Final Year Project Report

The Whereabouts Clock

Christine Trant

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BA/BSc (hons) in Computer Science

Supervisor: Graeme Stevenson, Lorcan Coyle, Steve Neely, Aaron Quigley

Moderator: John Dunnion

UCD School of Computer Science and Informatics
College of Engineering Mathematical and Physical Sciences
University College Dublin

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Table of Contents

Abstract

A goal of ubiquitous computing is to integrate computers into our everyday lives without being invasive. This project attempts to display the locations of individuals in an unobtrusive display from sensed real-time location information. This deals with the issue of combining real-time data with unobtrusive displays; real-time data is concerned with privacy while adding real-time data to situated displays is still relatively new. The Whereabouts Clock originally implemented by Microsoft Research is a situated display to show the whereabouts of family or friends. The Whereabouts Clock is used to find the locations of people such as family members and display it in a way that is unobtrusive, similar to the way a clock displays the time. While Microsoft Research use cell towers to track mobile phones, this project used computers with machine IDs and visible wireless devices to track users. The result of this project has been the development of a novel implementation of a Whereabouts Clock to determine and display a user's location. To test the value of the Whereabouts Clock, a user study was carried out over a course of 5 days. The user study found that the Whereabouts Clock was well received and would be a useful application for friends and family.

Acknowledgments

Thank you so much Graeme, Lorcan and Steve, I couldn't have done this without all of your help and ideas!

A big thank you to Microsoft Research - Abigail Sellen, Lorna Brown, Alex Taylor, Tim Regan and Sharam Izadi for taking the time out to talk to us and I really appreciated the ideas given and it made me look at my project closer.

Thank you to Olga, Colin and my family for putting up with me and helping me with the testing section of my project, I really appreciate it!

Chapter 1: **Introduction**

Ubiquitous computing is concerned with integrating computers into people's everyday lives without being obtrusive; a single person could be going about an everyday routine using more than one computer device at the same time without even noticing. Ambient Devices are a form of ubiquitous computing, the main idea behind them being that they are "at-a-glance" technology. They are not meant to be noticed, but they can be seen if required. Mark Weiser felt that ubiquitous computers bring a sense of community into homes and workplaces as people will have more interaction with each other and everyone will feel connected [1].

The Whereabouts Clock is a situated display originally created by Microsoft Research to display the current locations of people, such as family members, and represent the information on a display; it locates people using mobile phone technology. The display is split into 4 sections each one representing a different location such as HOME, SCHOOL, WORK, and OUT which is placed in the centre of the Clock. Each user has their own icon with a picture to distinguish between them and the icon is displayed in the section corresponding to where they currently are, this is seen in Figure 1.1. Below the Clock is a small area where the settings are; there is a pendulum in the middle which represents the signal strength of the GPRS, the left hand side consists of five buttons to alter the brightness while the right hand side has five buttons to adjust the volume.

Figure 1.1: Microsoft Research's Whereabouts Clock

Microsoft Research tested their Clock and displayed it in two different settings - the office and the home. Although the Whereabouts Clock is not a clock, it is called this as it is displays information that is glanceable like a clock whilst being unobtrusive. Sellen et al. gave five

reasons as to why they named it a "Clock" [3];

- It is designed to be used like a clock, to be placed where it can be glanced at with ease and become integrated into a family/office routine.
- It is a device to be used by many people, for example in a home, every family member can see the information displayed.
- The Clock is "always on", like a clock it is "persisting in the periphery of vision."
- It can only be viewed from inside the home and so the only people permitted to view the Clock would be family or friends.
- The information is "coarse-grained", a specific location is not needed.

Microsoft Research's Clock located people using cell tower triangulation to approximate an individual's mobile phone; this project implements a version of the Whereabouts Clock similar to Microsoft Research's but using rather than mobile phone technology, this projects obtains locations via static and mobile devices using device IDs and visible wireless access points. It will also be displayed differently to Microsoft Research's Clock as it is not tangible, this project will all be web based with the Clock running from a website.

While this project is similar to Microsoft Research's, the implementation differs. As the internet is being used to pass users locations this assumes that a user always has access to a computer with internet access to use the Clock. As the project is web-based this means that unlike Microsoft Research's Clock, it is not a remote device, it can be accessed from anywhere. Ultimately, the benefits are the same; users get to see where their friends and family are.

For the purposes of this project, the intended audience is family and friends, and therefore the evaluation was carried out on family and friends. This gave insight into if it suits both or if it is not suitable for either set. The intended audience was chosen because from the Microsoft trials it showed that a family Clock was successful and it had not yet been tested to see how groups of friends felt about the Clock. From the evaluation it was shown that the Clock, like Microsoft Research's, was a success. It became clear that a web-based Clock appealed more to the younger generation of participants and thought of as glanceable while the older participants did not consider it to be at-a-glance but did enjoy the idea of a Whereabouts Clock. The older participants had trouble understanding the technical side such as finding their Machine ID and the name of their Bluetooth devices, this became a problem at the beginning of the trial and time had to be set aside to explain the technicalities in more detail than was first anticipated.

The original Project Specification is outlined below. The Whereabouts Clock is a situated display originally created by Microsoft Research; this along with the field of ubiquitous computing is dealt with in Chapter 2. The Whereabouts Clock system is illustrated in Chapter 3 in which the initial approach is described. The implementation is discussed further in detail in Chapter 4. Testing was carried out on the author's family for five days, the results are discussed in Chapter 5 and it is shown that the system works. The Clocks uses are also evaluated in this chapter. Conclusions about the whole project and how it was carried out are discussed in Chapter 6 also outlining work that could be carried out on this project in the future.

A blog [1] has been published for this project and regularly updated as the project has progressed.

[1] The project blog is available here: http://ctrant.blogspot.com

1.1 Project Specification

In the field of Pervasive Computing, the term "calm technology" is used to describe the goal that users should not be consciously aware they are using technology when interacting with computationally-enhanced devices. One example of calm technology is the class of Ambient Information Systems - systems designed to provide useful information while blending smoothly into their surroundings.

One of the interesting research projects in this area is Microsoft's "Whereabouts Clock", a situated display for the family home that visualises the general whereabouts of family members through use of a clock metaphor. Cell tower data transmitted from mobile phones using SMS is used to deduce the location of family members (one of HOME, WORK, SCHOOL, or UNKNOWN). The clock is a communal display that makes this information available to anybody in the family home and is perceivable at a glance.

