BlueMall: A Bluetooth-based Advertisement System for Commercial Areas

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ABSTRACT

Recently, research for context-aware systems has risen significantly. New social needs require the use of brand new technology to build rich ubiquitous computing spaces. Such spaces allow users to use services without being aware of any interaction with the system. For such an important and dedicated task, some context awareness is needed so computers, based on their environment, can react accordingly. Advertising on mobile devices is one of this new needs and has demonstrated to have a large potential due to the very personal and intimate nature of the devices and the possibility of reaching a broad range of targets. In this paper we present BlueMall, a context-aware pervasive system for advertising in large commercial areas. BlueMall uses Java and Bluetooth wireless technology making it a very portable system. We describe the overall architecture and discuss the implementation steps taken to build our application. To evaluate the performance behavior of our system in relation to the environment, we run some experiments in our testbed in order to receive detailed performance information. Experimental results show that the system provides a viable solution for permission-based mobile advertising.

Index terms - BlueMall, Java, Bluetooth, Ubiquitous computing, Context-aware systems.

1. INTRODUCTION

Mobile communications are one of today's fastest growing markets. In a short amount of time, mobile phones have become multimedia devices and evolved into personal assistants. They are used not only for making phone calls, but also for data services, surfing the Internet and for various multimedia applications. New mobile application domains adapt new paradigms that specifically target the mobile business environment.

In marketing, mobile advertising has two distinct meanings: advertisements moving from place to place, like advertisements displayed on the sides of trucks and buses, and advertisements delivered to mobile devices such as mobile phones and personal digital assistants (PDAs). Advertisers typically use a variety of delivery methods to maximize the number of different adverts displayed, and thus increase their overall exposure to target audiences. In this paper we study the latter, focusing on delivering advertisements to our clients' mobile devices. Sometimes, the term wireless advertising is used to refer to mobile advertising.

Mobile advertisement is a growing area of development. Recently, lots of applications have been developed for mobile devices in a broad range of areas and, in particular, in the advertisement area. Harris Interactive [1], a market research company that specializes in public opinion research using both telephone and surveys on online panels, announced the results of new research into consumer acceptance of mobile phone advertisements. The research examined current levels of consumer interest in mobile phone advertisements, preferred advertising formats and the willingness of consumers to be profiled. According to the study, a surprising 35 percent of adult cell phone users are willing to accept incentive-based advertisements which indicates a potential market to invest in.

Allowing clients to receive controlled advertisements and shopping information in their mobile devices without even making any interaction with the system itself grants them a strong grade of integration with their surroundings. This kind of system is called a pervasive system, also known as ubiquitous computing. Users can profit from pervasive computing environments in many ways: context aware applications may actively react, leading to, for example, information being displayed based on the user's current location. By bringing more and more of these technologies together their potential will rise; yet, the effort to keep these systems running will increase [2].

Usually, an ubiquitous system requires some kind of external information to be able to perform its task properly. Usually, this includes awareness about its surroundings and environment, such as its location and what resources are nearby. This applications gather contextual knowledge about their users and operating environment [3]. Contextual knowledge is typically obtained from time-varying sensory data – in real time and sometimes after making inferences. Equipped with knowledge about the current situation of usage, context-aware applications are able to automatically perform appropriate actions without the user needing to request them

