# Poster Abstract: Human Tracking and Activity Monitoring using 60 GHz mmWave

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***Abstract*—We propose human mobility tracking and activity monitoring using 60 GHz millimeter wave (mmWave). We discuss the benefits of using mmWave signals for the purpose over existing 2.4/5 GHz based techniques. We also identify related challenges of determining human's initial location and tracking, and demonstrate the feasibility of activity monitoring using an example of walking activity.**

## I. Introduction

Tracking human mobility and monitoring activities are of great interest for applications ranging from ubiquitous computing, healthcare to enabling smart homes/offices. Compared to wearable-based approach which requires users to carry/wear a sensing device, sensing approaches based on RF (Radio Frequency) can enable device-free and contactless human tracking and activity monitoring. RF-based sensing has been utilized in device-free human localization and even in determining fine-grained human motion for gesture recognition [1]. Most of the existing work leverages 2.4/5 GHz bands for designing RF sensing techniques. These techniques have shown to have the limitations of rich signal multi-path, low accuracy, complex signal processing methods and necessity to maintain a controlled environment. Although previous work can track human body by sweeping a very large bandwidth of 1.7 GHz in 6 GHz band [2], it is very difficult to conduct human activity analysis while tracking a person. Existing works either require a person to stay stationary and detect the person's activities [1], [3] or purely track and localize a moving person [2]. Such systems have limited practical usage scenarios, since many applications require conducting activity analysis while a person is moving. Another design challenge remaining in existing research is the complex training and calibration process. It is required to train the system properly in order to conduct the analysis. Such training procedure has to be repeated for different locations and users, and there is a lack of an existing technique that allows activity monitoring in a deterministic and unsupervised way.

To overcome the limitations of existing RF-based sensing techniques, we seek to design a solution that can track a moving person and analyze her activities at the same time. Such a technique is useful in applications like mobile interaction in smart homes/offices, gesture recognition and contactless health monitoring. To track and analyze the activities of a moving person is challenging to achieve purely based on wireless signals. Current techniques rely on signal phase/strength variation or Doppler patterns to detect human activities, however, the location changes introduces complex variations for 2.4/5 GHz signals, which makes it difficult to track and monitor at the same time.

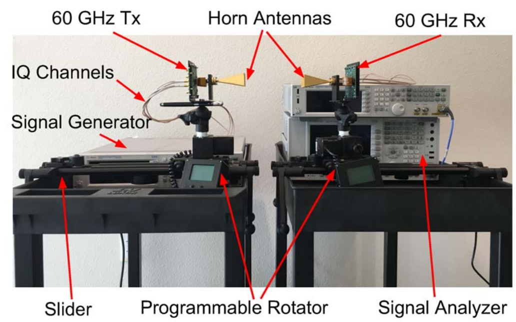
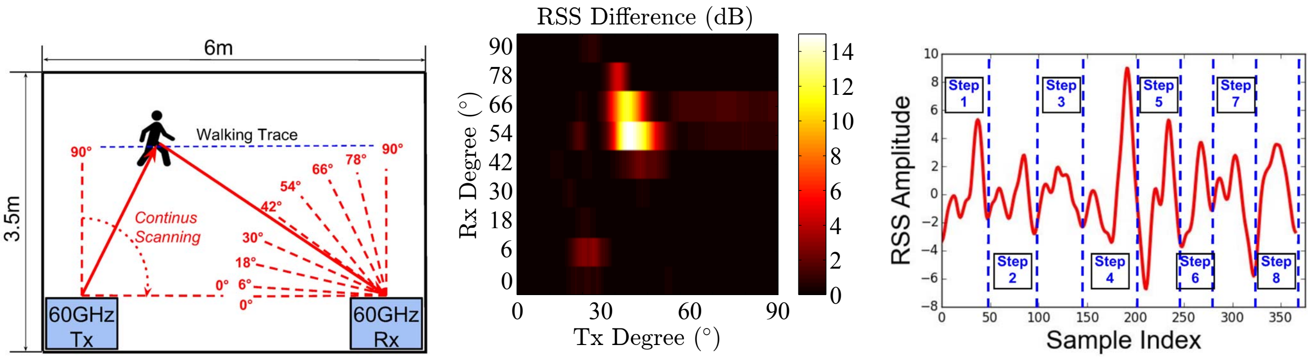