This project seeks to emulate the functionality of the Whereabouts Clock using alternative sources of information to deduce user's locations (namely the identities of visible wireless access points (for mobile devices), and MAC addresses (for static devices). Sufficiently capable students are encouraged to extend the project to incorporate other possible sources of information.

Mandatory Milestones:

- Database Design
- Design a front-end to the database that will allow users to:
  - Authenticate
  - post new 'sightings' to the database
- Build the client application
- Algorithm for "locating users"
- Build the Whereabouts Clock

Discretionary Milestones:

- Augment the display with status messages
- Develop of a web interface to the clock
- Extend the client application

Exceptional Milestones: An exceptional project should complete at least one of the following in addition to the above.

- Implement of at least two alternative "views" on the display
- Build a web-based interface for creating customised clocks
- Additional means of inferring a user's location
- Carry out a user study of the clock

Chapter 2: **Background Research**

This chapter discusses *Ubiquitous Computing*. Weiser introduces the term of ubiquitous computing and is known as the "father of this field". The concept of ambient devices is discussed, while the core of the background research follows a few of the technologies in that field. The core of the background research follows a number of papers written by Microsoft researchers during the development of their Whereabouts Clock. The chapter concludes with a discussion of the related work as it relates to this project.

2.1 Ubiquitous Computing

Mark Weiser's *The Computer for the 21st Century* [1] is seminal in the field of ubiquitous computing. In it he asked us to consider ubiquitous computers, i.e., computers so tightly integrated with everyday objects that we do not consider ourselves to be using "a computer" on a conscious level. Weiser's opinion was that traditional desktop and laptop computers got in the way, instead he wanted computers to be an "integral, invisible part of the way people live their lives". Weiser discussed the integration of laptops into our everyday lives but was aware that a "single box" is still in the way and not "invisible".

Figure 2.1: Palo Alto Research Center's (PARC) liveboard[1]

Weiser saw the integration of computers into our everyday routine as the goal, and described three early lab prototypes he had developed with researchers as Xerox Parc - *tabs, pads, and boards*. Tabs are effectively "active Post-It notes"; 'Pads" are the same as tabs but bigger, they are similar to an A4 sheet of paper. "liveboards" as seen in Figure 2.1 are electronic blackboards which are useful for when a conference is being held in two different locations,

[1]Picture obtained from http://dictionary.zdnet.com on 04/03/08

much like video conferencing. Both places have a liveboard displaying the same information, and if someone were to write additional material on the board with the electronic chalk it would also be displayed in both locations. These liveboards can also be used as bulletin boards with the added benefit of the bulletins being specific to an individuals needs. All the user needs is an *active badge* which allows the user to be uniquely identified usually using infra-red signals [1], for example, a college student interested in sports may be shown bulletins relating to the college sports events while another student may be shown upcoming concerts scheduled in the college.

Weiser concludes by saying that ubiquitous computers will bring a sense of community into workplaces as workers will have more interaction with each other. In field trials run by Microsoft Research for the Whereabouts Clock [3, 4] this prediction appears to be realised.

2.2 Ambient Devices

Taylor et al. encouraged the idea that computers should be thought of as "a resource for intelligence" [2]. They want to "augment and support" life, enhance it rather than change the way people go about their daily routines. The paper made a good point about this type of technology only benefiting people who really need it, (i.e., the elderly or disabled), and that people who do not have a need for it might not see the point. The paper describes *HomeNotes*, electronic note pads which are similar to Weiser's tabs [1]. Notes are meant to be intrusive; their only purpose is to be noticed so it is important where they are placed. HomeNotes are a tablet computer which has a SIM card and GPRS in it so people outside the home can communicate via SMS. It was tested and the results showed that people felt they had a presence in the home even when they were not there.

Ambient Devices specialise in designing products in the ambient computing field. One of their products is the Ambient Orb, it is a glass ball that glows and changes colours to represent different real time occurrences such as the weather, traffic congestion and stock market trends[2].

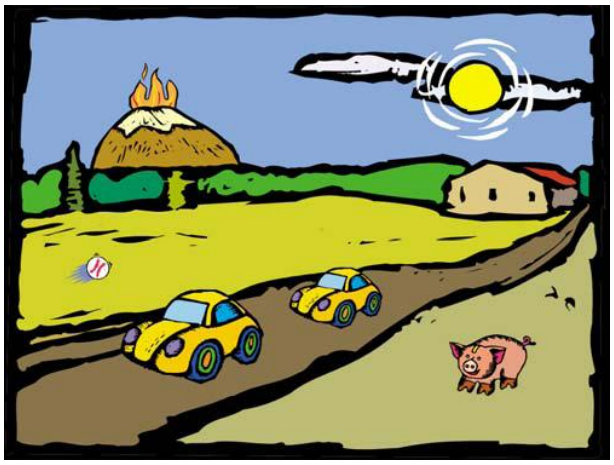

Figure 2.2: An example of the InfoCanvas

InfoCanvas is an example of an ambient display. It is a "pictorial representation of a variety of information sources" that is designed to manage the ever increasing information that is

[2]More information about this company and its products can be found at: http://www.ambientdevices.com

available on the web such as weather forecasts or traffic news. From Figure 2.2 it can be seen that there are objects such as a car to represent a specific piece of information, "A piggy bank could expand or contract in size as their bank account balance changes". It is a personalised display designed to be used much like a picture in a frame or a painting on a wall. A web interface is used so that people can choose what information they would like to be displayed on the *InfoCanvas*, there is also the option to choose how the information is visualised. This ambient data is called "peripheral awareness information". There is a need for devices like *InfoCanvas* as people have a need to find out the weather forecast or what the traffic will be like but sometimes obtaining this information can be time consuming [7].

Another clock based project is the Millennium Clock Digital Message Board. It is not used for location but for displaying information to a town community in Niagara Falls. The Millennium Clock Digital Message Board consists of a clock with two digital message boards [6] used to display events and anything relating to the town. Some advantages are that it is free of charge to place these bulletins up on the clock and it gives a sense of a close community.

