3D ALGORITHMS TO IMPROVE DEPLOYMENT OF WIRELESS LOCATION SYSTEMS EFFICIENCY

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ABSTRACT

Real-Time Location Systems (RTLS) have become very popular in recent years. These systems provide a contemporary layer of automation named automatic object location detection. Location measurements involve the transmission and reception of signals between hardware components of a system. A RTLS consists of at least two separate hardware components: a signal transmitter and a measuring unit. The positioning of the components in the monitored area is of great importance (regarding both location accuracy and resources required). This work presents the development of 3D software that can simulate the installation of a RTLS network in a virtual representation of the real world, helping in the decision making for the setup of such a network. The software utilizes a modified site survey algorithm, specifically developed to suit the needs of RTLS. Furthermore, it is capable of identifying the distance between two wireless nodes and the type and size of obstacles between them (walls, furniture, reflecting surfaces) calculating their effect on the formation of the network.

INTRODUCTION

The world is going mobile all the more as technology advances. Wireless communications have reached a degree of maturity that allows development of complex tasks, which were previously unachievable. Indoor location detection has drawn much attention both from researchers and manufacturers, as it constitutes the next step after outdoor position calculation - already achieved with GPS technology. Various solutions are currently under research utilizing different methods for location-tracking, such as Cricket, Mote Track, GPS and RSSI (Erin-Ee-Lin et al., 2008), as well as WiFi and RF fingerprinting. RSSI, as discussed below, is the simplest and least expensive solution, as it depends on RF propagating properties and requires no special hardware manipulation.

Zigbee wireless protocol provides location detection, along with many advantages. Zigbee have been explicitly designed for low consumption and minor radiation levels, making it the best choice for applications involving people tracking. In addition, its long battery life guarantees that infrequent maintenance is required - reducing the cost.

Hardware efficiency, cost effective planning and minimizing logistic operations are some of the many reasons for creating an assistive system; with smart algorithms, user-friendly intuitive interface and high scalability for deploying a Zigbee Real Time Location System (Z-RTLS).

Providing an indoor Real Time Location System (RTLS) solution offers many advantages over other possible approaches, to name a few:

- reduces the time needed for locating assets or people - improving productivity particularly when time critical issues arise
- enhances centralized management and control, as information acquired can be available both locally and remotely
- decreases time required for any statistical calculations over samples of data gathered, as data logging is fully automated
- strengthens security and allows for custom rules definitions over accessibility of certain areas of importance.

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Implementation of the above contributes for example in asset tracking and cataloging of products stored in warehouses, hospital equipment, finding tagged maintenance tools scattered all over a plant and much more. In addition location detection of people enables for monitoring their situation, providing relative info to them, banning admittance to an area for specific groups by issuing alarms when and where applicable and so forth.

Therefore, software was developed to provide all necessary services for setting up swiftly wireless networks, specializing in location tracking installations. Conclusively, the proposed solution stands apart for taking into consideration variables that are specifically more important in location detection systems that are otherwise mostly ignored, or handled manually in a subjective, insufficient way. Key variables such as the line of sight among network nodes and path loss estimation are estimated based on network topology and the RSSI measurements - the localization method used.

ZIGBEE PRO NETWORK TOPOLOGY

Zigbee Pro, an evolution of Zigbee, features mesh networking topology, which allows link connections between several points of the network structure. That means that each node can communicate with all other nodes in range, providing stable and versatile grid formation with increased resistance to transmission errors. These qualities, along with very low levels of energy consumption and radiation emission, forge a great candidate for indoor location system assembly.

Table 1: Classification of Factors the Affect RSS

Effect on	Factors	Options
Data Collection	1. Proximity of user	User's presence or absence
	2. Orientation of user and terminal	North, East, South, West
	3. Make of Radio	
Statistics	4. Time of measurement	Time of day & days of week
	5. Period of measurement	Second, minute, hour
	7. Interference	Co-channel/ adjacent co-channel
	8. Building environment	Small offices or large hall.

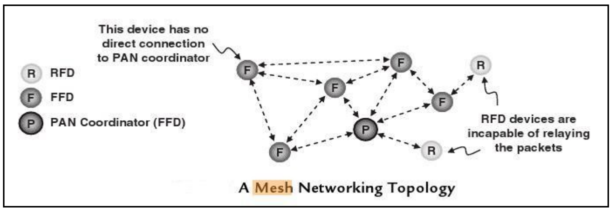

Figure 1: A Mesh Networking Topology

Mesh networking allows nodes to transmit and receive information using the best available path in real time. Such a topology results to an auto repairable wireless network with multiple routes for successful signal propagation. Furthermore, environmental influences on transmissions are greatly reduced.

