Poster: Occupancy State Detection using WiFi Signals

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ABSTRACT

A large amount of energy could be saved by detecting home occupancy and automatically controlling the lights, HVAC, water heating, and other mechanical systems. Existing systems rely on motion information, which usually fail to detect occupied rooms with stationary people. In this project, we study the possibility of converting commodity WiFi access points to occupancy sensors by exploiting multipath reflections as individual spatial sensors. The proposed method measures fine-grained distortions caused by human body on phase and amplitude of WiFi signals. Our initial results suggest that formulating WiFi parameters into angle of arrival provides a more sensitive metric to measure occupancy.

1. WIFI-BASED DETECTION

Homes, the spaces we spend more than 60% of our time in, are becoming increasingly automated, with automatic control of lights, heating and cooling systems. However these smart applications require knowledge of the occupancy state of the spaces in a home. Such knowledge can benefit both monetarily and environmentally, as homes consume nearly 40% of the total US energy budget, and 70% of all electricity, with heating and cooling responsible for nearly 45% of it [1].

Recent advances in wireless techniques such as MIMO-OFDM have extended its use to a device-free human sensing tool. The previous WiFi-base detection works [2] require the mobility of the target to detect signal interference with human body. To overcome this limitation, we leverage on the ubiquity of commodity WiFi devices to detect both the stationary and moving targets. The presence of several WiFi-enabled devices in a building such as laptops or smart TVs creates a wireless mesh, which can serve as a sensor network and provides rich information about the environment. However, in indoor places such as homes, WiFi signals suffer from rich multipath propagation, which distorts the received signal and masks the weak signal variations produced by the stationary body. Hence, monitoring disturbance on wireless signal strength is ineffective for occupancy detection.

MobiSys'17 June 19-23, 2017, Niagara Falls, NY, USA

ACM ISBN 978-1-4503-4928-4/17/06.

DOI: http://dx.doi.org/10.1145/3081333.3089305

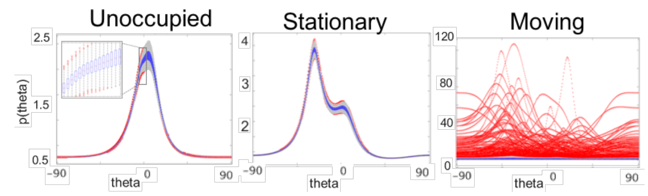

Figure 1: Changes in multipath characteristics of empty room in the presence of people.

In this project, we take advantage of the multipath distortions by converting them into a stable metric to detect occupancy. For that, we resolve and analyze multipath reflections of an empty room and characterize superimposed signals with their angle of arrivals. Then, we detect a person's presence by looking for changes in the multipath environment. We hypothesize that analyzing multipath reflections is a more sensitive approach because people affect the multipath reflections even when they are perfectly still, while other approaches require the person to be moving at least a little bit.

Figure 1 illustrates the presence effect of a person on the resolved AoA pseudo-spectrum for a sample experiment. The figure contains the variations in the power values for each angle across 1000 packets shown in a boxplot. Changes in the resolved angles of the scenario with a stationary target, and temporal changes caused by movements of the moving target reveal that the multipath resolution and resolved angle of arrivals play a key role in determining the occupancy. To implement this idea, we leverage the PHY layer Channel State Information (CSI) provided by commercial WiFi NICs, which provides fine-grained channel responses at the granularity of OFDM subcarriers. To evaluate this hypothesis, we do an in-depth analysis with different occupancy states of unoccupied, stationary target, and moving target. Our initial results show that we can detect the occupancy states with 96.7% accuracy, compared to the conventional signal strength-based solution with 56.1% and 76% accuracies.

2. REFERENCES

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