2.3 The Whereabouts Clock

Figure 2.3: The Whereabouts Clock from the Harry Potter films

Sellen et al. described the first implementation of the Whereabouts Clock [3]. The Whereabouts Clock is a device that gets the location of people through mobile phone technology and shows it on a clock-like display, in this case using a 19 inch LCD touch screen. It obtains locations by locating a users mobile phone through cell towers and associates this with a registered address such as HOME, SCHOOL, WORK or OUT. The device is motivated by a customer's desire to have peace of mind in knowing where their workers or family members are, a "sense of reassurance" [3]. The Harry Potter novels by J.K. Rowling are credited with the concept of a clock that displays where people are, although there are differences: the Whereabouts Clock uses icons rather than hands pointing to the people and of course the obvious one of relying "on technology rather than wizardry to make the Clock work"! The

Clock from the Harry Potter films is pictured in Figure 2.3.

The Whereabouts Clock is described as having "persistent availability" [2], it is not a necessity in the home but it is there if it is needed, it is unobtrusive, "at-a-glance" technology.

The Clock design is simple to keep in with the style of unobtrusiveness as seen in Figure 1.1. The Clock has a few features that are creative: the "pendulum" [4] located below the Clock in a hidden settings panel that is animated to show the signal strength, and the Clock chimes whenever someone moves location.

The early field trial that was carried out had very encouraging results; it is useful that it was tested early on as Sellen et al. got an idea if it was useful or if anyone even used it. Fourteen people were involved in the trial and the feedback gained would be more than sufficient to get an idea of the need for this Clock. In the office trial it was beneficial, for example, if a person were working at home or in a meeting, not everyone need be told individually; it is right there displayed on the Clock.

The volunteers described the "wonder" of the Clock and it was also described as "visual enchantment" [3]. This sums up the entire idea of the Clock and why it would be well received - it is almost magical. The location was not the only important issue brought up by the volunteers; where someone is going next, what they are doing and why seemed to be significant at times. This makes the Clock not just about location but making a person more real, that person is in a family member or work colleague's personal life.

The drawbacks the field trial came up with were that sometimes people wanted to convey more, for example if an individual's computer was not working or they'd be in the office after lunch, a location was not enough. This problem was addressed by the inclusion of a touch screen in time for the next trial; to get additional information, a person's icon would be pressed and a new window popped up. The researchers recognise that the inclusion of a touch screen to find out more information about an individual makes it less "clock" like. This trial was for office use, the next trial took place in the home. Overall the researchers seemed to find no negative areas only constructive criticism and room for improvement.

Sellen et al. mention the Whereabouts Clock as "privacy preserving" given the fact that the locations are so vague and "coarse-grained" [4]. The Clock designers went on the basis that "less is more"; the user only needs to know who the person is and where they are. There are only limited applications in this field possibly because it is not yet delivering "compelling value for [the] user". As mentioned in [1, 2], the Whereabouts Clock was tested on five families consisting of 26 people in total over a period of six months. The Clock provided reassurance, it was used for telling family members what they "already know". The location awareness also meant that people knew if someone was not where they were supposed to be and this would prompt action such as a phone call to check if everything was fine.

The Clock brings location based services and situated displays together. Location based services are preoccupied with privacy issues involving tracking, and situated displays which do not usually have "real-time data". It becomes "part of the routine of life", the same as a regular clock and it is not "stirring for accuracy or completeness" it is just giving a broad location. There is only the need to register a location such as SCHOOL [4] once, although the option to re-register is available.

From the field trials, participants said that they had more of a sense of togetherness, much like the trial done by Microsoft Research in the office [3]. People adapted to the Clock and used it in different ways, if no one in the family went to school, that location came to mean something different and all the family knew what it meant. From the Microsoft Research trials it was noted that people liked to dim the Clock as it became darker in the evenings and families with small children appreciated the volume adjuster as sometimes the noises could

be too much. Participants identified a requirement to be able to change the labels which was addressed later on in the paper.

Overall the Clock showed more than "just co-ordination and awareness" but also "reassurance, connectedness, expression of identity and social touch" [4]. The Clock was not seen as an invasion of privacy as it was just showing and confirming what people already knew. People adapted and did more than was expected by the researchers. The two trials carried out gave a good indication of what the Clock tests for this project should be like.

A trip was organised for the author and one of the supervisors to visit Microsoft Research in Cambridge. This was an opportunity to meet the researchers who worked on the Whereabouts Clock and to view a demonstration of the Clock. The differences between Microsoft Research's project and this one were discussed with the main differences being the technology used to locate people and the method of displaying this information. The researchers felt this was defeating the purpose of the Clock being at-a-glance but with the intended audience slightly different, a web-based application worked as shown in the user study.

Figure 2.4: Christine Trant and Lorcan Coyle at Microsoft Research

The author and supervisor had the opportunity to see the original Whereabouts Clock and were shown a demo of it. There were a few icons on the Clock representing a family and when an icon was pressed a new display popped up showing text messages that had been sent with the most recent being on top and you could scroll through these messages. One of the icons represented a child who would be too young to take part but when pushed the icon would make a sound and do random animations e.g., the icon would turn into a flower. Also when someone changed location the clock would make a noise. It was a beneficial trip as ideas were given especially regarding future work. Figure 2.4 shows the author and supervisor Lorcan Coyle with Microsoft Research's Whereabouts Clock.

2.4 Conclusions

Weiser wanted computers to mimic and replace everyday objects and to work together, for instance paper will beep if it is mislaid or a file cabinet will open with the file that is being searched for – it will have found the file for the user. He mentions cost as an issue but thought that a standard screen will be very cheap in the next few years so it will not be a

huge problem. He wrote this paper in the 1990s and this is what is holding the idea back, computers and screens are not quite that affordable yet.

Computers are related to stress a lot of the time, whereas if they are less intrusive people will not make that connection. This paper and its ideas relate to this project as the Whereabouts Clock is a computer but so integrated into normal life and this is exactly what Weiser describes if only a small step into the world envisaged.

Privacy is a large concern in the field of location based services, as mentioned by Weiser; he recognised that in the wrong hands these ubiquitous computers such as active badges could have adverse effects, exposing personal data. But using *cryptographic techniques* [2], a form of digital fingerprint would be left and could then be traced [1]. The researchers came to the conclusion that as the Clock is in a home, anyone who sees it will more than likely be a family member or close friend. Also the vagueness of a location such as WORK, HOME or SCHOOL alleviates this problem even more. Privacy is clearly a big issue in *location awareness* as mentioned by LaMarca et al. [5]. They realise that individuals and corporations have the concerns about being tracked or people trying to steal network access from them and so would not want to broadcast their location.

