PUBLISHED IN: PROCEEDINGS OF SYMPOSIUM 2005 LOCATION BASED SERVICES & TELECARTOGRAPHY, G. GARTNER (ED.). WIEN: INST. OF GEOINFORMATION & CARTOGRAPHY, TU WIEN. PP. 47-51.

WIRELESS CAMPUS LBS
A test bed for cartographically aware database objects

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1. Introduction

The Wireless Campus LBS project has been started in early 2005. It’s an informal co-operation between people at the University of Twente (UT) Computer Architecture Design and Test for Embedded Systems group (Arthur van Bunningen, Kavitha Muthukrishnan, Nirvana Meratnia, Georgi Koprinkov), the UT department of Information Technology, Library & Education (Sander Smit, Jeroen van Ingen Schenau) and the International Institute for Geo-Information Science and Earth Observation (Barend Köbben). The initial ideas for the CampusLBS were reported earlier in the workshop report in [1], its first test phase was executed and reported on during SVG Open 2005, the 4th Annual Conference on Scalable Vector Graphics [2]. The Wireless Campus LBS is intended to *serve as a test bed* for research as well as to *benefit from the outcomes* of this research. The research mentioned goes deeper into Wireless LAN *positioning techniques*, into *context awareness* of ubiquitous data management system, and into adaptive delivery of mapping information for LBS and mobile applications by using *cartographically aware database objects.*

This paper firstly describes the setup of the system as realised until now (September 2005) and reports on the results of the first real use case, providing the participants at SVG Open 2005 with an LBS to help them navigate the conference locations and locate fellow attendants. Secondly the paper will introduce the use of the Wireless Campus LBS as a test bed for the application of cartographically aware database objects.

2. The Wireless Campus at the University of Twente

In June 2003 the “Wireless Campus” was inaugurated at the University of Twente (UT), allowing cable–free internet access to staff and students anywhere on campus. University of Twente is a young university in the Eastern part of The Netherlands. It employs 2 500 people and has over 6 000 students. On its campus, the university has 2,000 student rooms. The university campus is situated between the cities of Enschede and Hengelo, near the Dutch–German border. Spread over the 140–hectare campus 650 individual wireless network access points have been installed, making it Europe’s largest uniform wireless hotspot. Anyone with a PC, laptop, PDA or other WiFi (wireless fidelity) enabled device can access the university's network and the internet from any building, the campus park and other facilities without cabling.

University of Twente's Wireless Campus aims at a broad range of research and applications of wireless and mobile telecommunication. Furthermore, a project has just started in cooperation with Enschede Municipality to install further access points to also cover the downtown area of Enschede.

Research projects investigate the technology and the applications of wireless and mobile communication in several ways, mostly in cooperation with industrial and other knowledge partners. The Wireless Campus has become a 'test bed' for wireless and mobile applications. The major part of this research takes place at the Centre for Telematics and Information Technology (CTIT) and the research institute MESA+. Both are key research institutes of the University of Twente. MESA+ is an institute that conducts research in the fields of nanotechnology, microsystems, materials science and microelectronics. CTIT is an academic ICT research institute of the University of Twente. It conducts research on the design of advanced ICT systems and their application in a variety of application domains. Its Computer Architecture Design and Test for Embedded Systems Group became interested in using the WiFi technology in the wider framework of the *SmartSurroundings* research program. This program is "investigating a new paradigm for bringing the flexibility of information technology to bear in every aspect of daily life. It foresees that people will be surrounded by deeply embedded and flexibly networked systems (…). This presents a paradigm shift from personal computing to ubiquitous computing, (…). Relevant knowledge areas include embedded systems, computer architecture, wireless communication, distributed computing, data and knowledge modelling, application platforms, human-computer interaction, industrial design, as well as application research in different settings and sectors" [3]. An important part of such systems is establishing the position of persons, services and devices, and one of the possible strategies to achieve that is to use WiFi technology.

3. Positioning using WiFi technology

Using WiFi technology for positioning is just one of the many wireless techniques available for positioning of mobile users. There are various reasons to choose WiFi based localization. One is the fact that it is an economical solution. Because the wireless network infrastructure already exists, localization can be done by software-only methods without adding any additional hardware. Secondly, compared to other techniques such as InfraRed, Bluetooth or RFID, the range covered by WiFi is larger. Thirdly, such as system is scalable and (re)useable in many situations, because wireless networks are currently being deployed all over the world in places like universities, airports, offices, shopping malls, etc.

