Wireless Campus LBS

Building campus-wide Location Based Services based on WiFi technology

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Abstract

This paper describes a project that has just started at the University of Twente (UT) in cooperation with the International Institute for Geo-Information Science and Earth Observation (ITC) to provide Location Based Services (LBS) for the UT campus. This LBS will run on the existing Wireless Campus system that provides the whole 140 hectare University grounds with WiFi based internet access. The project serves as a testbed for research activities as well as an infrastructure to develop practical use cases upon. The former includes research into wireless LAN positioning techniques, into context awareness of ubiquitous data management systems, and into data dissemination for LBS and mobile applications. A first use case will be to provide the participants of SVGopen2005, the 4th Annual Conference on Scalable Vector Graphics (August 15-18, 2005) with an LBS to help them navigate the conference locations and locate fellow attendants.

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.

For education, the WLAN improves the flexibility and independence of time and location. This powerfully facilitates new ways of teaching. The new bachelor's programme Industrial Design, for example, now provides its students with a laptop, to make use of all possibilities including high-performance CAD software. Students of all programmes use the so–called TeleTOP digital learning environment. These new teaching concepts also enable a more flexible use of teaching rooms.

University of Twente's Wireless Campus aims at a broad range of research and applications of wireless and mobile telecommunication. The UT wants to use the WLAN in cooperation with the adjacent Business and Science Park. Therefore this B&SP is being covered by access points as well. Furthermore, a project has just started in cooperation with the municipality to install further access points to also cover the downtown area of Enschede.

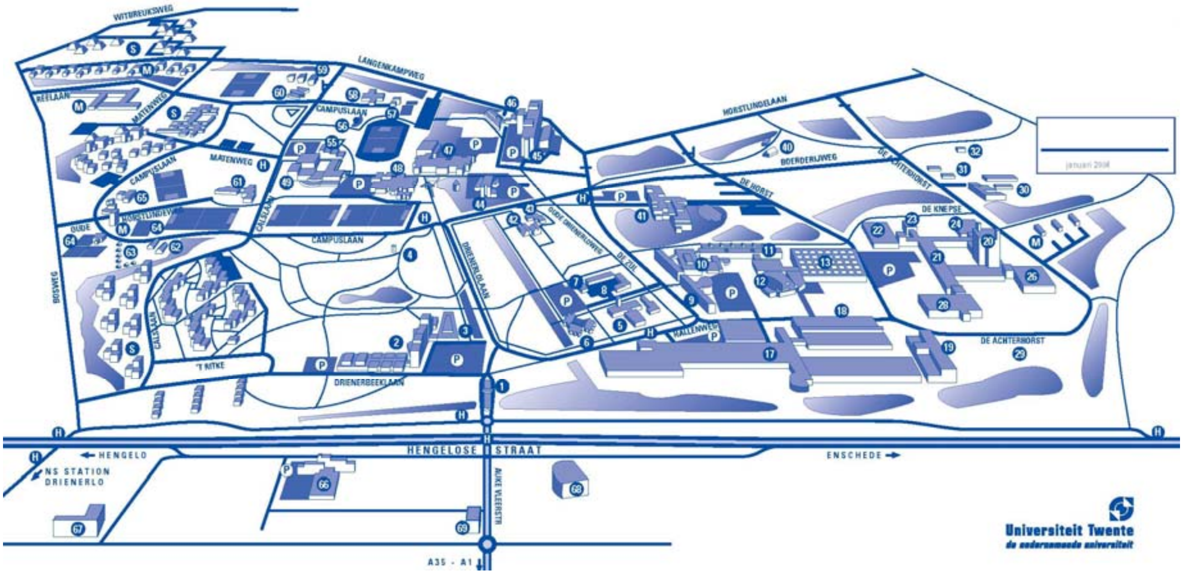


Figure 1: The University of Twente campus in Enschede, The Netherlands.

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 'testbed' 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. 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. MESA+ is an institute that conducts research in the fields of nanotechnology, microsystems, materials science and microelectronics.