The Whereabouts Clock had a feature where peoples faces appeared to be "fading" [3] on the display when they were out of range or had the application switched off and when they were using the application their faces would "appear bright and also animated (appearing to float slightly)". Another feature was the touch screen, although a touch screen takes away from the notion of a clock, it is a good feature and its uses can be seen. The Whereabouts Clock also used icons for family members even if they were too young or just did not have a mobile phone; the icon would animate or make noises when touched. This was interesting, as it allowed younger children to feel included. It would be interesting to give the choice of different background colours to match people's décor or their personalities. This would make the Clock even more integrated in the home. The casing for the Clock could also be changeable, this could be a big seller especially for younger family members.

The message that can be learnt from Microsoft Research's office trial is that as the Clock is well received there may not be a need to test on such a substantial amount of people. The test subjects did not pay for services such as SMS, this project did all the work in locating them all they needed was to have a computer on and the project program running. This made the testing simpler as we already know that the Clock is a success so we primarily tested to see if a web-based Clock was as popular as a Clock in the home.

Across all the Microsoft Research trials, the tests found that the Clock was accepted and more than that it integrated into the home and the office with an easy transition. The office findings found the limitation of wanting more information to be conveyed and this was addressed in time for the home trials where a touch screen with the option of receiving text messages was included. Families adapted and changed the way the Clock was first anticipated to be used, such as sending sentimental messages rather than just stating where they were. People would anticipate the next move, for example, if someone moved to HOME on the Clock, a family member would boil the kettle just in time for their arrival. Families interpreted the Clock differently and each made it their own, fitting into their daily routine and this is exactly what Weiser envisaged. It is a strong possibility that the types of technologies mentioned will be integrating into our homes very soon; they are a very useful tool to have.

Chapter 3: **Problem Analysis**

3.1 Whereabouts Clock Comparison

There are two main differences with Microsoft Research's project and this project, the first is how people are being located; Microsoft Research's project used mobile phones with SMS while this project will use laptops to obtain MAC addresses or the nearest wireless access point depending on whether the person is in one place or in transit. MAC addresses would be used in the situation when a computer is only used in one place and never moved, for instance, a PC in the home. Visible access points are necessary for the other situations when one computer may not be in the same place, for example, a student with a laptop would use this laptop in college and at home. Using two methods to obtain a location has the advantage that it accounts for situations where a user may have a laptop in different locations. Disadvantages of using this method is that the range to obtain wireless access points may not be large enough, and a registered location could quickly become out of range. When using MAC addresses this brings up a different disadvantage that it is a slightly more technical way of obtaining a user's location and the user has to know what a MAC address is in order to register.

The second difference is where the Whereabouts Clock is displayed; Microsoft Research designed their Clock for the purpose of being inside a family home or office, while this Clock is an applet running on a web page on the internet. A web-based Clock was chosen to open up the range of people that could use this Clock, so far the Clock had been designed for use in the office or in the home. A web-based Clock enables friends to get involved and it can be used for close groups of people who don't necessarily work or live together.

As this project is web-based the social aspect is different to Microsoft Research's Clock, this project strays even more from the original metaphor of being a "Clock" as it is no longer glanceable; the user has to actively bring up the web page with the Clock application. It is still persistent availability as anything on the internet is always there whenever you want it. The assumption that user's will always have access to a computer with internet access is valid in this case as all of the user study participants had access to a computer in each location they were in. This assumption is not true of everyone, for example people's routines do not always involve being near a computer but it is fast becoming a true assumption to make regarding the future.

There were visible advantages and disadvantages of this project against Microsoft Research's before the project evaluation was carried out. A web-based Clock is not at-a-glance as mentioned by the Microsoft Researchers, this is a disadvantage in one respect but as found in the user study it was glanceable for some of the participants. As it is a web-based Clock, this is an advantage in some respects as more people can access the Clock, not just people that live together. This widens the community the Clock can create, as it no longer applies only to single families, friends can also be included as part of an "extended family". When obtaining locations of users, the method taken by Microsoft is more advantageous as they use mobile phone technology and almost everyone these days owns a mobile phone, the same cannot yet be said for computers although it is fast catching up in today's society.

The idea of the Whereabouts Clock straying from the original idea of being like a "clock" as it is web-based was a concern at first and it was evaluated in the user study to see if people used it much like they would use a clock.

These advantages and disadvantages were explored throughout the duration of the project, especially when the user study was carried out.

3.2 Design

Before starting the project, an approach to the design of the Clock first needed to be put in place. Making the project web-based meant that the technology options were scaled down and it was easier to make a decision relating to how each component would be carried out.

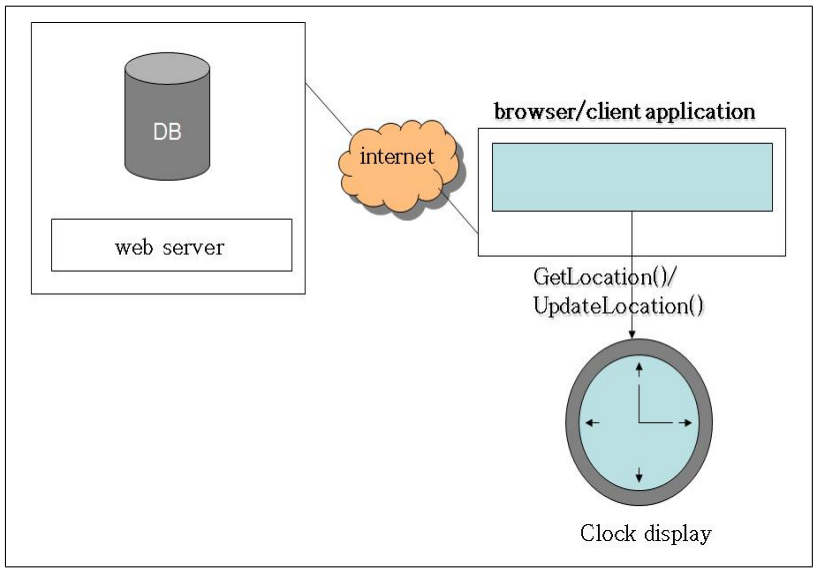

Figure 3.1: General System Architecture Diagram

An initial architecture diagram was created to generally visualise the overall Clock and break it down into three components: the back-end of the application, the client application, and the Clock display. Figure 3.1 represents these three components.