3.1. Methodology

As in most WLAN-based indoor positioning systems, our localization algorithm relies on the observed signal strength distribution as its input to determine the location. There are three basic methods of using WiFi signals for determining the location of users [4]: (a) triangulation that requires at least three distinct estimates of the *distance* of a mobile device with a WiFi receiver from known fixed locations, (b) using the direction or *angle of arriva*l of at least two distinct signals from known locations and (c) employing *location fingerprinting* schemes. In indoor areas, the signal will almost always be reflected from various objects (such as walls and ceilings). Because of this multipath environment, techniques that use only triangulation or direction might not be very reliable. Location fingerprinting refers to techniques that match the fingerprint of some characteristic of the signal that is location dependent. The fingerprints of different locations are stored in a database and matched to measured fingerprints at the current location of a receiver. In WLANs, an easily available signal characteristic is the received signal strength (RSS) and this has been used in CampusLBS for fingerprinting.

But the RSS is a highly variable parameter and issues related to positioning systems based on RSS fingerprinting are not understood very well. The big advantage of RSS-based techniques is that we can use the existing infrastructure to deploy a positioning system with minimum additional devices. It is far easier to obtain RSS information than the multipath characteristic, the time or the angle of arrival, these all require additional signal processing. The RSS information can be used to determine the distance between a transmitter and a receiver in two ways. The first approach is to map the path loss of the received signal to the distance travelled by the signal from the transmitter to the receiver. With the knowledge of the RSS from at least three transmitters, we can locate the receiver by using triangulation. The main drawback is the necessary calibration of signal strength as a function of a particular location. There is a trade-off between the amount of effort put into the calibration (it requires lots of time and work and should be performed repeatedly) and the accuracy obtained. Little research as of yet has addressed the issue of optimising the calibration effort.

The current WiFi based component is based upon an earlier project called “FriendFinder” [5], done in 2004 for two specific buildings on the University campus. In this project a prototype client-server architecture was built, where the client program on the mobile device determines its location by detecting the Access Points (APs) in range and comparing them with data about the APs that are in a server-side database. This database stores the location in XYZ of the, their BSSIDs (the unique identifier of an AP), and the strength of their antenna output (in mW).

Tests have shown that the FriendFinder pilot achieved an average positioning accuracy just under 5 meters (4.6m), and only for non-moving devices. In the Wireless Campus LBS project the positioning component is part of a wider PhD research, described in [6], into a variety of positioning techniques for LBS. To achieve this, the research investigates the positioning algorithms, the filters and methods used, and also the effects of signal-reflecting obstacles on the measurements. These obstacles, such as walls and pillars, are included in the geodatabase and could therefore be accounted for in the positioning algorithm. Another area of further research will be the self-learning abilities of the system, that should theoretically make the positioning more accurate over time. One of it’s main research goals will be to have calibration-free localization preserving quality and accuracy.

3.2. Mapping the Access Points

The WiFi based positioning algorithm is dependent on an initial mapping stage, in which the coordinates of all the access points in 3D coordinate system had to be recorded in a database. For the FriendFinder project mentioned above, only a limited number of the Access Points (APs) had been used. As no geoscientists where involved at that stage, their positioning was done in a rather improvised way. The height of the APs especially was a problem, it was determined only by estimate and with respect to the building's ground floor height. In this limited project that was not a big problem, as only one building was involved, but for the larger project the elevation differences between the buildings (more than 5 meters, which is a lot for the Dutch!) had to be taken into account.

The 650 individual wireless network APs that have been installed were only indicated on paper maps, one map per floor, of the individual buildings of the University. The base maps are print-outs from CAD–drawings ("blue–prints") maintained by the Facility Management Services that have a high level of detail, but they are not georeferenced and thus have a local, arbitrary, coordinate system that's basically just 'paper coordinates'. Furthermore, the location of the APs had been indicated on these maps haphazardly by hand-drawn symbols at the time of installation of the devices.

Therefore the first task has been the digital mapping of the AP locations in a geodatabase. In order to do this, it was decided to digitise all locations using GIS software and digitally georeferenced versions of the CAD-drawings. The georeferencing was achieved by transformation of the CAD drawings, using control points from an overview map of the whole campus that is available in the Dutch national coordinate system "Rijks Driehoeksstelsel" (RD). It was established that it would be possible, when using simple first order transformations, to achieve Root Mean Square Errors of less than 0.1m.

