us to the limited selection of SymbianOS and especially Series 60 phones on the market.

3.1 Bluetooth-Based Positioning on Symbian

For a Bluetooth device, it is optional to implement the host controller interface command Read_RSSI for reading received signal strength information [5]. It is not implemented in the

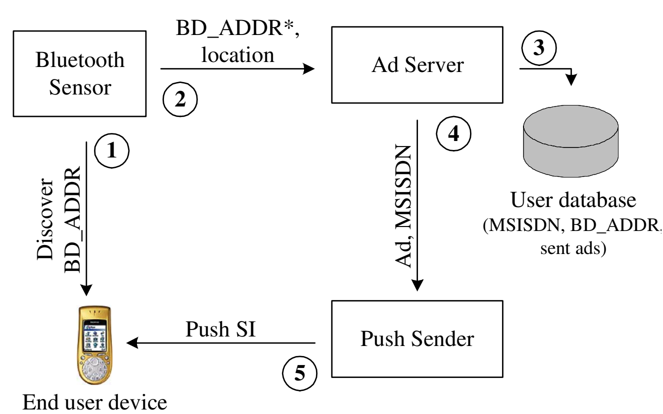


Figure 1. B-MAD Bluetooth-based positioning and mobile advertisement delivery system.

SymbianOS Bluetooth stack, for example. Therefore, measuring received power levels is not an option and we are only left with cell identity positioning. To do that, nearby Bluetooth devices need to be discovered. This process is called an inquiry.

When a Bluetooth device is in the inquiry state, it continuously transmits inquiry packets carrying an access code and hops frequencies 3200 times a second, twice as fast compared to the normal connection mode. A device that allows itself to be discovered, regularly enters the inquiry scan state to respond to inquiry messages, hopping frequencies only once every 1.28 seconds. When it receives an inquiry packet, it first waits for a random period of time. Then it listens for another inquiry packet and responds to it with a frequency hop synchronization packet. This packet essentially carries all necessary information for establishing a connection between the devices. The reason for the random delay is to avoid all nearby devices responding simultaneously to the first inquiry packet. In order to discover all discoverable devices in an error-free environment, the device must spend at least 10.24 seconds in the inquiry mode. [5]

SymbianOS supports Bluetooth device discovery with its RHostResolver and TInquirySockAddr classes. By default, inquiry results are cached for about two minutes. This cache can be disabled so that there will not be false positive position fixes two minutes after the user has left the vicinity of a Bluetooth Sensor.

There is still one problem: when tested on a Nokia 3650 device, the inquiry state is terminated after about five seconds. We have not found a way to change this inquiry timeout, although the bt_sock.h system header file declares a KInquiryTimeOpt option. Because of this timeout, there is only about a 50 % chance for a device to be discovered during an inquiry period; this is discussed later in more detail.

We implemented the Bluetooth Sensor in the SymbianOS Series 60 version 1.x environment. The Bluetooth Sensor periodically scans for nearby Bluetooth devices. Positioning based on the Bluetooth Sensor can be realized with two different approaches:

1. Run the Bluetooth Sensor software on an end user's mobile phone. Use dummy Bluetooth tag-like devices in known locations as reference points to be discovered. Location can be derived based on the addresses of discovered tags. If multiple tags have been discovered, positioning accuracy can be improved by triangulation.
2. Run the Bluetooth Sensor software on a suitable device (e.g. a mobile phone or a PDA) in a known location. End user mobile phones are devices to be discovered, and their device addresses map to user accounts.

In this paper we use the second approach. The Bluetooth Sensor sends the unique Bluetooth device addresses (BD_ADDR) of discovered phones to the Ad Server over a WAP connection. Since most of our service functionality resides on the server side, honoring the web services paradigm, we decided to keep the Bluetooth Sensor software thin and associate device addresses with users in the Ad Server. Location-awareness is provided in local hotspots in the vicinity of Bluetooth Sensors.

The possibility of this dual configuration is also the reason why the Bluetooth Sensor software uses a WAP connection to send its data instead of a direct socket connection. This way the Series 60 version 1.x mobile browser can run simultaneously with the Bluetooth Sensor, both sharing the same WAP access point settings. This is likely to change in later Series 60 versions where WAP is deprecated and the browser uses an Internet access point.

3.2 Mapping Device Addresses to Advertisements

The Ad Server is a collection of PHP (PHP Hypertext Preprocessor) scripts running on a LAMP (Linux, Apache, MySQL, PHP) platform. When an end user subscribes to the mobile advertisement service, an association between his/her phone number (MSISDN) and Bluetooth device address (BD_ADDR) is stored in a database.

When the Ad Server receives a request from a Bluetooth Sensor, it scans the database for known BD_ADDRs in the request that can be mapped to user accounts. Then it checks if there are any undelivered advertisements associated with the user account and the location identifier passed in the request. If there are, the recipient's MSISDN (stored in the user account data), URL addresses and short textual descriptions of the advertisements are passed on to the Push Sender.