The back-end of the application requires a programming language that is capable of interacting with a database and enables server-side programming which will involve queries. The database is in the background to store the necessary information about users and their locations. The web server enables the query component to access the database to store and retrieve information.

The Clock must be designed with a language capable of retrieving information about users' locations and graphically displaying this information. It is also important that this graphic technology integrates easily with a web page as this is where it needs to be run from.

The client application must be written in a programming language where there is support for getting MAC addresses and device names of visible access points. As it needs to communicate with a web server, there must be support for network programming, preferably with support for the HTTP protocol. This application is designed to run on a range of mobile and static devices and most mobile devices have support for Java Virtual Machines (JVM).

Chapter 4: **Detailed Design and Implementation**

The high level architecture as shown in Chapter 3 is discussed in more low-level detail in this chapter. This chapter deals with what technologies were needed to carry out the project these chosen technologies are justified. Bluetooth is discussed stating why it was chosen against Wireless Access Points. The main system architecture components are discussed individually in low-level detail describing what each part of the system does and how it is all connected. The system is then evaluated against what was set out in the project specification.

4.1 System Architecture and Technology

The goal of this project is to develop a display that shows the location of specific people. The technologies that are used are: WAMP, PHP, SQL, Java, Processing and Bluetooth.

The overall system can be seen in Figure 4.1, this shows all the necessary components required to create and run the Whereabouts Clock. WAMP is the back-end of the system which consists of a database to stores the necessary data, a web server to access the database and enable other parts of the project to access it and a web page which contains PHP pages to enable queries. Java Code is used as a bridge between users and the back-end to obtain the MAC and visible Bluetooth device names. The user only has interaction with the web page and the computers they are on; the clock display is shown through the web page.

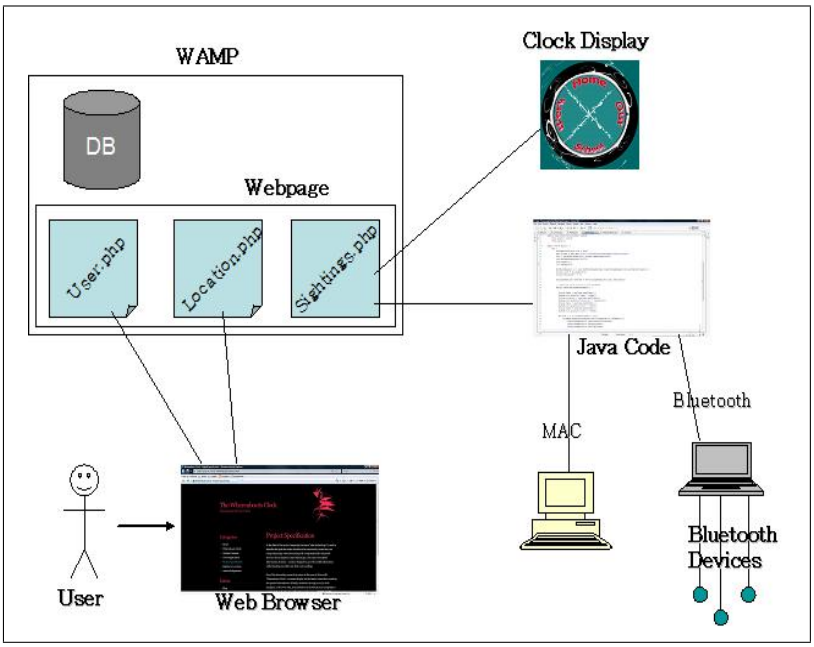

Figure 4.1: Whereabouts Clock System Architecture Diagram

WAMP [1] is an open source tool which is ideal for this project as it is designed for the purpose of rapidly making web applications with little configuration. WAMP is used as it encapsulates

[1]The WAMP website can be found at http://www.wampserver.com/en/

everything needed to run a server with a database; Apache, PHP and MySQL. Apache is the web server, PHP is a programming language mainly used for use with accessing databases in conjunction with web pages, and MySQL is a database manager which works very well with PHP - PHP accesses the server and the database through SQL. The MySQL database is used to store all the necessary information about each individual. PHP was chosen over similar technologies as it is tightly integrated with MySQL and it handles web requests efficiently.

The web interface incorporates a web page which has three forms, one for a user to register their name and assign a user name, one to register a location with a specific address and another to add an additional status. There is another PHP page, Sightings.php, which gets the current locations of users.

Java is a high level programming language, this language was chosen as it is platform independent, many mobile devices have JVM support and it is a strong language for running internet based interactive applications. Using the HTTPClient library it is possible to access the server via PHP pages and the java.net library is used to get and store the MAC addresses and visible wireless access points of user's devices. While Java is not as fast as alternative languages such as C, when weighing up what was needed from a programming language Java is more portable and has an extensive range of libraries which were needed to run this application.

Processing [2] is a programming language that is defined for the purpose of graphics and is ideal for visual interactions. As it is a form of Java it will fit in with the client application and this also deals with accessing the database as Java is able to do this. Java applets are popular in web pages so Processing will integrate into a web page quite well. It also can be used with Eclipse which makes it better than using separate IDEs. Processing is used to get the information of users locations and display it on a GUI.

4.2 Wireless Access Points To Bluetooth

In the Project Specification it was originally said that visible Wireless Access Points would be used to obtain the locations of mobile devices. Over the course of this project, this specification was altered and instead of obtaining wireless access points it was decided that Bluetooth would be used to obtain Bluetooth devices as it made more sense when it came to testing and for demonstration purposes. While Bluetooth was not the original option, the method used is identical to the method that would have been used to obtain wireless access points; Bluetooth is ultimately imitating wireless access points. This has proven very useful for testing as mobile phones can be included in the list of devices and each phone could represent a different location. For example, when testing, two mobile phones were used; one had a registered location of HOME, while the other had a registered location of SCHOOL, Bluetooth was active on only one mobile phone and this was represented on the Clock display, then the Bluetooth was made available on the second mobile phone and deactivated on the first and the display showed the user moving from HOME to SCHOOL on the Clock display.