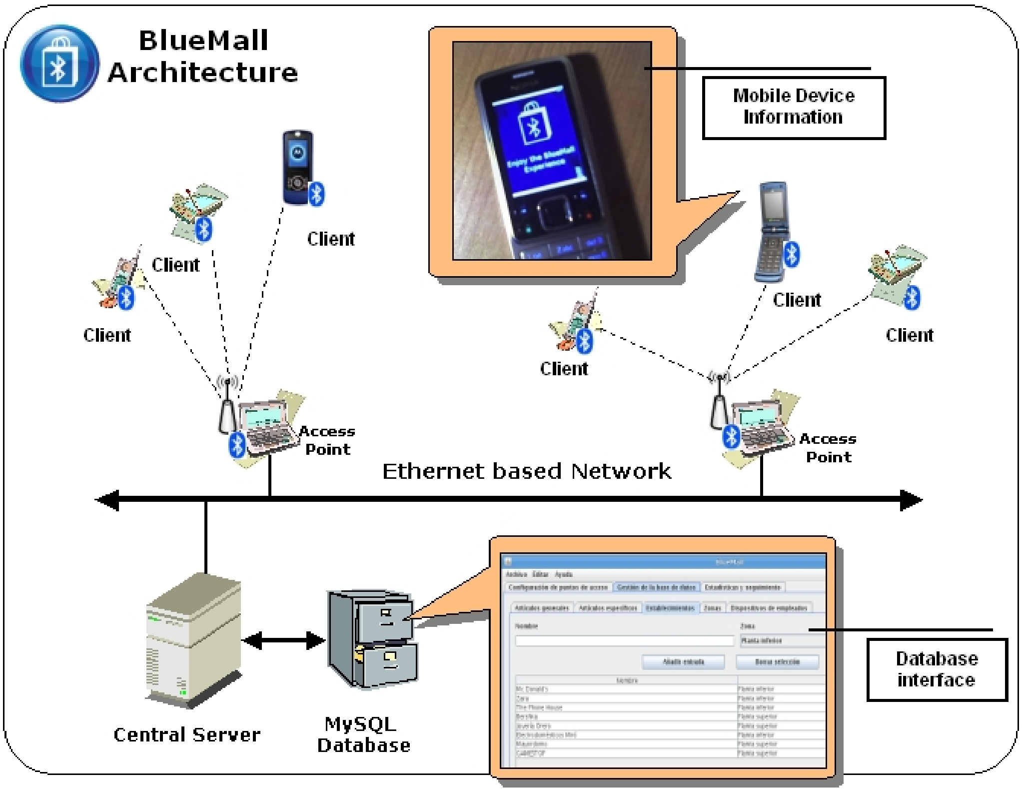

Figure 1: The BlueMall System Architecture.

explicitly. A system with these capabilities can examine the computing environment and react to changes. In such an environment secure issues become extremely important [4].

In this paper we describe the BlueMall system, a pervasive context-aware application for advertising in large commercial areas. The system delivers advertisements and shopping information based on the clients' current location. BlueMall cares about pushing advertisements in a non intrusive way, taking into consideration "what" information was sent to "whom" and "when". This is done to avoid advertise spamming and to turn BlueMall into an user-friendly system; we do not want clients switching off their mobile phones, after all. There are several context-aware applications like BlueMall developed for other areas like museums [5], hospitals [6], other forms of advertisement [7] and even games [8].

Bluetooth [9] is a versatile and flexible short-range wireless networking technology with low power consumption. Bluetooth has the ability to locate close-by devices and discover what type of services they offer. For our application, Bluetooth is the best bet to ensure we reach the maximum number of clients. Nowadays, almost every mobile device comes with Bluetooth integrated so all of them are potential BlueMall's clients. Moreover, using a technique known as spread-spectrum frequency hopping and using low power wireless signals, Bluetooth devices mostly avoid interference with other wireless devices. These are the basic reasons we decided to use Bluetooth as the main wireless technology for BlueMall instead of 802.11. Our prototype allows us not only to confirm the correct behavior of the designed application, but also to acquire experimental data to evaluate the suitability of Bluetooth for advertisement systems.

The rest of this paper is organized as follows: Section 2 describes the overall system architecture. Section 3 presents the details of the implementation prototype. Section 4 illustrates the evaluation of the proposal. Finally, in Section 5, we have some concluding remarks.

2. BLUEMALL SYSTEM ARCHITECTURE

The overall network architecture is based on the cooperation of an edge wireless network and a core wired network. The edge side is solely based on Bluetooth technology used by mobile devices like phones or PDAs. The core network is based on a fixed 100 Mbps Ethernet local area network used to connect the BlueMall edge infrastructure with the central database and file server. We developed both client and server code, providing routines to handle detection of mobile devices, client information gathering and file deliver. To do so, our system employs Bluetooth wireless technology.