The Ad Server has limited profiling capabilities. The markup language (XHTML Mobile Profile or WML Wireless Markup Language) and color capabilities of the devices can be configured. Users can choose the language in which to receive the advertisements. Advertisements can have some simple sending criteria associated to them, for example, what other advertisement has to be sent before this advertisement can be sent, or how much time has to pass after the user was first located at a certain place before sending the follow-up advertisement.

3.3 Sending WAP Push Messages

The Push Sender in our system, a Push Initiator in WAP Push terminology, transmits push content and delivery instructions to a Push Proxy Gateway using the Push Access Protocol, which uses XML over HTTP. The gateway encodes the pushed message to a binary over-the-air format and uses a Short Message Service Center (SMSC) with SMS as the bearer to deliver it. [18]

We use Push Service Indication (SI) messages to deliver our notifications on available advertisements. An SI message contains the description of the offered service and an embedded URL pointing to the content. The user can choose to download the content whenever (unless the message has expired) since the message is stored on the phone. The user can also simply discard the SI message. Figure 3 shows an example of a SI message as displayed on a Nokia 3650 phone.

WAP Push also provides Service Loading (SL) messages, which allow content to be silently pushed without user confirmation. Due to security concerns, SL messages are often ignored on mobile terminals. For example, the Nokia 3650 ignores SL messages. The WAP 1.2.1 and 2.0 specifications do not require terminals to support SL messages.

4. QUANTITATIVE EVALUATION

In this section we evaluate the components of the B-MAD system quantitatively in a laboratory environment.

4.1 Theoretical Positioning Time

Given the fact there is only a 50 % chance for a device to be discovered (see section 3.1), a larger number of attempts is needed to discover all devices within range. Thus, theoretically, the number of attempts needed X has the geometric distribution with parameter $p = 0.5$. Its expected value and standard deviation are

$$EX = \frac{1}{p} = 2 \quad \text{and}$$

$$\sigma_X = \sqrt{\frac{1-p}{p^2}} = \sqrt{2}.$$

If we assume that the Bluetooth Sensor's update period is set to 10 seconds, we get a new random variable T for the discovery time in seconds: $T = 10X$. Its expected value and standard deviation are respectively (in seconds)

$$ET = 10EX = 20 \quad \text{and}$$

$$\sigma_T = 10\sigma_X = 10\sqrt{2} \approx 14.14.$$

4.2 Observed Positioning Time

Positioning time was measured using two Nokia 3650 phones. One was running the Bluetooth Sensor software while the other was used as the user device to be discovered. Manual timekeeping was started when the Bluetooth radio was turned on in the device being discovered and stopped when its BD_ADDR was processed in the Ad Server. Thus, the measurement consists of device discovery time and the joint latency of the network, WAP gateway server, Ad Server and the manual timekeeper.

The measurements were taken in a laboratory environment. The distance between the Bluetooth Sensor and the mobile phone ranged from 0.4m to 28 meters, so that in the case of 0.4 m the devices were placed on top of a desk, otherwise the measurements were carried out in a 28-meter corridor. There were also other Bluetooth devices present, and the environment has a WLAN network installed. It is well known that Bluetooth and WLAN networks that are operating in the same 2.4 GHz ISM (industrial, scientific, medical) band interfere with each other, especially if the devices are close to each other [7]. It may take some extra time for the Bluetooth protocol to cope with the interference.

A summary of the measurements is shown in Table 1. Generally, the device discovery worked well over the whole 28 m length of the corridor. This result is surprisingly good, because the transmit power level in class 2 devices usually only gives a 10 m maximum distance. The shape and materials of the corridor that give only a small effect on signal fading can explain this. The distance starts to affect the results at around 20 m.

The mean positioning time and standard deviation improvement observed around 14 m is because at that time of the measurement the clock was 4:30 PM and the level of interfering WLAN traffic dropped significantly. There were only nine quantified observations at 26 meters, as three measurement attempts at this distance were aborted after 300 seconds. This is due to a WLAN base station located at the same exact spot.

Considering network, server and manual timekeeping latencies (cumulatively some 0.5–2 s), WLAN network interference, the fact that the Bluetooth Sensor is in inquiry mode only the first five seconds of its ten-second period, and random variation, we are reasonably close to the theoretical expected values.

Table 1. Summary of positioning time measurements at different distances in a laboratory environment.