[2]The Processing website can be found at http://processing.org/

4.3 System Architecture Components

4.3.1 Back-end

From Figure 4.1 it is shown that WAMP encapsulates the database, the web pages and the necessary PHP pages. In the diagram there are three PHP pages: User.php which is used to register a user with a corresponding username; Location.php which is used to register a user with a corresponding address to one of the three locations given - HOME, SCHOOL or WORK, this also represents the PHP page btLocation.php which is used to store a user's Bluetooth device name with a corresponding address; Sightings.php and btSightings are used to get relevant information about a user's current location. While Users.php, Location.php and btLocation.php obtain the information by a user inputting the information through the web page, it can be seen that Sightings.php (as well as btSightings.php) obtain their information via the Java code in place - Connect.java. A user can only register three locations as the fourth location, OUT, is the default location for when no location has been registered.

The back-end of the system contains a database that stores information in 6 tables, Users, Location, btLocation, Sightings, btSightings and Status; Users - stores personal details for users, Location - associates a location with the corresponding MAC address, Location - associates a location with the corresponding Bluetooth Device Name, Sightings - logs the time that a user changes their location using a static device and btSightings - logs the time that a user changes their location using a mobile device, Status was added after the user study; this is where a user can give a status message. This is only related to Users as it is used for an additional feature of the Whereabouts Clock. Querying a combination of these tables generates user "sightings" This satisfies the requirement of locating users in the project specification. An Entity-Relationship diagram is shown in Figure 4.2 to help visualise the database design.

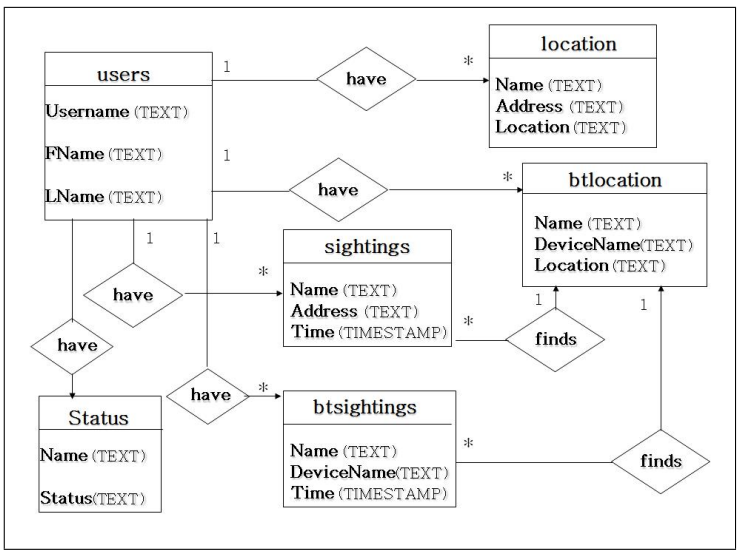

Figure 4.2: Entity-Relationship Diagram showing the Database Design

Users has six fields: ID, Username, FirstName, LastName, email address and password. This table is used to register users, the user selects a username to distinguish them from others, and this is specific to them in the case that two people may have the same name. They need a password as there is a login page, this password is encrypted when sent to the database.

Location has three fields: Name, Address, and Location. Name is the username which corresponds to Name in Sightings and Username in Users. Address refers to the MAC address of the static address of a user's computer; this is the same as Address in Sightings. Location

is the place name corresponding to the MAC address in this table, it is one of three options; HOME, SCHOOL or WORK.

btLocation also has three fields: Name, DeviceName, and Location. Everything is the same as Locaton except for the field DeviceName in place of Address. DeviceName refers to the ID of the wireless device with Bluetooth.

Sightings has three fields: Name, Address, and Time. Name and Address are the same as the fields in the Location table with the addition of time. Every time a record is updated it is given a unique timestamp, this is for getting the most recent location from a user.

btSightings also has three fields: Name, DeviceName, and Time. Name and DeviceName are the same as the fields in the btLocation table with the addition of time, the same as in Sightings.

Status has two fields: Name and Status. Name corresponds to Username in Users and Status holds information when a user wants to convey more about what they are doing.

To test that the database and the PHP components were working, test data was used to input data and then retrieve the necessary parts of that data. This involved querying several tables, selecting data and combining these into one output on a PHP page.

A PHP page retrieves information from the database via the server and displays a user's location and what time they were last seen at. Bluetooth is a specification that can pass any kind of information wirelessly over short ranges and will be used to find users locations on laptops for instance. It also gets the user name which satisfies the mandatory milestone development of an application that will run on a user's computer and transmit the identities of currently visible access points (or the MAC address if not wireless) to a server.

To get a users current location SQL is used in a PHP query. The information in the database table Sightings is compared to the latest location given and if it is different, then the location is changed using the UPDATE statement, and the icon on the display will move to the right location on the Clock display.

4.3.2 Client Application

The client application is the part of the system that obtains information from the user such as their user name and location. This is executed through a DOS Batch file, Clock.bat where the user enters their username, they are then asked what type of connection they have as seen in Figure 4.3. Their corresponding MAC address or Bluetooth device name is then obtained along with the current time.

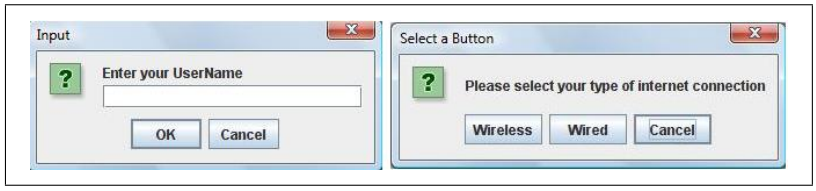

Figure 4.3: The Client Application Interface

There is Java code implemented which automatically obtains a user's MAC address or available Bluetooth device names and places it in the database with the aid of PHP using the Apache HTTPClient libraries. A Bluetooth library BlueCove was also required to carry out a Bluetooth device search.

