Poster Abstract: Towards Wide-Area Contactless Human Sensing

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ABSTRACT

Contactless wireless sensing without attaching a device to the target has achieved promising progress in recent years. However, one severe limitation in this field is the limited sensing range. This paper presents WideSee to realize wide-area sensing with only one transceiver pair. WideSee utilizes the LoRa signal to achieve a larger range of sensing and further incorporates drone's mobility to broaden the sensing area. We have developed a working prototype of WideSee for human target detection and localization that are especially useful in emergency scenarios like rescue and terrorist search. We also evaluated WideSee with field study in a high-rise building, which demonstrates the great potential of WideSee for supporting wide-area contactless sensing applications with a single LoRa transceiver pair hosted on a drone.

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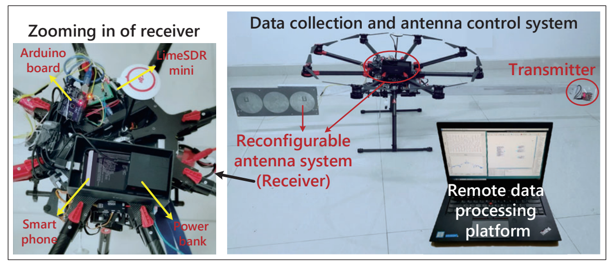

Figure 1: Overview of WideSee. We use a drone to carry the LoRa transceiver pair and its control system. The data are sent back to the remote data processing platform to perform real-time target detection and localization.

1 INTRODUCTION

Besides traditional data communication, in recent years, wireless signals have been employed for contactless sensing and have enabled new applications, such as indoor navigation, health care, and human-computer interactions. However, one evident issue with existing contactless wireless sensing is in its limited sensing range. This is mainly because the signals reflected from the target, which contain information related to the context of the target, are much weaker than the direct-path signals between the transmitter and receiver. The fact that contactless wireless sensing captures information from the reflected signals makes the sensing range much smaller compared to when the signals are used for communication purposes. For example, the current WiFi-based systems are capable of performing sensing in a room-level range (i.e. approximately 3-6 *m*) [2, 4], whereas RFID or mmWave-based systems show an even smaller sensing range of 1-3 *m* [3, 5].

Recently, efforts have been made to extend the contact sensing range of wireless signals. Ashutosh *et al.* introduced an approach to employ multi-hop nodes to track the sensor attached targets that are located deep inside a building structure [1]. In another example, Ma *et al.* leveraged drones to relay sensing information, which extends the contact sensing range from 5 *m* to 50 *m* [6]. Employing multiple devices or multi-hop transmission schemes can increase the sensing coverage range. However, such approaches require a complicated process of sensing infrastructure deployment and could be vulnerable to changes or failure of even a single device.

In this paper, we present WideSee– a contactless wireless sensing system based on the emerging LoRa technology *with only a single transceiver pair*. WideSee is designed to push the boundary of wide-area sensing. Our key insight is that the low-power, long-range wireless communication capability of LoRa offers a long propagation range (i.e., several kilometers) and a strong penetration capability through obstacles, which in turn can be used to significantly increase the sensing range compared to other existing wireless technologies. In this work, as a proof-of-concept, we explore the opportunities of the LoRa technology for non-contact human target sensing in wide-area scenarios. To further increase the sensing area coverage, we leverage the mobility of a drone to carry the transceiver and move around the target area to perform wireless sensing. We believe the proposed study is particularly useful for human target sensing (detection and localization) for applications in urban search and rescue missions, such as rescue in natural disasters like earthquakes, hurricanes, and tsunamis in the urban areas, as well as terrorist search and security surveillance.

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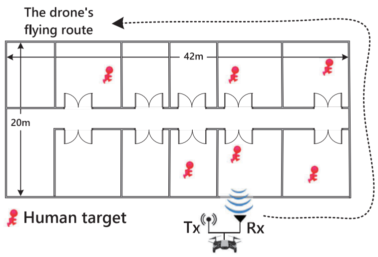

Figure 2: Building-scale experimental setup.