RSSI AS A DISTANCE CALCULATION METHOD

Several methods exist for measuring the distances between two antennas in a wireless network: RSSI values, signal angle of arrival and time difference of signal arrival using multiple nodes are the most common. The Received Signal Strength Indicator is the simplest and most cost effective way, as it is merely a property of signal propagation. Thus, not requiring specific hardware, it has gained the majority of interest. RSSI is the quantized expression of Received Signal Strength (RSS) (Shahin 2008), which directly refers to the power level of a received packet. Hence, it is greatly affected by many parameters as discussed in (Shashank 2006) and seen in the table below.

What is more; RSSI, being directly affected by the distance the signal has travelled until reaching its destination, can be used to obtain information about the source's location if more measurements from other network nodes are available. The formula proposed and RSS (and thus RSSI) relation to distance is shown in (Aamodt 2008) in the figure that follows.

$$RSSI = -(10n\log_{10} d + A) \qquad (1)$$

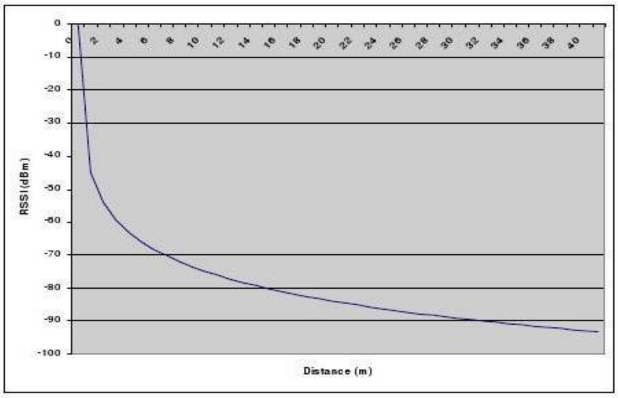

Figure 2: RSSI versus distance for A=40, and n=3

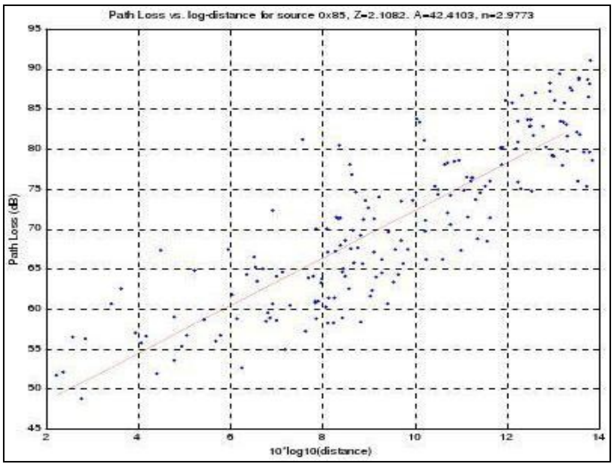

Figure 3: Path Loss vs. Log Distance

Evidently, path loss does have a great role in reducing the power level of the signals recorded. In (Texas instrument CC2431), parameter 'n' is also defined as "the path loss exponent"(although Texas Instruments uses an index analogy for parameter 'n'), highlighting even more the need of a clear line of sight when possible (Chuan-Chin and Hoon-Jae 2011).

METHODOLOGY

Clear Line Of Sight

Wireless transmissions, being waves, decay over distance. The least power loss of signals is usually observed when propagating on a path of what is known as a clear line of sight (Breeze Wireless Communications Ltd). Clear line of sight for radio waves is an imaginary straight line connecting two points of the wireless network, free - at a percentage of 80% minimum (Breeze Wireless Communications Ltd) - of obstacles in the Fresnel Zone of the signal.

Fresnel zone is defined as a circle around the theoretical line that shows the direction of a wave (Breeze Wireless Communications Ltd).