For all buildings a base elevation was determined in meters above NAP (the Dutch vertical datum) by combining the campus map with the Actual Height Model of the Netherlands, a detailed elevation model of the whole country made by airborne laser altimetry, which has a point density of minimal 1 point per 16 square metres and a systematic error of 5 centimetres maximum [URL1]. In order to get precise location measurements, it was deemed necessary to physically visit all APs and use a laser measurement device to determine the relative location of the AP antenna with respect to the elements of the building present in the CAD drawings (walls, floors, windows). By combining these relative measurements with the georeferenced maps a precise XYZ location has been determined and put into a geodatabase. The added bonus is that all APs have been checked and additional attributes was gathered, such as antenna type, antenna connection length (for estimating signal loss), etc.

3.3. Localization algorithm

The WiFi device inside the laptop or PDA periodically scans its environment to discover access points in the vicinity. During the access point scanning phase, the BSSID address of the access points and their Recorded Signal Strengths (RSS) are determined and stored. At any unknown location 'n' in the conference venue, the variation of the signal strength will be:
a*t each n RSS varies as 0 >=RSS <=MAX.*

However, the signal strengths are usually contaminated by noise. In order to have a better estimation of the actual location, an *exponential moving average filter* is employed to smoothen the signal strength. Equation 1 shows the formula used in doing so, in which α =0.125 and SS denotes the observed signal strength:

$$\text{Current RSS} = \alpha * (1 - \text{Current RSS}) + \alpha\,(\text{previous RSS}) \qquad \text{(Equation 1)}$$

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To compute the users location, the top three access points having the best signal strength are chosen. If the device gets only one or two access points in the scan, it can still estimate a position. But, as triangulation is used, the localization will be of better quality if at least three access points are used.

4. The Wireless Campus Location Based Services

Their has recently been a lot of industry and research activity in the realm of "Location Based Services" (LBS). The purpose of the project described here is not the development of 'the' or even 'a' Wireless Campus LBS, but rather to investigate and set up the *infrastructure* necessary for LBS's based on it. It combines input from several research projects with the practical application of new as well as established techniques to provide useful services for the UT campus population.

4.1. FLAVOUR: first tests at SVG Open 2005

The first use case test of the Wireless Campus LBS was to provide the participants of a conference held at the UT grounds this summer (15–18 August 2005) with an LBS to help them navigate the conference locations and locate fellow attendants. This conference, SVG Open 2005, the 4th Annual Conference on Scalable Vector Graphics [URL2], was deemed to be a good test bed as it drew a crowd of some 180 people from 20 countries all over the world, from a very wide field of applications: electronic arts & media, geospatial sciences, information technologies, computer sciences, software developers, Web application designers, etc. They share an interest in Scalable Vector Graphics (SVG), the W3C open standard enabling high-quality, dynamic, interactive, styleable graphics to be delivered over the Web using XML. Most of them are technology–oriented and there is a high degree of interest in, and ownership of, mobile devices.

The application built for testing by the participants has been called FLAVOUR (Friendly Location-aware conference Assistant with priVacy Observant architectURe). Services offered by FLAVOUR can be categorized into:

- *Pull services*, in which location of attendants play an important role as the attendants' request will be replied by the system on the basis of their whereabouts. Examples of pull services offered are:
  - Finding fellow attendants;
  - Locating resources available in the infrastructure such as printers, copiers, coffee machines etc.
- *Push services*, in which individual and bulk messages are sent to the attendants. This enables the attendants to:
  - Be notified about important events by conference organizers;
  - Communicate with their contacts, i.e., colleagues, friends, etc.