Distance [m]	*n*	Mean [s]	Std dev [s]	Median [s]	Min [s]	Max [s]
0.4	20	18.7	8.69	17.5	6.0	42.5
5	10	18.2	9.50	18.2	6.5	37.8
8	10	22.3	10.92	21.5	3.5	38.7
10	10	27.5	14.23	28.8	4.6	41.7
12	10	33.0	21.94	21.8	15.9	77.1
14	10	22.8	8.77	19.3	14.1	38.4
16	10	18.2	8.38	18.5	3.9	35.7
18	10	19.2	4.64	19.6	10.7	24.8
20	10	26.4	15.69	20.4	5.4	50.9
22	10	33.2	22.75	33.2	6.9	77.8
24	10	30.2	13.32	30.6	12.6	49.0
26	9	31.4	15.90	25.8	15.9	61.9
28	10	36.3	29.37	32.0	5.7	107.7
All	139	25.4	15.86	19.6	3.5	107.7

Let us assume that the user walks at a speed of 1.5 m/s (5.4 km/h) and that a Bluetooth cell is circle-shaped with a 25 m radius. Walking across the diameter, the user spends 2*25 m/1.5 m/s = 33.3 s within the cell. In the measurement data, 73 % of the observations are less than or equal to 33.3 s. Thus, even with these favorable assumptions, the system cannot reliably detect moving users. This should not be a critical disadvantage in the mobile advertisement case: those users the system cannot locate simply do not get the advertisement.

If it would be possible to make the inquiry process more reliable by increasing the inquiry timeout period to a large enough value (10.24 s in an error-free environment, more in the real world), the maximum positioning time could be limited to this timeout value most of the time, and positioning time deviation would be considerably smaller as well. Mean positioning time would increase, however: the request containing the discovered device addresses is only sent after the inquiry is complete. In that case it might be useful to send the device addresses individually as soon as they are available and not wait for the whole inquiry process to complete.

4.3 Positioning Accuracy

Given the measurement data from the previous subsection, the mobile phone being positioned can be at least 28 m away from the Bluetooth Sensor. Thus, when estimating the positioning error, we will either have to content ourselves with rough estimates like 50 m or 100 m, or calibrate the system for the environment of each Bluetooth Sensor.

In the mobile advertisement case, we do not need the exact position of the user. It is sufficient to know that the end user is near the Bluetooth Sensor.

4.4 Scalability

We tested the system in the Octopus test network [11]. Its WAP gateway license allowed only ten requests every ten seconds. We had nine Nokia 3650 phones running the Bluetooth Sensor software simultaneously with an update period of ten seconds. Test period lasted for an hour from 2 PM to 3 PM. Most BD_ADDR post requests were sent successfully on the first try, but there were three occasions where about half of the Sensors simultaneously failed to send their requests. We believe that this was caused by somebody else's browsing session via the same WAP gateway. The Bluetooth Sensor software was able to recover from these errors gracefully. Even with the upgraded license, the Octopus WAP gateway is a bottleneck in our system. Commercial operator WAP gateways are expected to handle larger request volumes gracefully.

It must be kept in mind that downloading the advertisements pointed to by the SI message uses the same WAP gateway. The download corresponds to one request for the advertisement XHTML and one additional request for each contained item such as external style sheets or inline images. To alleviate the problems caused by the gateway limitations and make downloads faster, the advertisements were made as simple as possible with no external style sheets and minimum number of inline images.

Throughput of the positioning system depends not only on the WAP gateway, but also the Ad Server's ability to handle requests. Using a shell script on the server host, we sent the Ad Server 50 sequential fake requests, pretending to be from a Bluetooth Sensor, and measured the time it took to process them. Each request involved database table lookups for one device address and for undelivered advertisements for one user but no Push message sending. The average processing time over 15 measurements was 0.57 seconds (std. dev. 0.22 s, min 0.25 s, max 1.05 s). Processing can be parallelized using standard Apache configuration techniques; there are no table-wide database locks involved that would cause blocking in a parallel setup. Therefore, Ad Server request processing time is not the first bottleneck if the system is scaled up.

4.5 Ad Server and Push Message Sending Latency

Push message sending latencies were also measured by sending a message to the Push Proxy Gateway of the Octopus network and measuring the time it took until the SI message consisting of two SMS messages arrived at the mobile handset. This latency is highly dependent on the GSM network and its SMS throughput. Most of the time is spent paging the device, i.e. locating it on the network, and sending the binary-encoded SI SMS messages to it.

The average sending latency measured over 15 measurements was 11.6 seconds (std. dev. 0.41 s, min 10.9 s, max 12.2 s). When combining the average 25.4 s for positioning with the average 11.6 s for push latency, we get an aggregate 37 second average latency for positioning and content push. Assuming 1.5 m/s speed again, the user has time to walk 37 s*1.5 m/s = 55.5 m in 37 seconds. Most of this time is spent walking away from the Bluetooth Sensor. Reacting to advertisements becomes more painful the further the user moves from the intended point of delivery.