Figure 1 shows a schematic representation of BlueMall's system architecture. The system considers three types of software entities: client mobile devices, BlueMall Access Points (APs) and the Central Database and File Server. A customer provided with a Bluetooth enabled mobile device is the basic example of a mobile client. There are several APs scattered all along the mall, and each AP is pre-configured

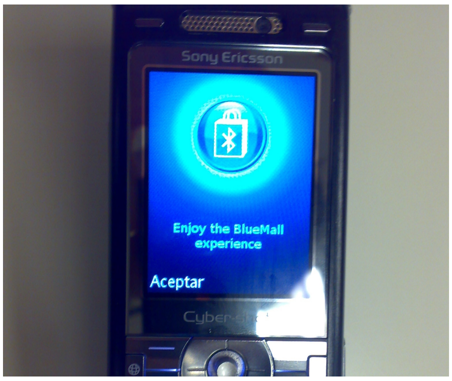

Figure 2: A client receiving BlueMall information.

to serve a different zone or area of the mall, although there can be some APs serving the same zone without disturbing each other.

While wandering around the mall, a client with a Bluetooth enabled mobile device will occasionally become within range of a well-placed AP. When the client's mobile device is spotted by the AP, the latter will contact the Central Server, searching for information about that client. If the client didn't receive some of the advertisements and/or general store information belonging to the zone the AP is serving, our AP will retrieve it from the server and push it to the client. Figure 2 shows a mobile device receiving information from one of our APs.

BlueMall is able to deliver advertisements to customers without requiring any user interaction or any additional device configuration. The system is capable of determining where the client is located by detecting proximity to an AP and sending the specific advertisements based on this information. Advertisements are carefully kept and managed in the Central Server, who controls when an advertisement is outdated or what information is going to be delivered in each mall zone. These advertisements are literally pushed into the client's device, waiting for a final confirmation to be transmitted and stored inside the client's mobile device memory.

Our system is capable of controlling when an advertisement is suitable to be delivered and to whom. If that advertisement was delivered some time ago to the same device, it will not be sent again until the system administrator considers the first message old enough. Having this kind of control makes BlueMall a non-intrusive advertisement application, consequently gaining the clients' indulgence.

When deciding what kind of advertisements we were going to deliver, we encountered two distinct options. To send text files in .txt file format was our first idea but studying the types of mobile devices currently available in the market, we noticed that not all of them, only the most powerful and expensive ones, were capable of dealing with this sort of format. So, a better approach came up. To deliver advertisements in the form of .jpg files. This format is recognised by all the mobile devices a possible client could have so BlueMall can reach a wider range of users. This was without any doubt our better solution.

3. ABOUT THE IMPLEMENTATION

The application was developed using the standard Java APIs for Bluetooth wireless technology (JABWT) proposed by the Java Experts Group JSR-82 [10]. The JABWT standard provides many useful APIs to develop applications using L2CAP and OBEX protocols. In our system, we are using OBEX as the main communication protocol. OBEX is a communications protocol that facilitates the exchange of binary objects between devices, similar in design and function to HTTP in that a client uses a reliable transport to connect to a server and may then request or provide objects.

3.1 The BlueMall APs

BlueMall's APs are located between the Central Server and the clients. First of all, every AP configures itself using a XML file, reading its setup for variables like AP location zone, time elapsed to consider a client's visit like a new visit and server address. In the previous configuration, we set what amount of time this AP can ignore the mobile device until it is considered as a new visit. In our prototype, we have set this period to one day.