The wireless network facility was made possible with financial support of the Dutch Ministry of Economic Affairs and has been built in cooperation with IBM Netherlands and Cisco Systems. It consisted in first instance mainly of access points that use the 802.11b wireless networking standard, offering a data transfer speed of 11 megabits per second for most users. However, upgrading the entire network to run using the new 802.11g standard, providing data at speeds up to 56 megabits per second, is an ongoing effort.

Positioning using WiFi technology

Using WiFi technology for positioning is just one of the many wireless techniques available for positioning of mobile users (others are eg. GPS, Bluetooth or Infrared, and mobile telephony). There are three basic methods for determining the location of users [3]: (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 arrival (AOA) 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 (like walls) and 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 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 angle of arrival, that require

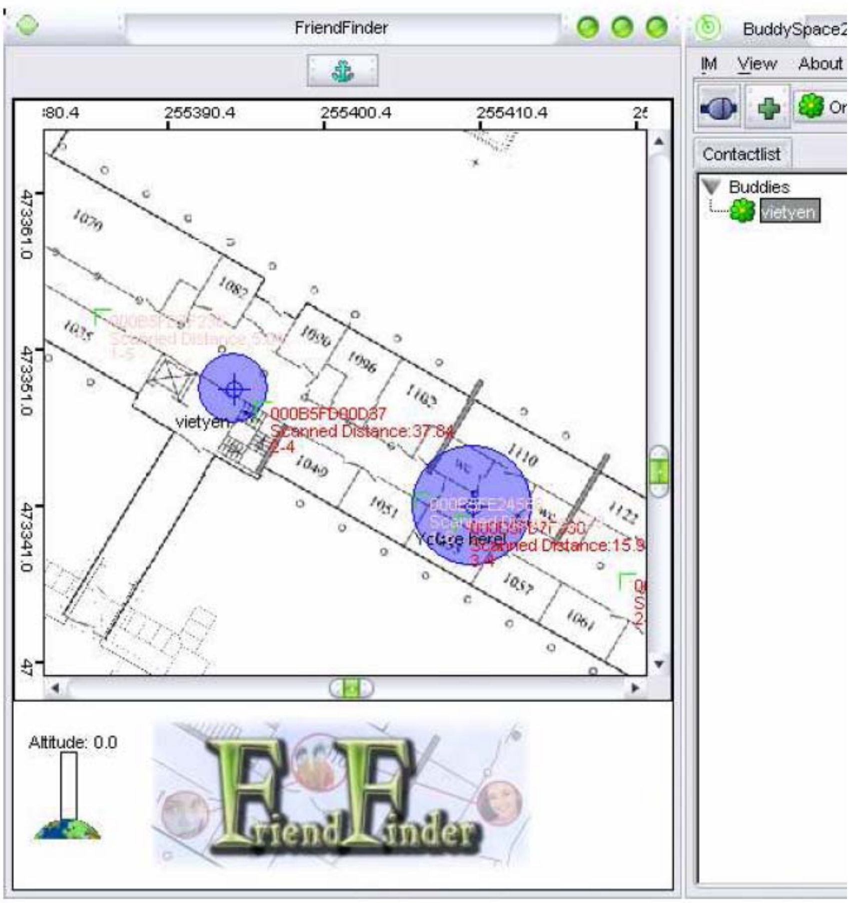


Figure 2: screen shot of FriendFinder prototype.

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.

In the Wireless Campus LBS project the positioning component is part of a wider PhD research into a variety of positioning techniques for LBS. This WiFi based component will build upon an earlier test done in 2004 for two specific buildings on the University campus. In this project, called "FriendFinder"[1], a prototype client-server architecture was built, where the client program on the mobile device determines its location with respect to the Access Points (APs) by determining the RSS-s and comparing them with data about the

APs that are in a server-side database. This database stores in the first place the location in XYZ of all APs inside the two buildings chosen, their

BSSIDs (the unique identifier of an AP), and their antenna signal strength. Furthermore, maps of the buildings are stored for use in the Graphic User Interface (GUI) of the client application.

