Suhas Bettapalli Nagaraj

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RADAR: An In-Building RF-based User Location and Tracking System

The main objective of this paper lies in **locating / tracking users inside a building**.

The main motivation behind this work revolves around the fact that **location aware services / applications can be exploited** for useful gain. One example could be targeted ads. Based on a user's location inside a shopping mall, ads can be sent to people for a Starbucks that is nearby which can prompt people to visit, thereby increasing Starbucks' revenues.

The authors of the paper look to first record and process the available signal strength followed by overlapping triangulation for the system to work.

Previous works have looked at IR based technology which had drawbacks such as limited range, IR can just locate but not transmit data, installation and maintenance issues among others. The authors instead propose using RF based methods which would solve issues such as improving range, scalability, maintenance and easier deployment. For experimentation, the authors build a prototype on the 2rd floor of a building. The functional components consist of a) **base stations** (Access points) and b) **mobile users**.

The authors propose two techniques to build the roadmaps : Empirical method and Radio Propagation method (RP). They also employ search techniques such as Nearest Neighbour in Signal Space (NNSS), NNSS Average and Viterbi-like algorithm.

The **data collection** is a key step in the approach. The signals are recorded as a function of the user's location. There exists two parts to this : a) Off-line analysis (**off-line phase**) as well as to infer the location of a user in real time (**real-time phase**). Following this, for every packet that has been received at the base station, the authors propose extracting : **a)** the signal strength, **b)** the noise floor at the transmitter, **c)** the noise floor at the receiver and finally **d)** the MAC address of the transmitter.

The data collection is followed by **data processing** where traces are collected from the off-line phase are then combined into a table that consists of tuples of the format :

$[x , y , d , ss_{(i)} , snr_{(i)}] , i \in \{1, 2, 3\}$ where, (x,y) = user's location, (d) = the direction, (ss) = signal strength and (snr) = signal to noise ratio at an "i" which correspond to one of the three base stations.

Empirical model : The empirical method can estimate user location with good accuracy. The median error distance is 2 to 3 meters (size of an office room - which is fairly good). 280 combinations of user location + orientation (70 points*4 orientations). This data is then used to construct search space for NNSS algorithm.

The impact of user orientation is that off-line readings for all orientations are not feasible and the work around for this is to calculate the error distance for all combinations which can be time consuming.

Some of the limitations include : **a)** significant effort is needed to construct the SS dataset for each physical environment of interest (each floor, each building, etc.) and **b)** the data collection process may need to be repeated in certain circumstances, e.g., when a base station is relocated.

Radio Propagation model : The RP model is an alternative method for extracting the signal strength information. The RP model is based on a purely mathematical model for indoor signal propagation.

The model **suffers** from a few issues, notably,

a) Reflection, scattering and diffraction of the said radio waves can hamper performance
b) Since it is a mathematical model, it needs some rework so as to compensate for the attenuation due to obstructions within the area.

The models include : Rayleigh fading model (infeasible), Rician Distribution model (Too complex) and Wall attenuation factor. Although there are issues, the advantages of RP model is that **it is cost effective** and **can easily be relocated**.

In a nutshell, Empirical model is accurate while the RF model can be easily relocated.

However, there were a few points that needed more clarity :

Questions :

1. There seems to be no mention of what the response time of the system is. Only then can we actually understand the dynamics involved.

2. While this experimental setup was done in the 2rd floor of a building, real world performance of the system has not been discussed. This would have been helpful to understand the system better.
3. Since the initial infrastructure needed is quite massive, quickly setting up the system or even expansion is not possible in a short time frame.
4. Due to the localization factor, the idea of privacy & security will take a back step.

More details about the paper

Bahl, P., & Padmanabhan, V. N. (2000, March). RADAR: An in-building RF-based user location and tracking system. In Proceedings IEEE INFOCOM 2000. Conference on Computer Communications. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies (Cat. No. 00CH37064) (Vol. 2, pp. 775-784). IEEE.