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Final Thesis Proposal

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Indoor Positioning Agent Locator

Despite the amazing accuracy of small portable Global Positioning Satellite (GPS) devices, these little handheld devices become as valuable as paperweights inside of many buildings. However, it is possible using the wireless networking protocol IEEE 802.11 to accomplish a fairly accurate indoor positioning system. Another big advantage to this strategy is the added ability to share data over a local area network (LAN). Combine a back end server some wireless access points and a wireless client and we may package a viable Indoor Positioning Agent Locator system, or IPAL. Signal strength, bi-directional communication, and precision timing are inherently built into all wireless networking clients. These traits also happen to be the key ingredients for developing any type of an electronic positioning system. My proposal is to build and document such a system. This system will include:

1. IEEE 802.11 client.
2. Multiple wireless access points.
3. An XML ACL Application Server for computing and managing client location data.
4. A central http web server, which reports multiple client locations through a friendly Flash interface.

1 Application Architecture

Each component in our IPAL design should complete very specific tasks so that we may divide and concur our final goal. Some tasks are limited to hardware constraints while others tasks that may work in a single platform are best divided into separate systems for scalability and common sense reasons. Here is a description of my proposed IPAL system:

Application Server or Engine

Provides all background mathematical calculations needed to determine location. Input and output communication with server is accomplished using Microsoft SOAP, XML compliant, Web Service and standard Agent Communication Language otherwise known as ACL.

Graphical User Interface

A Macromedia GUI providing new client setup and calibration, location of a requested person or node from any web browser with flash reader installed, and other possible features, such as a site map, that may prove useful. Communicates with Application Server using XML.

Client Software

A Windows CE based or other OS based embedded software package that responds to queries for the Application Server reporting measured signal strength data of the nearest access points.

Hardware

This project is mostly software based. The build of material includes but is not limited to: A Microsoft .NET enabled Web Server connected to an 802.11 network, an 802.11 enabled PDA, a minimum set of three 802.11 Access points.

2 Interface Issues and Risks

Several interface issues may arise that may prove as hurdles during development of the IPAL system. These issues include:

- Obtaining signal strength data from wireless access points
- Obtaining signal strength data from wireless nodes
- What is the best way to analyze the signal strength information for determining position?
- Signal Discrimination and qualification

Each of the following categories is discuss in the following sections.

2.1 Obtaining signal strength data from wireless access points

Microsoft's RADAR: 802.11 In-Building RF-based User Location and Tracking System, uses three APs to gather signal strength data about the node under query. The obvious advantage to using an AP to gather signal strength information about available nodes is all 802.11 device positions may be queried and located without having to install or write different client systems on each device. Initially the flexibility of this design grabbed my attention and tempted me to pursue this route. The biggest problem with this method is not all access points have solutions for reporting signal strength of available clients.

Furthermore, not all AP's will report nodes that are broadcasting but have not logged into that particular AP. So even if it does support signal strength reporting, it may not be possible to get the data from the three APs needed to triangulate the position of the node. Assuming the IPAL system is able to use this method of collecting signal strength, what happens when the node under test goes into power save mode or some other low-power broadcasting mode? This may inhibit our ability to take accurate measurements.

2.2 Obtaining signal strength data from wireless nodes

Every 802.11 client (node) has the ability to select from a list of available networks and calculate signal strength of the access point it is connected to. It is conceivable that having the server ask the client what it's signal strength measurements are will work well. In a large network where there are a large number of clients this method may prove best. In contrast to using the AP method described in section 2.1, going this route will require a client software package that works with different wireless NIC card drivers and operating systems. Our complete IPAL system will also be limited to the clients that have the client software installed on them.

2.3 Selecting the correct approach

Our target location is the university of Utah's wireless network in the MEB and EMCB buildings. The development platform includes the wireless network in my home. Because of the unknown implications discussed with using wireless access points, initially we will design the system using the client-based model, with one client, described in 2.2. After successful implementation of collecting just the measurements from our client under test, I will identify and if possible implement the wireless access point model on the system I have installed at home. If the wireless access point model proves reliable at home then I will extend the research of this approach to the Universities wireless system. If I am able to implement the access point model at the University, then the reliability of both models will be measure, compared and used in the final design.