5. QUALITATIVE EVALUATION WITH A FIELD TRIAL

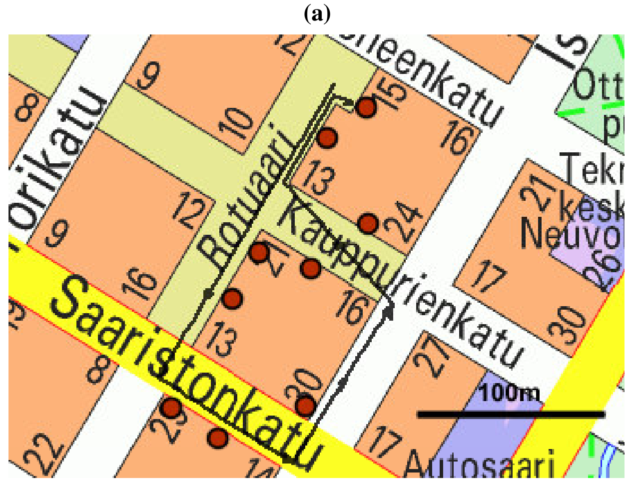
To qualitatively evaluate the B-MAD system and the end user experience, we conducted a field trial in real use of environment.

5.1 Setup

Nine Bluetooth Sensors (Nokia 3650 phones running the Bluetooth Sensor software) were placed in the display windows of eight retail stores around the Rotuaari area, which includes pedestrian streets at the center of the City of Oulu in Northern Finland (see Figures 2a and 2b). Among these stores were one cafeteria, a jewelry store, four clothing stores, a bookstore and a nightclub. The stores were selected so that the test users could walk a 600 m route past all stores in a reasonably short amount of time. Field trial office was set up in the cafeteria.

The stores produced eleven advertisements in total, containing some special offers and/or discounts, except for the nightclub, which just advertised its upcoming live music events. Two advertisements had some delivery criteria attached to them: if the

(a)



(b)

Figure 2. Bluetooth Sensor in the display window of a store (a) and a map of Bluetooth Sensors (dots) placed around Rotuaari (b).

Figure 3. Example Service Indication message and mobile advertisements on a Nokia 3650.

users spent four minutes in front of the jewelry store, they received another advertisement with a gift certificate offer. The other special advertisement was a thank you note sent when the user returned to the cafeteria. The users were not told where exactly the Bluetooth Sensors were placed or how many advertisements they could receive.

The advertisements were XHTML Mobile Profile web pages with one inline image. For each advertisement, there was a Finnish and an English version of it. Figure 3 shows two examples of the advertisements and a Push SI message in the messaging inbox.

In the field trial office, test users were handed a Nokia 3650 device. We call this the user device to distinguish it from a Bluetooth Sensor device. The users were given a short introduction on the device usage and also told which route they were supposed to walk to receive mobile advertisements. When the users returned, they were rewarded with a cup of coffee or tea with a pastry. When the user device was returned, its messaging inbox and browser cache were emptied.

Data was collected via a questionnaire presented to the test users and automated logging at the Ad Server. The questionnaire consisted of three pages. The first page contained questions on user reactions to mobile advertisements and factors important to the user. The second page addressed any technical issues the user was possibly confronted with during the use, together with space for free-text comments and feedback. The third page was reserved for demographic and other background information like gender, age and familiarity with mobile technologies and services.

Figure 4 shows a test user being given an introduction to the Nokia 3650 phone and a couple of test users filling in the questionnaire.

5.2 Field Trial Execution and Test Users

We ran the field trial during two afternoons, Thursday and Friday, 30–31 October 2003. We had 35 test users in total. About half of them (19) were colleagues from the university who were asked to participate. The rest were friends or volunteers recruited from the street. Because of the weather, around 3° centigrade with drizzle, there were not that many people on the street with spare time to spend on our tests.

On the second day, we removed one of the nightclub advertisements because it advertised an event that was held the previous night.

One Bluetooth Sensor device crashed on the morning of the second testing day. Another crashed in the afternoon when 2.5 hours of that day's testing period had passed. The crashes were due to the Bluetooth Sensor's and SymbianOS WAP stack's internal state machines getting out of sync. We did not restart the crashed Bluetooth Sensors during the field trial.

Figure 4. Briefing a test user on how to use the device (left) and test users filling in questionnaires (right).