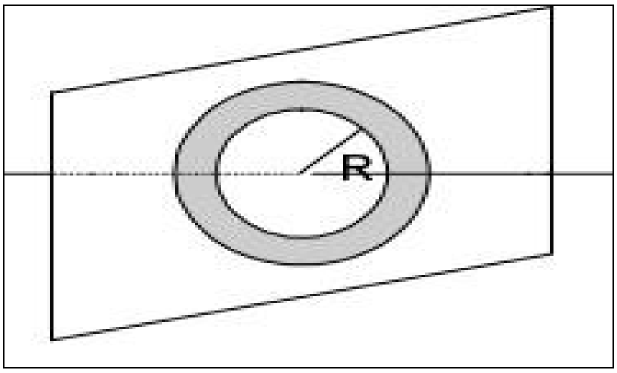

Figure 4: Fresnel Zone

$$\text{Fresnel Zone } R = \tfrac{1}{2}\sqrt{(L * D)} \qquad (2)$$

Where R is the radius of the first Fresnel zone, L is the wavelength and D is the distance between sites.

For example at 2.4GHz the wavelength is around 12cm, thus the radius of the first Fresnel zone is around 1.22 meters at 50 meters distance. Ergo, indoor deployments should avoid placements of nodes closer to ceilings or floors than 1.22 meters to refrain from blocking the clear line of sight from the start.

Being indoors can greatly distort one's view of clear line of sight in many other ways as well; mainly due to reflections, scattering, diffraction which cause, among others, a multi-path fading and shadowing of the frequency band in use. Best practice to take all these into account and minimize data loss later on, is to define the effect these have on wireless transmission on site (Tadeusz and Zepernick 2000; Erin-Ee-Lin et al. 2008).

Experimental setup followed (Tadeusz and Zepernick 2000), but in this case along a corridor with clear line of sight:

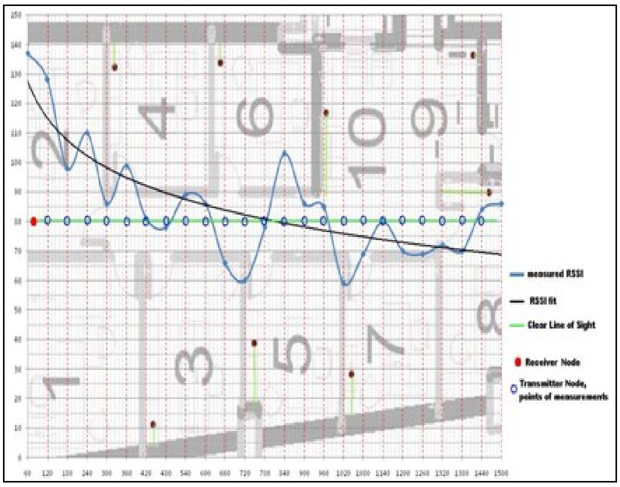

Figure 5: RSSI vs Distance over Clear Line of Sight, Indoor Corridor

Attenuation

Whenever a Radio Frequency (RF) signal loses portion of its original power, it is due to the attenuation that the medium it travels through exhibits under current circumstances. Conditions such as heat and humidity also affect signal absorption, as well as angle of incidence upon joints of different materials. Furthermore, it is evident that space travelled by a transmission may not be of uniform attenuation, hence calculating how much power the signal has in the end is not always trivial.

Attenuation unit is dB, and it is calculated via the expression below.

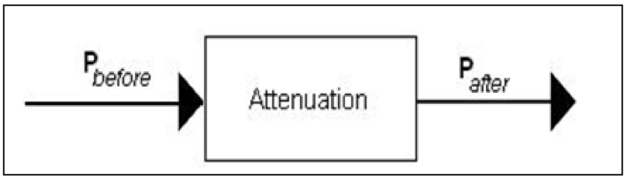

Figure 6: Calculating Attenuation Sample

$$\text{Attenuation} = 10 * \log_{10} * (Pafter / Pbefore)_{dB} \qquad (3)$$

An example of attenuation calculation is demonstrated in (Erin-Ee-Lin et al. 2008) as follows: *"If, due to attenuation, half the power is lost (Pout/Pin = 2), attenuation in dB is 10 x Log (2) = 3dB"*

In supplement to the previous statements, path loss, material absorption as well as any other reason why network link quality suffers, can be attributed to attenuation and is measured in dB.

RESULTS

Path Loss estimation

Deploying wireless networks has always been a challenging task to plan, due to the complexity of the problem. Efficiency of signal propagation depends upon a large set of environmental variables; such as obstacle frequency along signal's path, the diffraction, reflection and scattering of the signal and many more. Path loss is a quantity that describes the overall reduction of signal level which derives from the former reasons. Thus, path loss estimation is necessary as it provides valuable data for predicting when wireless communication is viable between two nodes of the network.