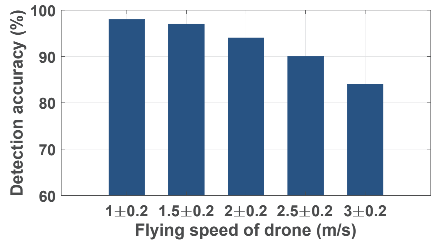

Figure 3: Target detection accuracy in building-scale field study.

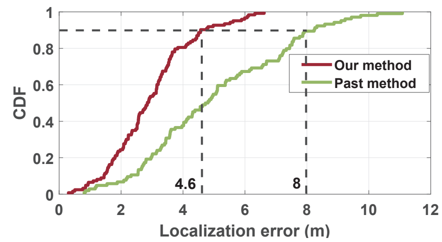

Figure 4: CDF plot of the localization error.

2 OVERVIEW OF WIDESEE

WIDESEE is a prototyping wide-range contactless human target sensing system built upon a single LoRa transceiver pair. The transceiver pair (both the transmitter and receiver) is carried by a drone so that by flying the drone WIDESEE can scan and sense a large area. Having a small, lightweight design for WIDESEE is essential to maintain a good endurance for the battery-powered drone. We focus on moving target sensing in this work.

WIDESEE operates by first transmitting the LoRa signal, and then capturing and analyzing the resultant signals from the direct signal path and reflections off the target and surrounding objects to detect the presence and location of the target. WIDESEE models how a human ambulating affects the received signal to sense human target.

As depicted in Figure 1, WIDESEE consists of three innovative components:

- A compact, *reconfigurable antenna system* to reduce the interference from uninterested areas. To ensure the sensing area during a certain time and adapt to the mobility of device, the antenna should be able to adjust its direction and radiation pattern in a dynamic and fast manner.
- A *data collection and antenna control system*, which includes a LoRa transmitter and receiver, a data collection subsystem, and a drone. The drone carries the LoRa transceiver pair and the data collection subsystems to fly around the target region. The collected LoRa signal data are sent back to a laptop (through a LTE mobile network) to be processed on the ground.
- A *target detection and localization system*, which runs on a data processing platform, i.e., a laptop in our case. The system analyzes the collected data to detect and localize the human target. Based on the calculation, the antenna control system employs an Arduino board carried by the drone to configure the antenna radiation pattern accordingly.

3 BUILDING-SCALE FIELD STUDY

In this field study, we employ WIDESEE with drone (see also Figure 1) to perform building-scale sensing. The task is to detect and track a human target located on the 9th floor of a 17-floor building structure with a size of $20 \times 42 \times 85\ m^3$. Note that this new building had no occupant at the time of our experiment. The thicknesses of the concrete walls and glass windows are $40\ cm$ and $5\ cm$, respectively. The transceiver pair was carried by a drone in this experiment. The distance (i.e., the LoS length) between the transmitter and the receiver is $2\ m$. Ten student volunteers participated in this study, serving as the target one at a time. Figure 2 shows the experimental setup. The students were arranged to walking in rooms on the same floor. We manually control the drone to fly to an initial position of the 9^{th} floor, and then let our data processing platform (Section 2) to control the drone's fly. We varied the flying speed of the drone in experiments.

Figure 3 shows the detection accuracy for each human target who was walking. When the drone was flying at a low speed of $1 \pm 0.2\ m/s$, WIDESEE can successfully detect 98% of the human targets who were walking. As expected, the detection accuracy decreases as the drone's speed increases, but WIDESEE is still able to detect the target most of the time. Once we have detected a moving target, we hover the drone for 2 seconds to collect the target movement information, and apply the localization algorithms described in Section 2 to estimate the target position. Figure 4 compares the localization error of our approach against the the state-of-art – Dynamic-Music [4] for localization. As can be seen from the figure, our approach delivers a better localization accuracy over Dynamic-MUSIC. It reduces the localization error from $8\ m$ to $4.6\ m$ for over 90% of the test cases. This is a significant improvement because in practice such a precision improvement would allow us to identify which rooms of a building a human target is located. This is particularly useful in disaster rescue where we might want to prioritize the rescue of survivors.

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