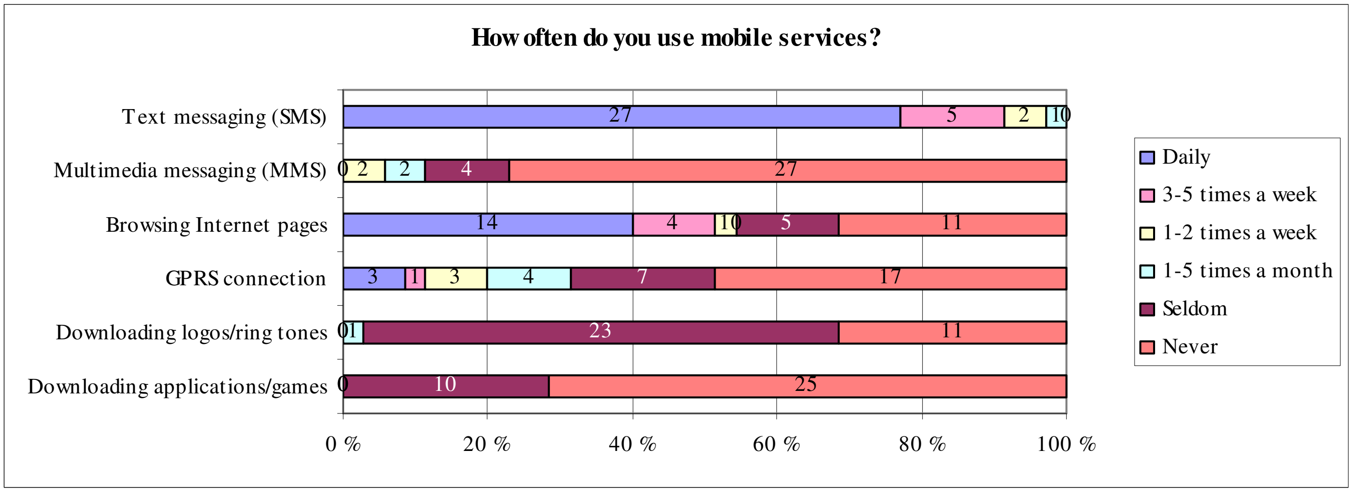


Figure 5. Statistics of test users' usage of different mobile services.

Of the 35 test users, 21 were males and 14 females. Four (11.4 %) were English speaking and were pushed advertisements in English and given an English questionnaire. 27 (77.1 %) of the users were students. Majority of the users were young: 14 (40.0 %) were 18–24 and 19 (54.3 %) were 25–34 years old. There was only one person (2.9 %) in 35–49 and 50–64 age groups each.

All users were frequent mobile phone users: for example, only three people stated that they use SMS messaging only one or two times a week or less often. Other mobile services were used less often as seen in Figure 5. Notice the high variance in browsing the Internet. We should have stressed browsing as a mobile service: browsing the mobile Internet. Now some test users interpreted the question as browsing the Internet in general.

5.3 Pushed and Downloaded Advertisements

There were 33 users that were assigned a user device; two users shared a device with someone else. The test users spent an average of 13 minutes on the street with the device. They were pushed 192 advertisements in total, averaging 6 advertisements per user (minimum 2, maximum 9). There was one test user who received only two advertisements. When asked, she said she had not walked the suggested route.

None of the test users received all eleven advertisements on the first day or ten on the second. The jewelry store advertisements were not received on a regular basis due to the thick lead glass window making positioning more difficult and the four-minute time criteria on the second advertisement. The two crashed Bluetooth Sensors made it impossible to receive advertisements from those two stores.

There were 149 advertisement downloads in the Ad Server log file, which corresponds to 4.7 downloaded advertisements per user.

5.4 User Reactions to Advertisements

Figure 6 contains summaries of the answers to selected questions in the questionnaire. Only seven users did not totally agree with "I downloaded mobile ads content immediately" when they received SI indication messages. This is expected since the test users were instructed to test the advertisements as they receive them. However, the test users did not always download all advertisements:

If a lot of messages arrived at the same time, it was difficult to view all of them at the same time for a new user. Usually I viewed only the first advertisement received.

There were also other usability issues. Although all test users were mobile phone users, the Nokia 3650 model and its user interface was new to some test users.

I did not know how to turn down the device. I was embarrassed when there was a loud tone when an advertisement was received.

Some test users mistook the SI message description for an advertisement, for example:

You do not necessarily associate the globe [Series 60 browser] icon with a mobile ad. The other notes [SI message description] icon was clear [...] beside it was the name of the store and it took the attention away from the globe icon.

However, most test users agreed that it was easy to figure out how to view the advertisements and that the user interface was easy to understand.

Because of the limited profiling capabilities in the Ad Server, some test users got irritated because they received advertisements that did not interest them. For example, the lady in the 50–64 age group did not like being pushed nightclub event advertisements. The need for profiling is well visible in user comments:

Targeting the advertisements is important so the user is not drowned in advertisements.

If I would receive advertisements at this frequency, I would shut down the whole service.

5.5 Technical Problems and Positioning Distance

About a half of the test users thought that downloading the advertisements took a too long time (see Figure 6). When asked about specific technical problems, half of the test users thought that the GPRS connection took too long sometimes (see Figure 7). However, test users familiar with GPRS did not feel this way.