When the configuration process concludes, APs start to work. APs can start the Bluetooth inquiry process in search of nearby devices with Bluetooth enabled. When an inquiry procedure finishes, all new discovered devices (because it is a first visit or a long time has elapsed) will be added to the database and/or its last visit updated. Then they will be handled using the OBEX Object Push (0x1105) service. This service is supported by the vast majority of devices and, in an advertisement system where our goal is to reach as many clients as possible, it's our best option. The number of simultaneous service searches supported is determined by the Bluetooth hardware used in our APs. However, notice that specific devices such as the Bluegiga [11] Bluetooth AP could be used in order to support several simultaneous connections.

When the required OBEX Object Push service is found in any of the devices, the database is updated accordingly. In the future, the next time the same device is detected, the system can retrieve related information from the database without performing another unnecessary service search.

When we have a list of all devices fulfilling our requisites and ready to be served, a new process will spawn for each

Algorithm 1 Algorithm for the file transmission.

```
IF (Access Point has file in cache AND that file is recent)
   Send cached file to client;
ELSE {
   Send RequestFileMessage to FileServer;
   Wait for SendFileMessage from FileServer;

   IF (File Not Found)
      RETURN ERROR;
   ELSE IF (File Not Modified)
      Send cached file to client;
   ELSE
      Send received file to client;
}
```

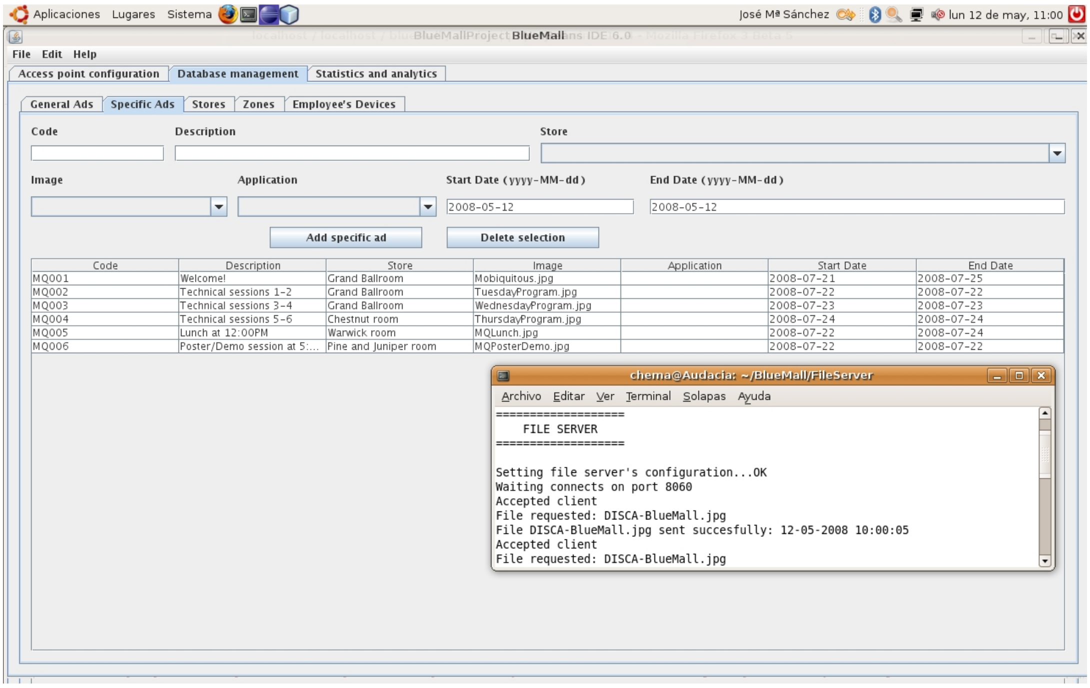

Figure 3: BlueMall's server GUI

device to carry on with the advertisement transmission.

Such process will get the service-route from the database in order to connect with the client. Apart from the service-route, that process will demand to the database all the general advertisements (sent from any AP, no matter what zone belongs) and those specific to the zone the AP is currently serving. All advertisements not sent before to the device will be sent concurrently. For delivery, all APs maintain a local file cache in case they have the file prior to requesting it from the server. Algorithm 1 shows this procedure.