The client application first buffers the RSS measurements because not all APs are detected in any single scan. Then it detects probable faulty measurements and deletes them. The accepted measurements are then put through a filter that calculates their centroid. Now the client has a first estimate of its position. Further filtering takes place, using among others standard deviations and maximum likelihood calculations, to get a better estimate of the position and the final estimate is determined by so-called "iterative multilateration". In this technique a clients position, with its estimated inaccuracy, is used by other clients as a reference frame. In that way all nodes use each others information to jointly improve the accuracy of the positioning. An important part is played by further filters that implement a learning effect from the stored positioning history of the application to achieve further improve the accuracy.

By using the XML–based Instant Messaging protocol "Jabber", the client applications can communicate and relay their positions to each other and show them in the GUI by placing symbols on the building maps mentioned earlier.

Tests have shown that the average positioning accuracy this first prototype could reach was just under 5 meters (4.6m), for non-moving devices. The system provides the user with an estimation of the current postioning accuracy. One of the research tasks for the Wireless Campus LBS project will be to reach better accuracy of positions. Fort that, a more precise determination of the locations of the APs and their properties is needed, covering this time the whole UT campus.

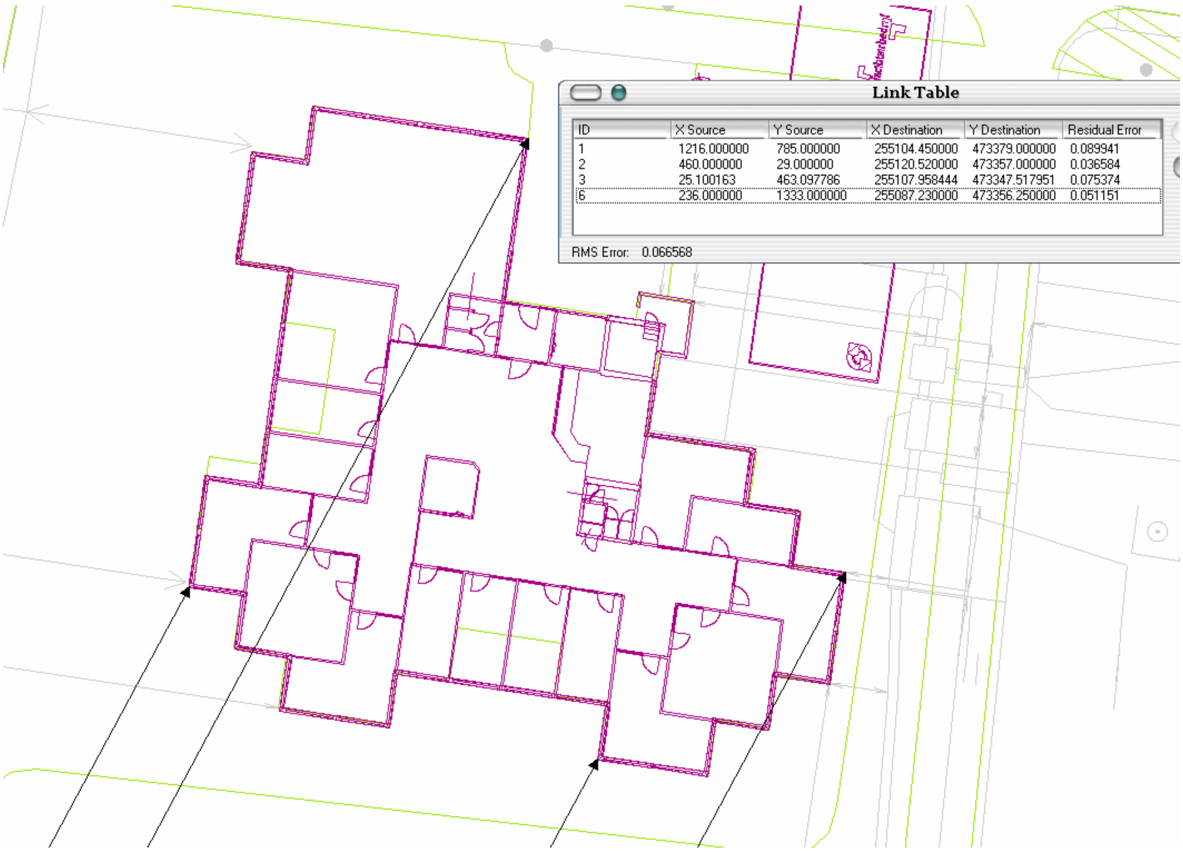
Mapping the Access Points

For the FriendFinder project mentioned above, only a limited number of the Access Points (APs) have 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!) will have to be taken into account.