Figure 4.4: Web Page for a user to register a location

There is a web page which enables the user to register their location and/or user name if they are not yet registered. An example of the layout is shown in Figure 4.4. There is also a web page so a user can add status updates and say what they are doing or give more information on where they are. The Clock interface has been designed and has been implemented to talk to the database and retrieve information through Java to update locations on the actual display.

4.3.3 Clock Display

Figure 4.5: The Whereabouts Clock showing icons switching locations

The Clock interface has been designed and was incorporated into the overall project using Processing. Whenever an update takes place the user icon will move to its relevant location, i.e., Christine is displayed as being at WORK and everyone else is OUT as seen in Figure 4.5's left picture. Looking at Figure 4.5's right picture, we can see that Christine and Peter have moved and are currently at HOME.

Processing is given the information and displays the icon relating to a person in the correct location. If the user's location has changed since the last update then their icon will move across the display to the new location. This covers the build of the Whereabouts Clock

milestone in the mandatory section.

Figure 4.6: The Status Button on the Clock display

When obtaining feedback from the user study it was mentioned that more information sometimes wanted to be shared. The addition of a status update was incorporated into the Clock design as a button on the top left, see Figure 4.6.

4.4 Development Tools

A Working environment was set up before the project could begin. Project management software was needed as was Version Control. GoogleCode was chosen for this as opposed to GForge or similar management software as it has been used on previous projects; it also incorporates a subversion repository in order to back up any work done.

The programming environment used when programming in Java or Processing was Eclipse IDE, mainly because both languages can be used together in this IDE and the author was familiar with this IDE over any others. Dreamweaver was used when programming html, PHP and SQL because the author has experience with using it over any other software.

4.5 Conclusion

The final Clock consisted of all the initial components needed as set out in the Project specification. This consisted of designing a database, creating the necessary tables and considering what information needed to be stored.

A front-end to the database was required which allowed users to add their current locations to the database. A user could enter their username and corresponding MAC address or Bluetooth device name manually through the web page or they could run the client application which asked for their username and then obtained their MAC address or Bluetooth device name and stored it in the database automatically. The manual update feature was removed after the trials found that most paricipants did not use this and some of the participants got confused as they were unsure if they had to update manually and have the program running

at the same time.

An algorithm was implemented to query for users locations and this would get the most recent sighting and print it on a PHP page as text. The build of the Whereabouts Clock was then incorporated into this algorithm so that the Clock would display a user's current sighting.

Additional tasks were also given, one of these being the development of a web interface to the Clock. As the entire project became a web-based project, this task was automatically completed. Another additional task was to augment the display to show status messages, this has been implemented so that when the status update button is pressed it shows what everyone is doing, it also meets the requirement of an alternative view to the Clock.

Exceptional tasks were outlined, one of these being a user study which was carried out and evaluated. This was necessary to do as it would highlight the strengths and weaknesses of the project and would give ideas that could possibly be included in future work.

Chapter 5: **Evaluation**

This chapter describes the user study undertaken during this project, detailing the strengths and weaknesses of the results given. These results are compared against the issues raised in Chapter 3 against Microsoft Research's trials. The strengths and weaknesses of the whole project are then considered.

5.1 Testing

As mentioned in Chapter 2, the Microsoft Research field trial in the home was tested over a period of six months with five families and it was well received by the families. With this information in mind, the testing for this project was carried out on the author's family and friends totalling six people; three of the volunteers were friends aged 22, 23 and 25, the mother, an accountant and the father, a teacher were both aged 54 and the brother of the author was a 19 year old student. The three friends were all students in the Computer Science field as was the brother of the author. All of the volunteers were familiar with using the web and did so regularly. The trial was carried out over a period of five days.

The user study was carried out with the aim of finding out if the results differed to Microsoft Research's and if a web-based Clock had the same appeal to users as a tangible clock in the home.

Each volunteer was given an executable program which would get their user name and their location address; this would update every two minutes to check that the user hadn't gone offline or moved locations. It updated just to check the location, if the location was different the icon would move to the corresponding location on the Clock display, if the location was the same it would do nothing.

To view the Clock the participants had to first register their user name on the web page, and register specific locations. Instructions were given on each web page detailing how to find a MAC address or Bluetooth device name. The participants would then be able to view the Clock and see their icon along with the other registered participants.

At the end of the trial the participants were given a questionnaire to give their feedback on the Clock. This was important as it would highlight any future work that could be carried out and as it is a web application and not a "clock" in the home it was unsure whether this Clock would be as popular as Microsoft Research's version.

The questionnaire consisted of the following questions:

- Did you like the Clock display?
- What features did you like about the Clock and what would you change?
- What features would you like to have had that was not available?
- Did you like the Clock in a web page or would you have preferred it to be on its own?

- Would you use this Clock regularly?

5.1.1 Results

Overall the feedback was good. There was some confusion at first for the two older members of the family as they did not know what a MAC address was so they didn't understand what to look for when given the instructions, and they did not know how to find out the name of their Bluetooth device but once it was explained step by step how to do it, they enjoyed using the Clock.

When the participants were asked about the Clock display, everyone said that they liked it and the option to customise it was only mentioned by the youngest participant.

All of the participants said they liked that the Clock was not just for family but that friends could be involved too; this was less restrictive than Microsoft Research's Clock as it allowed more than one social group to be a part of the Clock.

When asked if they would have liked more features, four of the participants said they would have liked to see more. They would have liked to view what a person was doing and to say what they were doing, they also would have liked to contact each other through the web page or leave a comment much like a social networking site. Since the user study a Status page has been implemented where users can say what they are doing and see other people's status.

When asked about the Clock being incorporated into a web page, everyone said that they would have liked an option for the Clock to pop out from the web page and be a stand alone application as they would have liked the Clock on its own and the two oldest participants commented that they would have liked to have the Clock as a tangible Clock, something they could have in their home.

Comparing these results to Microsoft Research's trial findings, there was not much difference, people wanted to convey more information in both cases. When comparing a web-based application to a tangible Clock there was mixed reviews; the older participants would have preferred it to be at-a-glance in the home whilst for the younger participants who were more familiar with computers felt it was at-a-glance as they would spend a lot of time on computers anyway.

Overall the Clock was a success, when asked if they would use it regularly four out of the six participants said they would use it especially with their friends, while the two older members of the family would have liked a "real" Clock in the home. A lot of constructive feedback was given and suggestions that had not previously been thought of were given on how to make the Clock better.