2.3 What is the best way to analyze the signal strength information for determining position?

I am drawing information from a few research reports I have read on systems that have tired different methods for analyzing the signal strength data they received and how they used it to determine location. In Microsoft's RADAR project an Empirical Method and Radio Propagation Method were used to calculate client positions:

2.3.1 Empirical Model

The Empirical method uses the nearest neighbor(s) in signal space (NNSS) algorithm. An initial calibration is performed through recording signal strength measurements ss'1, ss'2, and ss'3 into a database for future comparisons. The idea is to compute the distance (in signal space) between the observed set of SS measurements, (ss1,ss2,ss3), and the recorded SS, (ss'1,ss'2,ss'3), at a fixed set of locations, and then pick the location that minimizes the distance [Bahl and Padmanabhan].

2.3.2 Radio Propagation Model

Using a mathematical model of indoor signal propagation, we generate a set of theoretically-computed signal strength data akin to the empirical data set. The

> data points correspond to locations spaced uniformly on the floor. The NNSS algorithm can then estimate the location of the mobile user by matching the signal strength measured in real-time to the theoretically-computed signal strengths at these locations. It is clear that the performance of this approach is directly impacted by the "goodness" of the propagation model [Bahl and Padmanabhan].

Of the two models the "Empirical Model" proved more accurate with an accuracy of 1 to 3 meters. While the "Propagation Model" was determined less accurate but still more accurate than a "Strongest Base Station Method," which predicts client location using only the known location of each base station and without taking into account walls and other signal interferences. The "Strongest Base Station Model" may work as an ideal model when less than three access points are within rage of our client [Bahl and Padmanabhan].

2.4 Signal Discrimination and Qualification

What is the best way to average measurements taken over small amount of time and derive our base signal strength? With a host of different types of antennas, and most of them being non-directional, the signal strength is going to have sharp peaks and valleys when examined on a graph as discovered by Kalid Azad [Azad]. There are different ways to average these peaks and valleys, but standard averaging may prove difficult without the use of a direction antenna such as a Pringles can. A Pringles can may improve signal strength readings but hinder regular network communications and besides who wants to carry a Pringles can around connected to their PDA. To solve this dilemma I suggest the following: During my in-class thesis presentation I proposed that taking the peek measurement of each sample may provide a more accurate representation of AP proximity. Of course this is a theory of my own that has yet to be tested or proven. I am merely basing my theory on my prior experience with a medical ear temperature measurement device that worked by taking three temperature readings and choosing the highest temperature would always be closest to the real temperature of the subject’s body. I am also supposing that there are few environmental variables that will amplify the broadcasted RF signal, so the maximum signal will most likely be the most unobstructed or non-attenuated signal.

Interesting enough Bahl and Padmanabhan with Microsoft during their RADAR research, mentioned in section 2.1, also found “Max Signal Strength Across Orientations” was more accurate. In their tests however they used it in a context where there were no obstructions such as walls, floors, or people obstructing the node under test.

3 Other Interfaces and Conclusion

My experience includes prior use of XML Web Services, Macromedia Flash XML integration and development, and hardware drivers. I have also worked on a number of embedded systems and engineering projects during my 4-year employment with the embedded computer manufacturer Parvus Corporation. Because of my experience, the most difficult yet appealing part of my senior project is most likely going to involve interfacing with the AP or client and applying different algorithms and techniques for determining client location. I fully expect most of my research and thesis will focus on the specifics of location calculations, algorithms, and client software integration.

4 Proposed Schedule Flows

<u>Week 1 through 2:</u>

Develop and write client software tests for acquiring signal strength information from an 802.11 client.

Benchmark: Client is able to report live numeric signal strength from all local access points.