Furthermore, in order to achieve a better performance and efficiency, there is a table in the database with the mobile MACs of employees to ignore them when performing the inquiry and to avoid sending advertisements to them.

3.2 The BlueMall Central Server

BlueMall's Central Server has two main functions: to serve connections and file requests from all the APs along the mall, and to run and manage the SQL database accessed by the APs to consult and modify all the information related to mobile devices and advertisements.

3.2.1 The File Server

The Central Server includes a file server to deal with file requests from BlueMall APs. On startup, the file server configures itself using an XML file. When it's running, it waits for an AP connection request on the default server port, defined as 8060. As soon as a connection request is received, a new server process is spawned to attend it, leaving the main process to continue waiting for new requests.

That process receives the AP message and checks if it corresponds with a standard BlueMall request message or if,

Figure 4: BlueMall's testbed.

otherwise, it must be ignored. If everything is correct, the process can obtain the requested file's name and when was the last modification of that file (in case the AP had a copy in cache).

When all that information is gathered, the server process checks if that file exists in the central server repository. If no such file is found in the server, a message reporting "File not found" is sent back to the AP for it to continue working normally, without sending that file. If that file is in the server, the process verifies wheter that file is newer than the one in the AP by looking into the last modification dates. In case no updating is necessary, a message containing "File not updated" is transmitted to the client AP, informing that the file kept by the latter is suitable to be sent, avoiding unnecessary traffic. However, if the file in the AP is older or the AP does not have such file in cache, a message holding the new file will be dispatched and kept in the AP's cache for future transactions.

3.2.2 The Database

The Central Server stores in an SQL database all the information related to the system. It is based on eleven different tables, containing all kinds of information from mobile devices detected to last visits of customers, mall zones, establishments and advertisements. SQL provides an efficient storage support and maintenance.

To facilitate the control of BlueMall and manage the database and all the advertisement messages ready to be sent to the clients' devices, we have developed a management application. By means of it, the complete management of the BlueMall System becomes very intuitive. Figure 3 shows a snapshot of this GUI.

4. EVALUATION OF BLUEMALL

We evaluated our application using a small testbed to confirm its correct behaviour. In figure 4 we have a small photograph of it where we can see some of the devices employed. We also acquired experimental data to investigate how well Bluetooth supports our pervasive prototype.

Our experiments focused on two different tests to evaluate the inquiry delay and throughput performance of the Bluetooth channel. We performed an analysis to evaluate the impact that the number of nearby devices can affect the inquiry discover delay and time elapsed when many simultaneous devices are handled by our system. Our objective is to keep client delay as low as possible when multiple clients are receiving advertisements near an AP.

The Central File Server and Database runs on an Intel Core 2 CPU 4300 1'8 GHz standard PC based on Ubuntu Linux 8.04. A single AP is running also on this machine. For clients we used a handful of PDAs and mobile phones: a Qtek S200, a Dell Axim X50V and an HP iPaq hx4700, all with Windows Mobile 5.0. Also, a pair of mobile phones - Nokia 6125 and N73 with Symbian OS - were used.

4.1 Inquiry Delay Evaluation

In this section we measure the duration of the inquiry procedure. Figure 5 shows the plot representing the distribution of inquiry delay as a function of the number of devices discovered. During this procedure, we try to detect as many devices that are nearby as possible to later use them as clients and send them our advertisements and all the general information we want to. As we can see, the higher the number of devices, the more time we need to detect them all.

Since none of the devices detected is handled as a client until the inquiry procedure finishes, we are forced to determine a suitable number of devices detectable during the inquiry process. We prefer having five clients receive our advertisements in a timely manner than ten devices detected too late. As we can see, six devices could be a good number. Invest more than ten seconds during the inquiry would be extremely chancy and we could lose possible clients.