Fig. 1: 60GHz transmitter and receiver system setup

In this paper, we propose a real-time system to track a moving person and conduct activity analysis using 60 GHz mmWave radios. 60 GHz mmWave frequency band provides over 7 GHz (57-64 GHz) unlicensed spectrum. Standardized by IEEE 802.11ad, mmWave band is shown to enable high-speed (up to 7 Gbps) wireless connectivity, which makes 60 GHz network an attractive choice for next-generation wireless local/personal area networks [4]. With rapid proliferation of 60 GHz-based devices, we reuse the existing devices for the purpose of human tracking and activity monitoring. Although recent work [5] has shown to use 60 GHz mmWave for tracking small objects with high-precision, our objective is to track and analyze human activity with unique challenges. Comparing to conventional 2.4/5 GHz bands, 60 GHz mmWave signal exhibits higher path-loss, requiring the use of directional antennas (horn or phased array). Due to a shorter wavelength, it allows us to design small phased-array antenna with dozens of elements. Such phased-array antenna creates highly-directional beams with fast electronically steerable functionality. The beamforming results in reduced multi-path and a more tractable measurement and analysis of reflections, which in turns increases the accuracy of tracking and activity monitoring.

## II. Human Finding and Activity Monitoring

We build a system to track a person and further monitor her activity while moving. The system consists of three major components: 1) human finding, 2) human tracking, and 3) activity monitoring. We first introduce our experiment setup. Then, we briefly discuss human finding module and use




(a) The layout of the experiment for human finding and walking analysis

(b) Heatmap profile for initial human finding process

(c) RSS profile for walking activity

Fig. 2: The experiment layout and human finding and walking analysis results

walking as an example to explain the activity monitoring module.

### *A. Experiment Setup*

We implement the system using Vubiq [6] 60 GHz development platform shown as Fig. 1. The platform provides a 60 GHz RF front-end and a waveguide module. We generate a 10 MHz baseband signal using a signal generator (Keysight EXG N5172B) as an input to Vubiq transmitter module. The 60 GHz receiver module is connected to a spectrum analyzer (Keysight EXA N9010A) for analyzing received baseband signal by calculating the Received Signal Strength (RSS). The sampling rate to collect RSS values is 62 Hz. Due to the unavailability of reconfigurable 60 GHz phased-array antenna, we use a horn antenna with 3-dB beamwidth of 12°and 24 dBi gain on both transmitter (Tx) and receiver (Rx) sides. A fine-resolution programmable rotator is used to conduct the beam steering and rotating.

### *B. Human Finding and Tracking*

In order to track a person, we need to first determine the initial location of the person. Considering a typical indoor space, Fig. 2a shows our experiment layout. We put 60 GHz Tx and Rx at the corners of the room and perform 90°scanning of the entire room. The Tx performs a continuous scanning with a fine-grained resolution of 0.03°from 90°to 0°. To reduce the finding time, the Rx scans in a discrete manner with an angular resolution of 12°. Note that the reason of choosing 12°is because the 3-dB beamwidth of the horn antenna is 12°. For each angle of the Rx, the Tx performs 90°continuous scanning and record the RSS values on the Rx side. Assuming that the distance between Tx and Rx is known, the location of the person can be calculated by determining Tx angle and Rx angle. We first do a brute-force 90°scanning for both Tx and Rx, constructing the RSS profile when there is no person presented in the room. Next, when there is a person in the room, we repeat the same procedure again and construct the RSS profile. We calculate the RSS difference between the two profiles. Fig. 2b shows the heatmap of the absolute RSS difference values. Due to the reflection changes introduced by the person, we observe that the points with highest density represent the initial location of the person. In our ongoing work, we are extending the human finding procedure to tracking, where the Tx and Rx beams follow the user by continuously monitoring the RSS change around the initial location of the user.

### *C. Activity Analysis*

Due to the highly-directional beams of 60 GHz mmWave, we need to rotate the Tx and Rx in order to maintain the signal always being reflected from the person we are trying to track. Assuming we can track the moving person accurately, the next step is to conduct activity analysis. Here we use walking activity as an example to show our initial results on activity monitoring. Fig. 2c shows the RSS profile when a person is walking along the walking trace shown in Fig. 2a. We collected the raw RSS data from the Rx and then process it with a band-pass filter (0.8 Hz to 4 Hz) to remove the DC component as well as high frequency noise. We can observe repeated RSS variation patterns indicating individual step as labeled in Fig. 2c. Since each location has different incident angle of reflecting the signal, the actual reflected RSS value will be different. We can see that step 4 has the best incident angle for the reflection, so we observe more signal being reflected (higher RSS amplitude). By analyzing the RSS profile, we can track the person and count the steps of walking activity. In our ongoing work, we are also developing novel methods of monitoring other activities of the human using the reflection characteristics, such as gesture recognition and vital sign detections.

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