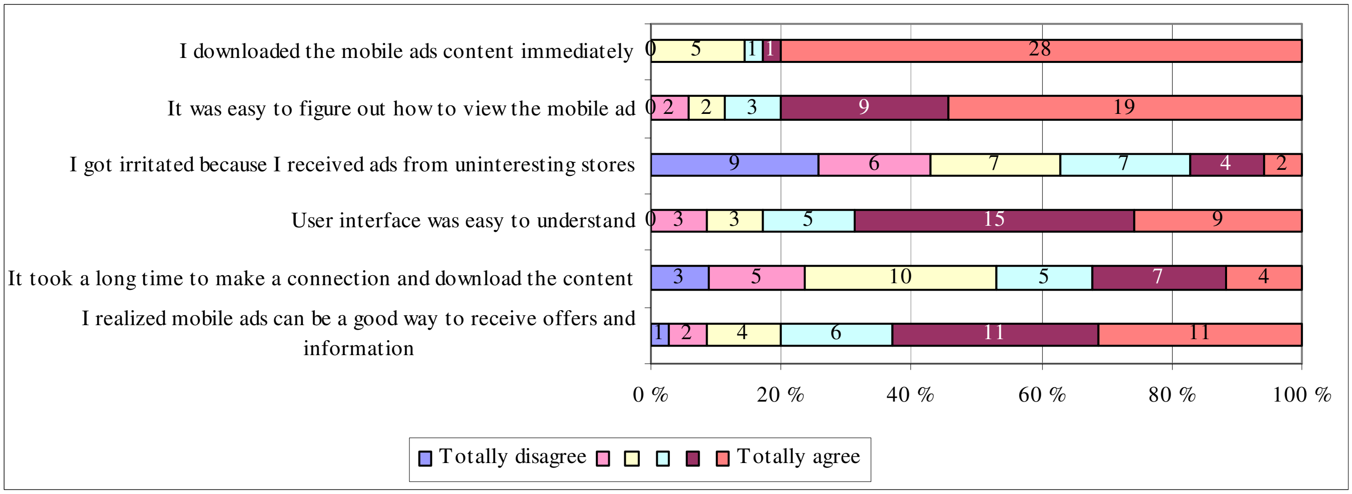


Figure 6. User reactions to pushed mobile advertisements.

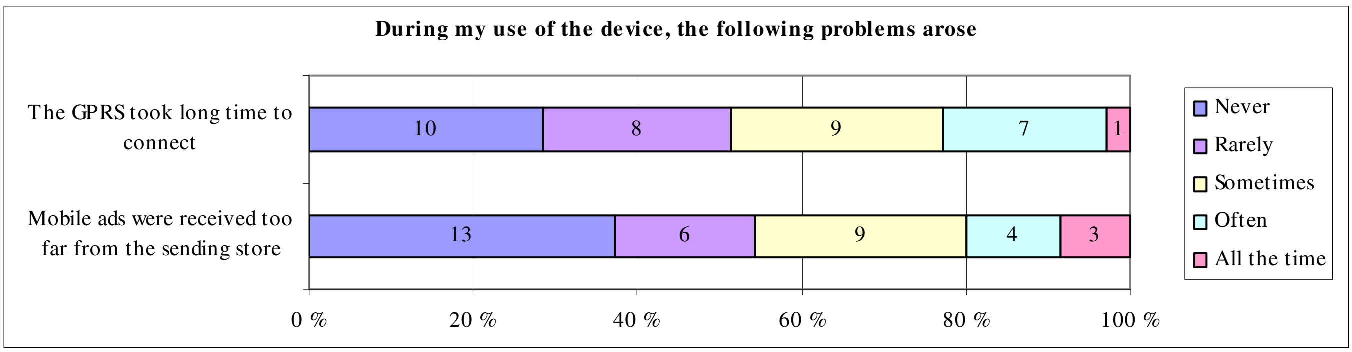


Figure 7. Selected technical problems the test users encountered.

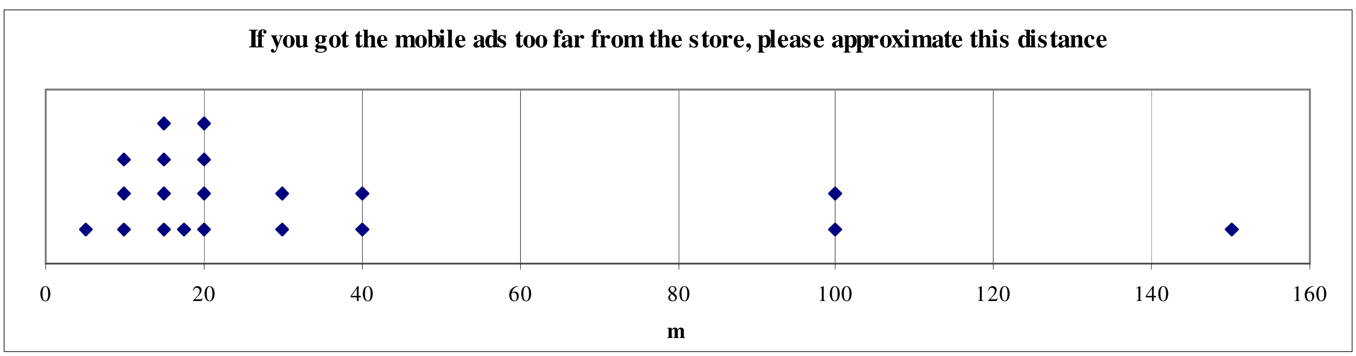


Figure 8. Estimates of the distance when users felt they received advertisements too far from a store.