Calculating path loss involves correctly combining mathematical formulas concerning clear line of sight and signal absorption due to attenuation, caused by physical objects. However, one should first define the path followed itself; a difficult problem on its own. Solution to the aforementioned tasks is a tiresome repetitive procedure, given that in addition to network stability, optimal RSSI measurements are needed as well. Hence, an algorithm was developed to transform all available data to something that can be used productively.

Empirical Attenuation Calculation

One of the things that hold a primary role in path loss calculations, are the materials that indoor physical obstacles consist of. This multidimensional variable is introduced by the building structure and indoor environment complexity, cited previously - being mainly responsible for signal attenuation.

Attenuation, as previously noted, relies greatly on the kind of material in question. Obviously, preliminary knowledge of each object's material, and therefore its attenuation is of high importance when planning a wireless network deployment. Attenuation also depends on the thickness of the object, as well as the angle of arrival on the object's surface. The latter is also determined by the type of the antennas being used. Concerning omnidirectional antennas, and their waveform spreading pattern, the importance of the angle of arrival is minimized and thus not taken into consideration. The following figure shows the radiation pattern of an omni – directional antenna with its side lobes in polar form. This antenna radiates and receives in all directions in azimuth, in an isotropic way.

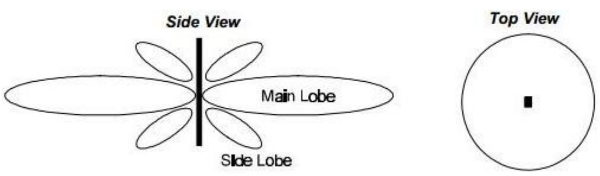

Figure 7: Omni – Directional Antenna

Finally and most importantly; given the material, a specific amount of attenuation is measured. This led to the establishment of databases that list attenuation of many standardized objects with detailed precision. Data can be extracted and used accordingly, forming tables containing data-set addressing certain needs is a common practice to tackle attenuation calculation.

However, mainly due to lacking the ability to correctly identify all materials of interest, experimental values are obtained on site as in (Shahin 2008).

Table 2: Signal Attenuation in Various Objects

Object (at Room Temperature)	Signal Frequency	Signal Attenuation (dB)
Soft cloth partition wall (2 inches)	914 MHz	1.5
Building floor	914 MHz	17
Building floor	1-2 GHz	23
Interior concrete wall (4 inches)	1-2 GHz	6
Interior brick wall (5 inches)	1-2 GHz	2.5
Plaster board	1-2 GHz	1.5
Reinforced glass	1-2 GHz	8

Procedure, known as site survey (Shahin 2008), for collecting attenuation data consists of simple steps:

- properly placing receiver and transmitter nodes at both edges of measured obstacle
- retrieve a satisfactory sample of measurements, reducing errors by using statistical tools
- define object's thickness
- divide attenuation result with object's thickness to find attenuation per length unit
- repeat steps for all kinds of objects of interest

Attenuation per length unit, for example dB per meters, can be applied for sets of obstacles consisting of the same material. Thus, it is most practical and is used by the algorithm mentioned above. It should be noted again, that attenuation does depend on signal frequency - yet it is common when deploying a wireless network to use only one specific RF band.

3D AS A TOOL TO CALCULATE COMMUNICATION STRENGTH

In this work the authors developed a 3D environment as a simulation of the real world, where the wireless nodes can be setup up effectively taking under consideration the real world obstacles (walls, furniture, metallic structures, etc). The achievement is that someone can predict communication losses, density of the network, required resources, before going on site, having only basic infrastructure information of the area.

The procedure consists of selecting the type of wireless nodes you want to add and put them in the 3D software. Then for each node you can see the strength of signal among its neighborhood nodes. The RSSI strength is then calculated with a modified site survey algorithm based on the obstacles between the node and the losses their materials causes to the signals send.