<u>Week 3 through 4:</u>

Attempt to develop and write software tests for acquiring signal strength information from multiple 802.11 Access points about individual nodes broadcasting their MAC addresses using my home network.

Benchmark: Access point is able to broadcast signal strength of all nodes within range.

Week 5 through 6:

If access point model successful: Attempt implementation of access point model in EMCB and/or MEB. This will also require getting special user rights to access the system. If I fail to implement the access point model then I will move on to the next stage in development.

Benchmark: Access points are able to broadcast signal strength of all nodes within range.

Week 7 through 8:

Address additional concerns about obtaining data from access points and clients. Compare and contrast the use of both models. Collect data through rigorously testing signal strength measurements in a variety of controlled and uncontrolled environments.

Benchmark: A database is populated with signal strength measurements and corresponding hand measured location measurements for later evaluation from controlled and uncontrolled environments

Week 9 through 10:

Employ two or three algorithms or techniques for calculating the location of a client. Evaluate the difficulty, speed, and result quality of each algorithm when providing each with real-time data. Choose one or two methods that will best implement the overall objective of locating the room our client is in. It might be nice to allow a user to select from more than one location calculation algorithm. Especially since my final software package is the product that will demonstrate my research.

Benchmark: Take recorded data and compute locations. Compare location results with hand measured location results.

<u>Week 11 through 44:</u>

On my laptop: Create a Macromedia Flash form based GUI for interacting with Web Service and build the .NET web service for interacting with Flash GUI. This will include a point and click graphical mapping interface that stores and retrieves location information in and from an SQL Server database.

Benchmark: Layout is presentable and responses from the server are displayed on screen. Tests are written for future development.

<u>Week 15 through 16:</u>

Write an alpha software package for the collection of signal strength measurements and location calculation. This includes an easy to use and port client location calibration interface.

Benchmark: Physical barriers, room sizes and stationary structures measurements are stored into a database and correlate with x, y, and z point on a map. The z is the floor level. This happens with a simple point, click, and enter interface.

<u>Week 17 through 18:</u>

Write a beta software package for the collection of signal strength measurements and location calculation. Must be configurable using a simple GUI interface, and will include support for simultaneous multithreaded device location monitoring and user interaction.

Benchmark: A Minimum software package is functional for reporting location information on a map and a working calibration system that may be buggy.

Week 19 through 20:

Generate user documentation and help files for the beta package. Rap up as many loose ends as possible.

Benchmark: Books on-line are complete to train and address conceivable user interface questions about using the software..

Week 21 through 22:

Port the required software routines and functionality into the .NET Application Server. Dress up the user interface and GUI. Work as many kinks out of the system as possible. An OS level user permissions scheme will be implemented ere. A login is required. Access to certain resources will be employed here based user rights auditing and hierarchy.

Benchmark: System is in its complete organizational state, Including security.

Week 23 through 24:

Bring complete working system to a candidate release phase. Test the system, tweak the system, demonstrate the system, and perform even more system tests. Let someone who is computer illiterate try to use the system. Tweak and test the system again. Release the candidate.

Benchmark: System is in its complete organizational state an "ideally" fully debugged, including all security concerns.

Week 25 through 28:

Complete my research and finish writing the Thesis.

<u>Week 29 through 32:</u>

Allow more time for things like sickness, homework, midterms, quality assurance, and emergency vacations to Brazil.

Benchmark: My stress level is high yet still tolerable.

<u>End of Spring Semester:</u>

Hopefully graduate!

Benchmark: I am smiling and not jumping out of a window.

Work Cited

Kalid Azad. "Indoor positioning using 802.11b wireless networks." 1 January 2003. February 20, 2003 <http://www.princeton.edu/~kazad/resources/cs/cs398.htm>

Paramvir Bahl and Venkata N. Padmanabhan. "RADAR: An In-Building RF-based User Location and Tracking System." Microsoft Research. 2000. 12 March 2005 <http://research.microsoft.com/~padmanab/papers/infocom2000.pdf>