Another commonly experienced technical problem was that the users felt that they received the advertisements too far from the store (Figure 7). Twenty test users also estimated the distance. For one user even 5 meters was too far, while some users received ads approximately 150 m away from the store. Usually the receiving distance was some 15–20 m (see Figure 8). The 100 m and longer distances can be caused by cumulative effects of positioning, Ad Server and Push SI sending latencies analyzed earlier, with possible network congestion. Of course, we cannot rule out that the users' distance approximations were incorrect. In any case, the user experience that the advertisements were received too far is the most important issue here.

5.6 Other User Comments

Those users who had used the previous PDA-based system [13] thought this system was an improvement.

Really good improvement when compared to the previous [version], in both content and speed sense.

More usable environment than the PDAs.

There were also some comments on under what circumstances the users thought they would use this kind of mobile service:

I would certainly use [a mobile service like this] at least when visiting another city.

I would benefit from mobile advertising if there were offers that I would otherwise not receive or notice. [...] I would not want an advertisement that does not differ from an advertisement in the morning paper for example.

5.7 Observations

Generally, delivering advertisements to mobile phones with WAP Push using Bluetooth positioning works. As smartphones like the Nokia 3650 become more abundant and people become more familiar with them, the usability problems become less severe. In this field trial we should have spent more time teaching the test users how to use the devices.

Bluetooth-based positioning was not very reliable or real-time. Many users could walk past a Bluetooth Sensor without an advertisement being triggered. This is not so severe from user point of view for an advertisement service, as users generally do not know to expect advertisements, while for some other location-based applications it could be a showstopper. There are inherent latencies in positioning and advertisement delivery, during which users can walk quite far away from the Bluetooth Sensor providing the positioning. At least with advertisements, users are very sensitive to this distance: it is annoying if the advertisement is received too late.

A mobile advertisement system needs to be augmented with profiling/personalization so that only relevant, targeted advertisements are offered to the users. It should also be possible to limit the frequency of advertisements. This profiling information can be set up when the user subscribes to mobile the advertising service. A related important issue is the added value of the received advertisements to the recipient: due to the very personal nature of the marketing channel, the paradigms employed in mass marketing may not apply as such, but the mobile domain may call for a more individual and personalized content.

Despite the technical limitations of the field trial, the users' attitude towards this kind of mobile services was very positive. When asked whether the user would want to use similar mobile services in the future, only one user disagreed totally. On the other hand, in her comments she seemed quite positive about the system. Three users disagreed somewhat and two did not get clear enough picture. The rest agreed (15) or agreed totally (14). Of course, we have to keep in mind that people willing to volunteer as test users in this kind of a field trial are generally sympathetic towards mobile services.

6. DISCUSSION AND CONCLUSIONS

We introduced a system for delivering permission-based location-aware mobile advertisements to mobile phones using Bluetooth positioning and WAP Push delivery. We presented a thorough quantitative and quantitative evaluation of the system. Experimental results showed that the system provides a viable solution for realizing mobile advertising. In this section we discuss the privacy and security issues in the system and provide ideas for future work.

6.1 Privacy and Security Issues

The system was not specifically designed with privacy and security issues in mind. Device address data sent from a Bluetooth Sensor to the Ad Server is not encrypted. The Ad Server and the Push Sender send Push SI messages as plain HTTP requests where the user mobile phone number is associated with location information, which can be considered sensitive information that must not be disclosed to third parties. Ideally, mapping device addresses to location information should be done locally in the client device [16].

Bluejacking, i.e. spamming discoverable Bluetooth devices with unsolicited phonebook entries, is technically possible and gaining more popularity [4]. Also, there are Bluetooth brute force scanning tools like RedFang [19] available. For these and other reasons, the privacy-cautious do not walk around with the Bluetooth radios in their devices turned on.

To address these privacy issues there had to be no connection from the SIM (Subscriber Identity Module) cards used in the field trial to actual user identities. Therefore, we did not allow users to use their own devices or SIM cards. There is also a technical reason for this: the Octopus Push Proxy Gateway can only deliver Push messages to Octopus subscribers.

The user data stored in the Ad Server database contained only a nickname of the user and a list of advertisements delivered. We wrote the nickname down on the returned questionnaire forms so that we could match the forms to log data we had. The test users were told about this logging and matching when introduced to the system.

6.2 Future Work

The Bluetooth positioning system needs to be made more reliable. To achieve this, the inquiry timeout should be made longer. This would make the positioning latency longer but more predictable. To shorten the latency the Bluetooth Sensor should not wait for the inquiry to time out before sending the device addresses of found devices but send them as soon as they are discovered. Guessing user location based on his/her previous locations could be another possibility.

Architecturally the Ad Server is not cohesive. If mapping device addresses to location information would be separated from the advertisement sending logic, Bluetooth positioning could be used with other location-aware applications as well. We plan to do this as we incorporate Bluetooth positioning to the SmartRotuaari service platform.