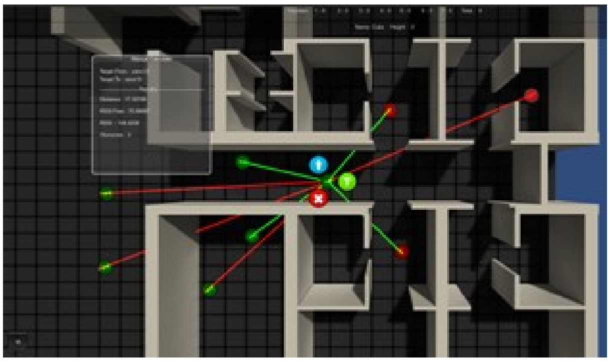

Figure 8: Wireless network with quality of signal between nodes.

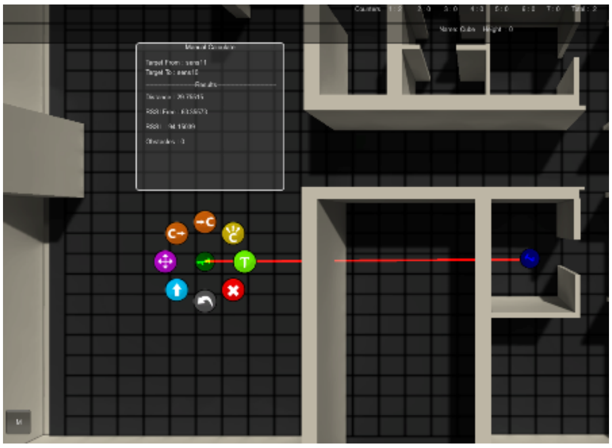

Figure 9: Obstacle identification and signal calculation among two nodes (available options visible)

CONCLUSIONS / DISCUSSION

To begin with, nowadays mainly two categories - asset and people tracking - demand a stable and useful implementation of an indoor Real Time Location System (RTLS).

Information about building structure, indoor environment complexity, quantity of wireless network nodes to be deployed, whether outdoor network coverage is expected and others, are supplied as input to a modified site survey algorithm(like the one described above). Firstly, assuming a grid that is able to cover the area of interest, nodes are assigned coordinates. At this stage the number of available nodes is ignored: the grid is arranged by the theoretical maximum communication points needed. Secondly, attenuation and actual node quantity are taken into account leading to adjustments on how the stationary transmitter will eventually form the network grid. This part utilizes the algorithm developed for path loss calculation, using attenuation data as well. Final results are demonstrated in a 3D building model for evaluation. Further manual adjustment is possible, assisted by presenting link quality in real time.

Highlight of the solution, is its specific design for optimized deployment of Zigbee Real Time Location Systems (RTLS) with minimum planning effort required. Considering particularities of the RTLS which distinctly differentiate such networks, this approach introduces significant insight in the site survey software category.

This research has a limited repository of materials tested and used during the pilot study. In order to cover greater variety, further and more detailed experiments should follow to complete the basic construction materials.

REFERENCES

Erin-Ee-Lin L., L. Boon-Giin, L. Seung-Chul and C. Wan-Young. 2008. “Enhanced Rssi-Based High Accuracy Real-Time User Location Tracking System For Indoor And Outdoor Environments”. *International Journal On Smart Sensing And Intelligent Systems*, Vol.1, No.2, June 2008, 534-548.

Shahin F. 2008. “Zigbee Wireless Networks and Transceivers”. Elsevier Ltd.

Shashank T. 2006. “Indoor Local Positioning System for Zigbee, based on RSSI”. MSc Thesis, Electronics Design in Electrical Engineering.

Aamodt K. 2008. "CC2431 Location Engine, Application Note AN042, Chipcon Products from Texas Instruments". pp. 2-8. http://focus.ti.com/lit/an/swra095/swra095.pdf [Accessed Feb 10, 2012].

Texas instrument CC2431 - System-on-chip for 2.4 GHz Zigbee/IEEE 802.15.4 with Location Engine: Data Sheet.

Chuan-Chin P. and L. Hoon-Jae. 2011. “State and Path Analysis of RSSI in Indoor Environment”. *International Conference on Machine Learning and Computing, IPCSIT.* Vol.3, IACSIT Press, Singapore. 289-293.

Breeze Wireless Communications Ltd. “Radio Signal Propagation”. http://didier.quartier-rural.org/implic/ran/sat_wifi/sigprop.pdf [Accessed Feb 10, 2012].

Tadeusz A. W. and H. J. Zepernick. 2000. "Characterization of the indoor radio propagation channel at 2.4 GHz". *Journal of Telecommunications and Information Technology*.

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