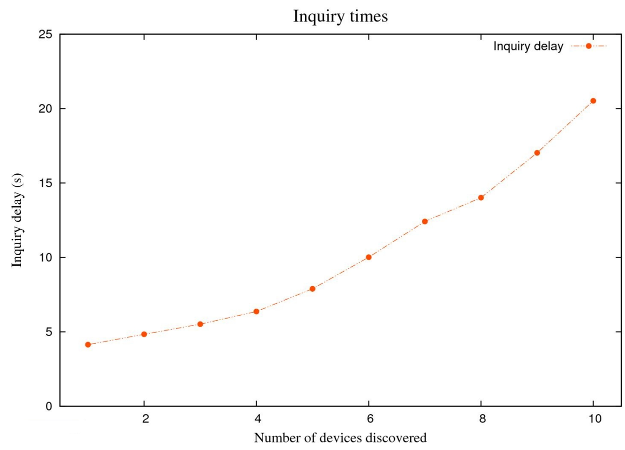

Figure 5: Inquiry delay graph.

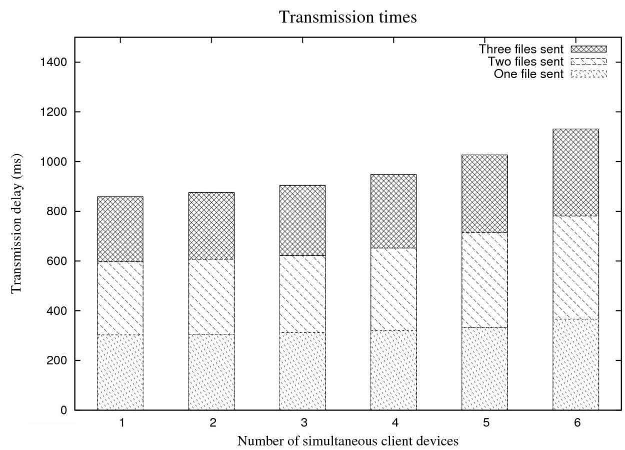

Figure 6: Throughput delay graph.

4.2 Throughput Evaluation

We now measure the impact of throughput by varying the number of devices receiving advertisements of size 10 KBytes simultaneously. We created a test advertisement with the BlueMall's icon specifically of this size in order to ease the study of throughput and to send what we considered it was a standard size for BlueMall's advertisements. We decided to deliver up to three advertisements concurrently to the same device to check how our prototype behaves. Tests with more than three files were not performed in our testbed because we considered than such kind of spamness on the client's device is not desired.

As we could expect, differences are minimal. Figure 6 shows the results obtained during the tests; clients experience similar service times no matter how many other devices are being handled concurrently. The system possess a powerful multithreading procedure able to maintain good performance on this conditions. When the amount of files delivered to the same client rises, time increases slightly; however, this increase is not very significant. As we have appreciated, in all the results we have achieved the time dedicated by one of our clients to receive all the advertisements we sent is, by far, irrelevant.

5. CONCLUSIONS

In this paper we presented BlueMall, our early experimental Bluetooth-based prototype developed in Java that provides context-aware information in the form of advertisements. BlueMall combines the convenience and productivity of Java with the universal connectivity of Bluetooth wireless technology demonstrating that Bluetooth might be a powerful wireless networking technology candidate to support pervasive context-aware applications. Application programming interfaces such as BlueZ and JSR-82, despite being currently under development, can be used to build mobile client and server code efficiently.

The system was designed to constantly deliver advertisements and information to wandering customers according to their location and previous visits. We developed a multi-process based Central Data Server. We built the BlueMall system using both an edge wireless network and a core wired network. The edge is based on the Bluetooth technology alone, while the core network is based on a fixed Ethernet Local Area Network. The edge network integrates one or more client mobile devices. From the BlueMall user's point of view, they are detected and linked to an AP without the user's intervention, and information and advertisements are simply pushed into their Bluetooth devices.

Performance evaluation of the proposed architecture for BlueMall was made with a special emphasis on throughput and inquiry delay, showing that the system performs quite efficiently.

Acknowledgments

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