Advertisements should be profiled for each user. Possible profiling factors are gender, age, language, interests, mood, advertising frequency etc. The system could also learn user preferences by placing options like "more ads like this" and "less ads like this" in each advertisement.

WAP Push is not the only possible advertisement content delivery channel. For example, the Bluetooth object exchange protocol could be used for that purpose, although it does not give the user the option to download and view the advertisements when he/she sees fit. However, in a heterogeneous mobile environment, multiple delivery channels should be considered. Also, in a mobile environment it is easier to take advantage of two-way communication, which should be thought of as well.

The field trial provided evidence supporting favorable user acceptance. However, a much more extensive and longer lasting user study would be needed to provide real assessment of the acceptance of mobile advertisements. Further, a larger scale deployment would require a thorough validation of the underlying candidate business models.

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8. REFERENCES

[1] Anastasi, G., Bandelloni, R., Conti, M., Delmastro, F., Gregori, E. & Mainetto, G. (2003) Experimenting an Indoor Bluetooth-Based Positioning Service. ICDCSW'03: 23rd International Conference on Distributed Computing Systems Workshops 2003, 480–483.

[2] Barnes, S. J. (2003) Known By the Network: The Emergence of Location-Based Mobile Commerce. Advances in Mobile Commerce Technologies, 171–189.

[3] Barwise, P. & Strong, C. (2002) Permission-Based Mobile Advertising. Journal of Interactive Marketing. Vol. 16, no. 1, 14–24.

[4] bluejackQ. http://www.bluejackq.com/ [referenced 4 Nov 2003].

[5] Core Specification of the Bluetooth System: Wireless Connections Made Easy. Technical specification. Version 1.1.

[6] Hallberg, J., Nilsson, M. & Synnes, K. (2003) Positioning with Bluetooth. ICT 2003: 10th International Conference on Telecommunications. Vol. 2, 954–958.

[7] Hännikäinen, M., Niemi, M., Hämäläinen, T. & Saarinen, J. (2001) Coexistence of Bluetooth and Wireless LANs. ICT 2001: International Conference on Telecommunications, 117–124.

[8] Kaasinen, E. (2003) User Needs for Location-Aware Mobile Services. Personal and Ubiquitous Computing. Vol. 7, no. 1, 70–79.

[9] Kotanen, A., Hännikäinen, M., Leppäkoski, H. & Hämäläinen T. (2003) Experiments on Local Positioning with Bluetooth. International Conference on Information Technology: Computers and Communications 2003, 297–303.

[10] Munson, J. & Gupta, V. (2002) Location-Based Notification as a General-Purpose Service. International Conference on Mobile Computing and Networking. 2nd International Workshop on Mobile Commerce, 40–44.

[11] Octopus. http://www.mobileforum.org/octopus/ [referenced 22 Oct 2003].

[12] Oiso, H., Kishimoto, M., Takada, Y., Yamazaki, T., Komoda, N. & Masanari, T. (2002) A Bluetooth-based guidance system in-building location estimation method. Applications and Service in Wireless Networks, 141–149. Milford, CT, USA: Kogan Page, Limited.

[13] Ojala T., Korhonen J., Aittola M., Ollila M., Koivumäki T., Tähtinen J. & Karjaluoto H. (2003) SmartRotuaari – Context-aware mobile multimedia services. MUM 2003: 2nd International Conference on Mobile and Ubiquitous Multimedia, 9–18.

[14] Randell, C. & Muller, H. (2000) The Shopping Jacket: Wearable Computing for the Consumer. Personal and Ubiquitous Computing. Vol. 4, no. 4, 241–244.

[15] Ranganathan, A. & Campbell, R. (2002) Advertising in a Pervasive Computing Environment. International Conference on Mobile Computing and Networking. 2nd International Workshop on Mobile Commerce, 10–14.

[16] Schilit, B.N., LaMarca, A., Borriello, G., Griswold, W.G., McDonald, D., Lazowska, E., Balachandran, A., Hong, J. & Iverson, V. (2003) Challenge: Ubiquitous Location-Aware Computing and the "Place Lab" Initiative. WMASH 2003: Wireless Mobile Applications and Services on Wlan Hotspots, 29–35.

[17] Varshney, U. & Vetter, R. (2002) Mobile Commerce: Framework, Applications and Networking Support. Mobile Networks and Applications. Vol. 7, no. 3, 185–198.

[18] WAP Push Architecture Overview. http://www.openmobilealliance.org/ [referenced 22 Oct 2003].

[19] Whitehouse, O. (2003) War Nibbling: Bluetooth Insecurity. http://www.atstake.com/research/reports/acrobat/atstake_war_nibbling.pdf [referenced 22 Oct 2003].

[20] WideRay Jack. http://www.wideray.com/product/hardware.htm [referenced 22 Oct 2003].

[21] Yunos, H., Gao, J. & Shim, S. (2003) Wireless Advertising's Challenges and Opportunities. IEEE Computer. Vol. 36, no. 5, 30–37.