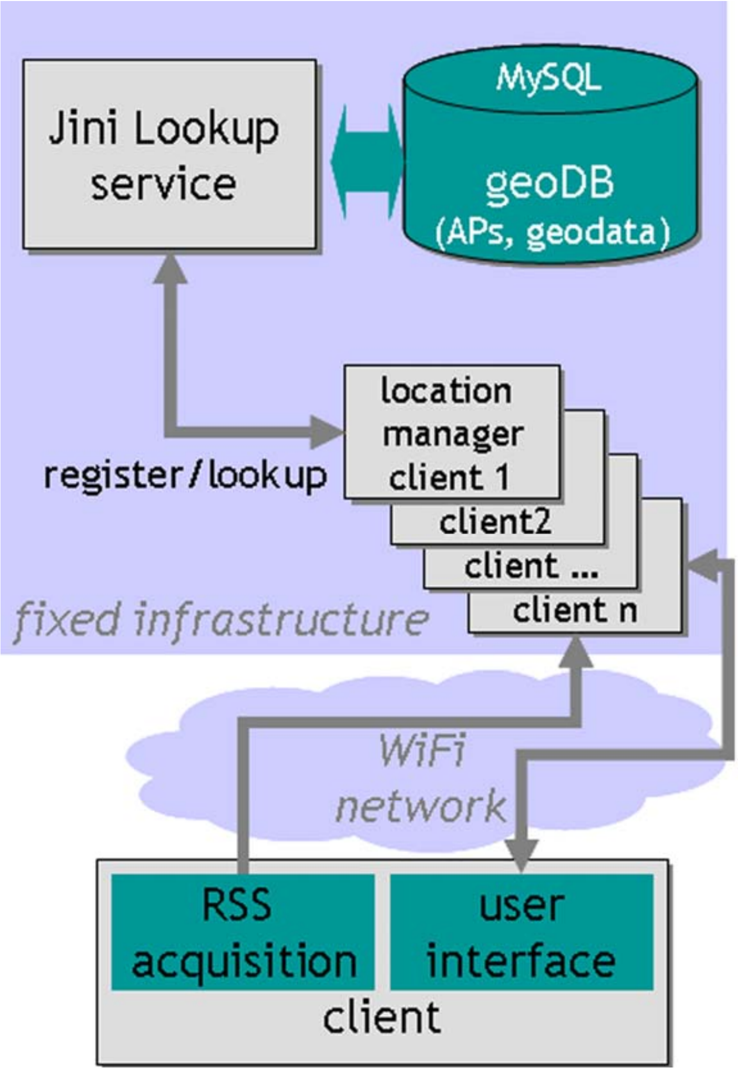

Figure 1. FLAVOUR architecture (from [2]).

The architecture, as seen in figure 1 and described in more detail in [7], is based on a Location Manager, which provides services using the Jini platform [URL3]. Jini is a Java-based open architecture that enables developers to create network-centric services. Each Location Manager registers with the Jini Lookup Service to offer the location of the user it represents. Interested users can look up the service and subscribe to the location of a given conference participant. This is done using publish–subscribe mechanism. The Location Manager uses a privacy policy to decide if a client is allowed to subscribe to the location of its owner (publisher). It also publishes to all the subscribers relevant changes in the location of its owner.

The Jini architecture also provides other kinds of services, such as a message board to which every conference participant can subscribe. The message board can be used by the conference organization to publish changes in the schedule, information related to the social events, etc. Participants can also use the message board to make announcements to the other participants, as for example asking about lost objects, or to chat.

The graphical depiction of the maps and the location of the users is done in SVG, providing vector graphics in high graphical quality with a small memory– and file–footprint. The system also provides the user with an estimation of the current positioning accuracy. A screen dump of the user interface can be seen in figure 2.

The tests at SVG Open 2005 were relatively successful: Most conference participants experimented with the localisation features of the system. The messaging and friend-finder functions were used to a lesser extent. Various extensive interviews have been held with test persons and also written feedback was collected. The localization functionality worked quite reliably, although the accuracy was varying quite a bit over the various conference locations. In the computer science building the results were clearly better then in the main conference halls. The tests still have to be analysed further, but the most obvious reasons are the non-optimal configuration of access points and the fact that the database of these access points still was incomplete at the time of testing.

