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You are facing the Mona Lisa: Spot localization using PHY layer information

The main objective of this paper is on exploring the viability of using precise indoor localization using physical layer information in WiFi systems. The authors propose using channel responses from multiple orthogonal frequency-division multiplexing (OFDM) subcarriers which can be a promising **location signature** and thus propose a system known as **PinLoc** which stands for Precise indoor Localization.

The main motivation behind this work revolves around the fact that Precise indoor localization has been a long standing problem and that it requires high location accuracy. For example, if a localization scheme incorrectly places a user in the adjacent aisle in the grocery store, or displays information about the adjacent painting, the purpose of localization is defeated. The paper discusses several existing methods such as :

1. **Cricket**: utilizes ultrasound/Radio-based infrastructure installed on ceilings to measure position very accurately.
2. **Horus**: Utilizes signal strength coming from multiple APs of 802.11 Wireless LAN
3. **UnLoc**: Dead reckoning combined with land marking system.

In comparison, PinLoc has the following **characteristics** :

1. Precise indoor localization.
2. Utilizes detailed physical (PHY) layer information.
3. Multipath signals components arrive in a given location with distinct phase and magnitude.

The distinct value of phases and magnitude aggregated over multiple OFDM subcarriers in 802.11 can provide the **fingerprint of a location**. Gathering data over all possible location in room can make a map that can be used to locate user.

Information is transmitted in modern digital radios using OFDM : $\mathbf{Y(f) = H(f)X(f)}$,

where **Y(f)** = received symbol, **X(f)** = transmitted symbol and **H** = channel frequency response (CFR)

CFR changes entirely once transmitter or a receiver moves more than a fraction of a wavelength. (12 cm for WiFi radio). CFR experiences channel fading due to changes in the environment at different time-scales.

Hypothesis :

1. The CFRs at each location look random but exhibit a statistical structure.
2. The "size" of the location (over which the CFR structure is defined and preserved) is small.
3. The CFR structure of a give location is different from structures of all other locations.

Size of location : a) WiFi has wavelength of 12cm. b) CFR cross-correlation drifts apart with increasing distance, and is quite low even above 2cm. However, PinLoc collects multiple fingerprints from around 1m x 1m spot.

Data Sanitation : Data cannot be directly used because of **unknown phase β** and **time lag Δt**. Thus, the authors propose to transform the equation to eliminate the need for the values of β and Δt.

CFR-Clustering : K-means is done with K=10. Clusters with smaller weight than a certain cutoff is dropped. It is observed that dropping small clusters don't affect the performance.

CFR-Classification : PinLoc begins by computing the macro-location based on WiFi SSIDs. The spots are shortlisted and put in the candidate set. Next, compute the distance between packet **P** sent by certain **AP** and the spots present in the candidate sets. The likely candidate spot is the one with the minimum distance.

War Driving : This is a way to collect data from multiple locations for supervised learning. In the experiment proposed by the authors, a Roomba robot is used to get data from 2cm x 2cm sized locations. The CFR is collected and then they are clustered. This however need not be from every possible location.

Accuracy : The results can be summarized as below :

1. 89% accuracy in the test location.
2. 7% false positive across 50 locations.
3. At least 3 APs to get reasonable accuracy.

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

Questions and limitations :

1. **Antenna's orientation** : The orientation plays a huge factor. In the paper, it was done on a **2D plane**.
2. **Height and 3D war-driving** : This too has been done on 2D and real world scenarios of 3D needs to be done to assess the performance in a real world environment.
3. **Phone mobility** : Mobility can affect the CFR (as mentioned at the beginning of Pg. 2) and this can severely affect the overall performance which needs to be looked into.
4. **Dependency on Particular hardware cards** : Cross-platform calibration would be necessary and rapid prototyping and changing hardware at short notice may not be possible.
5. **Localization and MIMO** : MIMO receiver provides as many CFR samples as the number of receive antennas, and could be highly valuable for localization. This could be a important point that could be incorporated.

More details about the paper

Sen, S., Radunovic, B., Choudhury, R. R., & Minka, T. (2012, June). You are facing the Mona Lisa: Spot localization using PHY layer information. In Proceedings of the 10th international conference on Mobile systems, applications, and services (pp. 183-196).