5.2 Strengths and Limitations

A limitation on this project was using Bluetooth device detection to obtain visible access points rather than using Wireless Access Points as the range was shorter with Bluetooth.

The strengths and limitations of this project were made apparent when the user study was carried out. Most of the issues were because the Clock was web-based while this also gave it the strong points of the project.

Having a web-based Whereabouts Clock seemed to appeal to the younger generation more as they are more computer literate. The older participants did not consider computers as a relaxing device, they associated computers with work which was the idea that Weiser was trying to discourage [1].

As the Clock was on the web it meant that it was not constrained to only being viewed in one place, most people are not at home during the day and this was an opportunity to view it whenever it was wanted, this makes the Clock persistent availability, it is always there when needed. This was a concern mentioned in Chapter 3 as the social aspect was different to Microsoft Research's.

Privacy is such a big concern when in the web, this is why a login feature had to be put in place, when discussing this idea with Microsoft Research they felt this took away from the idea of the Clock being at-a-glance. While this is true the same can be said for a Clock in the home, it is only at-a-glance whenever someone is at home.

In this study, everyone had a computer to correspond to their different locations which was an issue raised in Chapter 3. The father who was a teacher always had a computer on in the classroom as his students would use it for educational work, this had been a concern of the author as it was not known if there would be a computer available at all times.

The Clock had the same strengths as the Microsoft Research trials found. People liked the idea of knowing where their friends and family were, it made them feel slightly more connected without having to be in contact with each other all the time

Overall the user study was a success, in ideal circumstances the trial would have had a longer timeframe as it is hard to gauge whether people can really adapt to an application in five days. The number of participants was sufficient for this study as the numbers were split evenly between friends and family. A drawback of this study was that there was not a tangible Clock to carry out a user study on. It would have been beneficial to carry out two user studies, one with a tangible Clock and the other with a web-based Clock with different participants each trial to see which Clock was better accepted and by who, friends or family.

Chapter 6: **Conclusions and Future Work**

6.1 Conclusions

This project aimed to create a display to show individuals locations in an ambient way. People's locations were obtained through their computers and this information was displayed on an applet running on a web page.

Throughout this project there has been the need to ensure that the Clock is still a form of ubiquitous computing. While it is still ubiquitous, it has strayed from the idea of an ambient device as it is on the web and has to be actively found to be looked at. The idea of making the Clock ambient without being a stand-alone device could be explored; the Clock can still be ambient on a computer although having it on a web page is not. A screensaver would complete the idea of the Whereabouts Clock being ubiquitous and ambient.

From the user study, it was overall a success like Microsoft Research's but there were mixed opinions on whether it should be in a fixed place or web-based. People liked knowing where their friends and family were and felt connected, much like the results from Microsoft Research trials and it was found that they sometimes wanted to convey more information and be able to contact someone through the Clock web site.

Comparing this project against Microsoft Research's Whereabouts Clock, this project has its advantages and disadvantages. It would have been interesting to carry out the user study for the same amount of time on the same demographic as Microsoft Research did and then compare the evaluation, although the time frame of six months was not feasible for this project.

After the user study, Microsoft Research had the advantage of the technology they used to get people's locations; everyone has a mobile phone and it is almost always switched on so everyone can hypothetically be tracked. While most people nowadays do own computers or laptops, when travelling or when not in use, the computers are switched off and so can't be located.

Also the range for mobile phones is much better than the range for the internet; cell towers aim to cover every area that their network company operates in, and even when not in range of a user's own network operator, the mobile phone automatically switches to roaming so it is still covered and in range. When it comes to the internet, not all computers are set up for wireless so they need to have wires, and computers that do have wireless network cards are not guaranteed coverage as households and companies secure these networks so that a passkey is required.

The web-based Whereabouts Clock is not suited to families, the Microsoft Research Clock would meet their needs more than this one, this is because a typical family is based in the home and a Clock in the home that could be glanced at would be of much more benefit to them than a web-based Clock. A web-based Clock is ideal for the intended audience of friends, it is on the right social level and the user study found that between friends it was very successful, with the success of social networking sites an application like this would be very marketable at this time. Friends want to feel connected and knowing where their friends are would increase the feel of an extended family.

The Whereabouts Clock was designed to be a glanceable application on the web. From the user studies the feedback given suggested that it was glanceable for some users while others did not fully use the Clock to the extent that they would have had it been a tangible Clock. The targets set out for this project were all achieved to the standard that was originally anticipated and the Whereabouts Clock was a success as seen from the user study. With more time, a tangible Clock could be incorporated into the project giving an option to use the Clock while at home or on the move and widening the range of locating mobile wireless devices would also make this feature much more efficient.

6.2 Future Work

From the user study a lot of new ideas were given to make the Whereabouts Clock more effective and to meet the needs of the people who would use it most.

The older participants did not know what a MAC address was and when they were asked to register they got confused. A way around this would be to implement a program that was more user friendly, it would automatically get a users MAC address, ask them where they were and store this information.

Although it was never mentioned in the trial, the option to customise the Whereabouts Clock could be given, this would give the Clock a personal touch and a user could add a picture to their icon rather than just text.

To customise the Clock even more, users could specify who they would like to view on their Clock and they could make different groups of friends. This would extend what was said in the user study, people liked that it was not just family and they could see where their friends were as well.

It was said by more than one user that they would have liked the Clock to be able to pop out from the web page, it could be made to be a stand alone application that a user could run from their computer.

Bluetooth can obtain visible wireless devices only within a short range; other options rather than Bluetooth could be considered to increase the range in which wireless mobile devices are found.

Extending the client application to dynamically prompt for a user's location would greatly enhance the Whereabouts Clock's functionality. If a user switches location and that address is unknown it will ask the user to register that address corresponding to a location.

It was said by two of the user study participants that they would have preferred a tangible clock in the home, this project could be extended to allow for this. This would then be able to take the ideas from Microsoft Research's Clock that was liked such as inclusion of small children who would not normally be a part of the Clock. Microsoft Research had a feature where small children each had an icon and when they pushed it, it would make a sound and animate itself, for example when the author was shown a demo of the Microsoft Research Clock, it was seen that when a child's icon was pressed it turned into a flower and then changed back.

Also when someone changed location the Clock would make a noise which would be a good feature to have.

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