The 650 individual wireless network APs that have been installed are currently only indicated on paper maps, one map per floor, of the individual buildings of the University. These 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 has been indicated haphazardly by hand-drawn symbols at the time of installation of the devices.

Therefore the first task, starting February 2005, 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 "RijksDriehoeksstelsel" (RD). First test have determined that it is possible, when using simple first order transformation, to achieve RMS errors of less than 0.1 meter.

Figure 3: Screenshot of the GIS used to map the APs. It shows one of the building CAD drawings (darker colours) after georeferencing on the UT overview map (light colours). The arrows show the control points, the link table depicts their unreferenced coordinates and their equivalents in RD, as well as the residual errors (all in m).



For all buildings a base elevation will also be 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). The height of each AP, measured from the floor or ceiling, will be combined with a determination of that floor or ceiling's height from the base elevation of the building. By combining all these relative measurements with the georeferenced maps a precise XYZ location has been determined and put into the 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, etcetera.

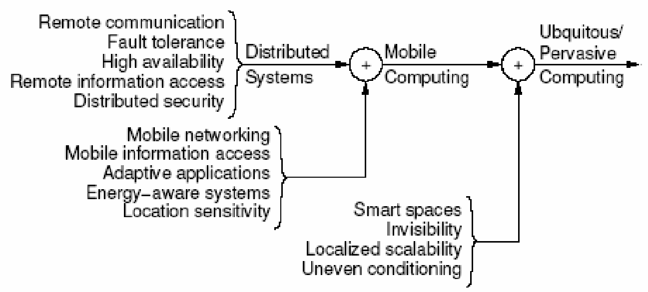
The Wireless Campus Location Based Services

Their has recently been a lot of industry and research activity in the realm of "Location Based Services (LBS), which have been defined in [7] as *wireless services that use the location of a (portable) device to deliver applications which exploit pertinent geospatial information about a user's surrounding environment, their proximity to other entities in space (eg. people, places) and/or distant entities (eg. destinations).*

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. The research mentioned has a wider scope then just this project: the Wireless Campus LBS is intended *to serve as a testbed for* the research as well as *to benefit from* the outcomes of the research.

These research projects include one PhD, described in [5], on various LBS positioning technologies, that will look, among other things, into improving the accuracy of the WiFi positioning. 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 postioning more accurate over time.

Figure 4: Evolution from distributed to ubiquitous computing (reproduced from [6]).



Another PhD concentrates on the impact of context awareness on ubiquitous data management. This research deals with consequences that the evolution from *distributed computing*, via *mobile computing* to *ubiquitous* or *pervasive computing* (as shown in figure 4) is having on data management issues. Context-awareness is thought to be a major requirement for computer systems to be ubiquitous. In a recent paper resulting from this research [2], a design is presented of a context-aware data management supporting platform. One of the important characteristics of context, and therefore of the supporting platform, is spatial information, and the spatial context information provided by the Wireless Campus LBS will be used in implementing said platform. Another factor of context for any system is the (un)certainty of the information it provides, and providing the user with relevant information about that uncertainty will also be part of the CampusLBS services.

On the client-side of the system, ongoing research on data dissemination for LBS and mobile applications [4] will be concentrating on the Wireless Campus LBS as a testbed for adaptive, task-oriented delivery of mapping information to mobile users.

The first use case test of the Wireless Campus LBS will be to provide the participants of a conference held at the UT grounds this summer (August 15–18, 2005) with an LBS to help them navigate the conference locations and locate fellow attendants. This conference, SVGopen2005, the 4th Annual Conference on Scalable Vector Graphics [URL2], was deemed to be a good testbed as it draws a crowd of people 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, stylable 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.

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 FriendFinder project, we expect that within a relatively short time the first results can be shown at the SVGopen conference in August 2005.

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 testbed 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.

URLs

URL1: AHN site - http://www.ahn.nl/english.php
URL2: SVGopen site - http://www.svgopen.org

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