School of
Engineering and Computing Sciences

Smartphone Indoor Localization through Power Consumption

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Abstract

Indoor localization using smartphones is a popular topic with both commercial and security applications. Current GPS technologies suffer from poor indoor localization accuracy due to signal obstruction. Previous research has shown location can be derived from signal strength between a device and multiple Wi-Fi access points through triangulation. The objective of this research is to find a correlation between smartphone power consumption and indoor location. In this research project, we designed an experimental framework that collects and analyzes power consumption, signal strength, and relative position using a Google Nexus 5 phone in a controlled test environment with one wireless router. Experimental results show the correlation of energy consumption of phone vs. distance from the router through a heat map.

Background

GPS Technology:

The GPS does not perform well indoors.

Apps require permission from the user to access GPS data, as shown in Figure 1. Using GPS generally drains the phone's battery.

Figure 1:Android Permissions Model

Power Spy[1]:

Stanford researchers used power consumption on the Nexus 5 for outdoor localization. They focused on route detection and real-time tracking. They were able to recognize routes with 85% accuracy.

Wi-Fi / Sensor Fusion:

Individual research teams from Carnegie Mellon and NYIT used signal strength along with other sensors including accelerometer, gyroscope, magnetometer, etc. to achieve indoor localization.[2]

Potential Applications

Indoor Map:

Smartphone users may have applications to aide indoor navigation, e.g.: college campus, mall, or subway.

Robotic Navigation:

Wireless devices could have automated localization so they can be programmed to move with more accuracy.

Device Tracking:

Lost or stolen phones could be tracked and found quickly.

Malware:

Apps can secretly track users physical location without their consent.

Methodology

Pings with significant packets size are sent from the smartphone to the router in a Wi-Fi network.

Factors including distance and interference affect the signal strength the between client and server. Signal strength affects power consumption.[3]

Figure 2: Distance vs. Signal Strength and Power Consumption- The further a phone is from router, the less signal strength and more power is consumed to ping router.

Data Collection

We created an android application in Java to help us profile the 11th Floor Auditorium of NYIT's Manhattan campus. The app makes a csv file for each sample location we choose.

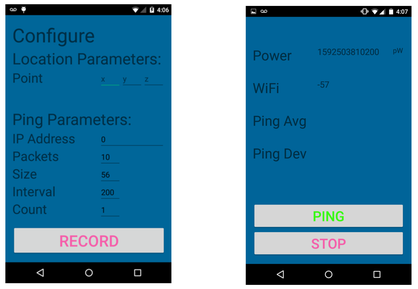

Figure 3: Android Application Screenshots- Allows user to input location coordinates, control ping parameters, time ping samples, and record power consumption.

Figure 4 shows the spikes in power consumption of the Nexus 5 phone while pinging. In this experiment, 10 pings were sent. We used a Google Nexus 5 phone to record power consumption of the phone with no other apps running in the background, which allowed us to generate a power consumption baseline. Here, we are interested in the energy consumed by the phone while the phone was pinging.

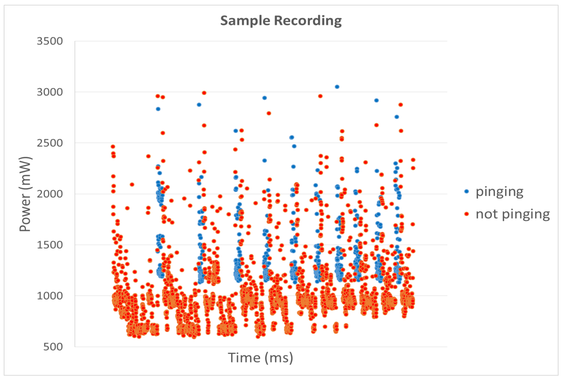

Figure 4: Power vs. Time

Results

We gridded the floor into small tiles and measured the power consumption at various points. Figure 5 shows the scatter map of the energy consumption of phone at different locations using MATLAB and Java. This was done while pinging ten 10 kilobyte packets at an interval of 200 ms to the router, which is depicted as a blue triangle on the top right corner.