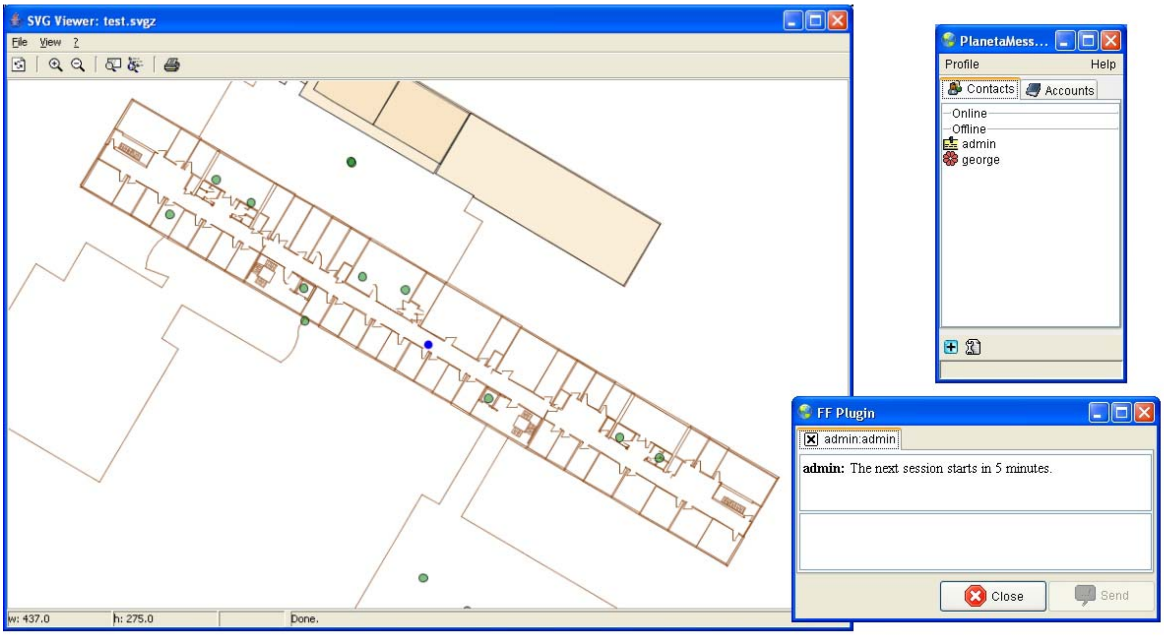

Figure 2. Screen dump of the FLAVOUR user interface.

5. Outlook

The implementation of the Wireless Campus LBS described in this paper has only just started. But as it builds on the solid foundations of the well-established infrastructure of the Campus-wide WLAN at the University of Twente, and has had a successful pilot in the FLAVOUR tests at SVG Open 2005, we expect that it will be put into use and expanding relatively quickly in the coming years.

Probably the most exciting aspect of the project is the fact that it provides the opportunity for a very diverse group of people from quite different disciplines to contribute to a technical infrastructure that can serve as a test bed for their respective researches, and at the same time has the potential to become a useful everyday feature for mobile users at the University Campus.

The research mentioned has a wider scope then just this project: the Wireless Campus LBS is intended *to serve as a test bed for* the research as well as *to benefit from* the outcomes of the research. These research projects include the PhD mentioned in paragraph 3.1 on LBS positioning technologies and another PhD that concentrates on the impact of context awareness on ubiquitous data management [8].

On the client-side of the system, ongoing research at ITC on data dissemination for LBS and mobile applications [9] will be concentrating on the Wireless Campus LBS as a test bed for adaptive, task-oriented delivery of mapping information to mobile users using *cartographically aware database objects.*

5.1. Cartographically aware database objects

Cartography and GIS more and more involve the use of spatial database technology. In the database world, there is a growing focus on *context awareness* of database objects. One of the important context parameters is location awareness, which is important for all spatial applications. Our goal is to extend context awareness with the idea of database objects that are *cartographically aware*.

Traditionally, cartographers have been focussing on methods and techniques for visualising spatial phenomena. As these spatial phenomena are nowadays stored in GIS systems and spatial databases, they have developed the DLM-DCM paradigm: a *Digital Landscape Model* that models the geographic world in geographic objects (point, line, polygon or raster) with attached thematic attributes. And a *Digital Cartographic Model*, that models the various representations of the DLM in graphic objects (point symbols, lines, patches) with their graphic attributes (colour, width, etc.). The theoretical treaties on this paradigm usually do not describe how these two models should or could be connected, if or how the DCMs are to be derived from the DLM, etcetera. Also in practice, surprisingly little has been done in this field. Most GIS systems, for example, do give little or no support to achieve this DLM–DCM model other than “by hand”, or by providing some templates and default settings. Truly ‘automated cartography’ using this concept has in fact not been made possible.

Connecting this problem with the context awareness research in databases might provide a way forward. Instead of treating the DLM and the DCM as separate parts, why not have single spatial database objects that represent spatial phenomena and that are cartographically aware…? One might think of an object that represents a road. The object would be spatially aware in that it has a spatial representation (eg. as a vector), and may be cartographically aware that to be represented for topographic purposes at scale 1:25 000, its should be a 2 mm wide red line with 0.1 mm black casing. While this concept on first sight might not seem to work out much different than the traditional legend tables of a GIS system, the main strength is in the fact that here the cartographic awareness is on an object level, not on a per layer basis, and could be subject to all kinds of (database) rules and triggers. This way, the cartographic (and other) characteristics of the objects can be influenced by other database objects and their context.

As a simple example one might think of a location map in the Wireless Campus LBS where the spatial distance of the objects to the focus of the map (the users position) influences their representation: Interior walls only show themselves in buildings that the user is in, room numbers only if the user is within reading distance. But more complicated systems could be thought up, which might be especially useful for generalisation techniques that are hard to achieve in traditional layer-based systems. It is our intention to use the Wireless Campus LBS to test these concepts in practice and provide a proof of concept application.

URLs

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[2] SVG Open 2005 – http://www.svgopen.org/2005/
[3] Jini platform – http://www.sun.com/jini/

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