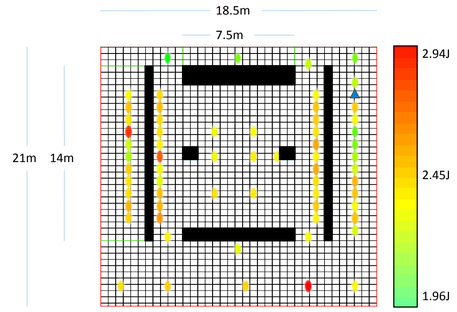

Figure 5: 11th floor Auditorium Power Consumption Map

This data was displayed in a heat map using MATLAB in Figure 6. The router position is displayed by a white triangle in the top right corner.

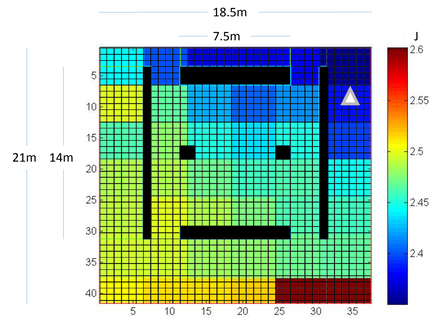

Figure 6: 11th floor Auditorium Heat Map

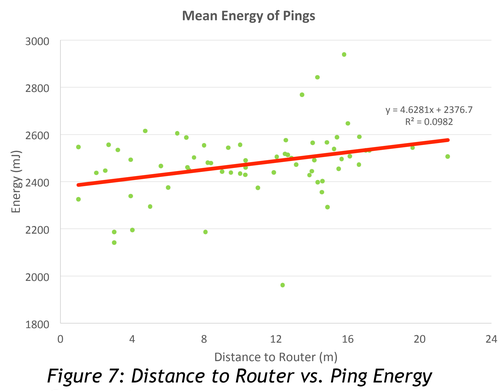

Figure 7: Distance to Router vs. Ping Energy Consumption

Results (cont.)

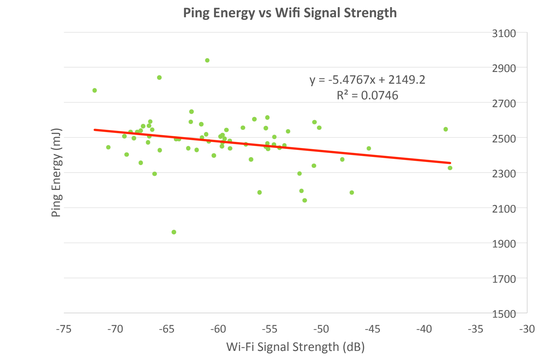

Figure 8: Wi-Fi Signal Strength vs. Ping Energy

Discussion

The heat maps in Figures 5 and 6 show how the energy of pings changes with respect to location. Generally the areas closer to the router yield lower energy consumption. The rightmost hallway, which is in direct line-of-sight with the router, shows the strongest trend. With minimal obstruction and reflection there was a gradual increase in power consumption with distance. These trends show how one can possibly create a power profile of the floor and use this to locate the phone. Figures 7 and 8 yield the following statistical statements. There is 30% correlation between distance (phone—router) and ping energy. There is 27% correlation between signal strength and ping energy.

Further Research

The next steps in this project would be to use multiple access points and to use classification techniques to actually infer the location from power consumption. Furthermore other key data such as ping time and signal strength could potentially improve localization accuracy. Once inferring location using power consumption is accurate enough without motion, the following challenge would be to implement sensor fusion to do real time tracking. Ideally localization with power consumption would impact the user as little as possible, therefore would not need to ping in order to get data. Instead it would monitor the power consumption of other apps on the phone that are connected to internet.

Acknowledgement

• The project is funded by National Science Foundation Grant No.1263283 and New York Institute of Technology.

References

[1] - Michalevsky, Yan, Gabi Nakibly, Aaron Schulman, and Dan Boneh. "PowerSpy: Location Tracking using Mobile Device Power Analysis." *arXiv preprint arXiv:1502.03182* (2015).
[2]- Kothari, Nisarg, Balajee Kannan, Evan D. Glasgwow, and M. Bernardine Dias. "Robust indoor localization on a commercial smart phone." *Procedia Computer Science* 10 (2012): 1114-1120.
[3]- Ding, Ning, et al. "Characterizing and modeling the impact of wireless signal strength on smartphone battery drain." *ACM SIGMETRICS Performance Evaluation Review*. Vol. 41. No. 1. ACM, 2013.