Poster Abstract: LocTag: Passive WiFi Tag for Robust Indoor Localization via Smartphones

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***Abstract*—Indoor localization via smartphones has attracted many researchers' attention over the past few years. However, it still lacks a mature solution robust to complex indoor environments. In this paper we design LocTag, the first passive WiFi tag for localizing commercial off-the-shelf smartphones in arbitrary indoor environments with or even without APs (Access Points) deployment. Unlike conventional passive WiFi tags, LocTag backscatters ambient WiFi signals from APs or smartphones for localization instead of communications. To do so, we propose several techniques including triggering source selection, WiFi compatible modulation, and random multiple access. We prototype LocTag using a FPGA (Field Programmable Gate Array) and apply it in a typical indoor localization scenario. The experiment results show that sub-meter level accuracy is achieved via LocTag. Although our work is still at its early stage, it sheds new light on the robust indoor localization via passive WiFi tags.**

***Index Terms*—indoor localization, smartphone, passive WiFi tag, backscatter**

I. Introduction

Indoor localization via smartphones has attracted more and more researchers' interests over the last few years due to the popularity of smartphones. Smartphone indoor localization algorithms make use of sensors equipped with smartphones, such as WiFi, IMU (Inertial Measurement Unit), light, and acoustic sensors, *etc.*. However, most of the existing algorithms are designed for one specific indoor environment, and thus suffer poor performance in another environment. For example, some WiFi-based algorithms are designed for indoors with high-density APs, and thus cannot achieve high accuracy in indoors with sparse APs. Furthermore, the performance of light-based algorithms are limited by light sources (LED or others); Acoustic-based are usually suitable for narrow space such as corridors, to name a few. Therefore, it still lacks a robust smartphone indoor localization system in arbitrary indoor environments.

In this paper, we aim to achieve robustness to arbitrary indoor environments with high localization accuracy by designing a novel passive WiFi tag, LocTag. As a passive tag, LocTag backscatters ambient WiFi signals from APs or smartphones. Since signals are backscattered, there is no requirement of WiFi transceivers, leading to low cost and ease of maintenance [1]. Moreover, LocTag is able to communicate directly with COTS (Commercial Off-The-Shelf) smartphones without extra hardwares.

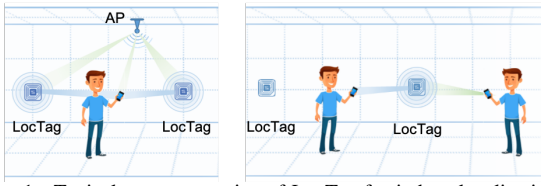

Fig. 1. Typical usage scenarios of LocTag for indoor localization.

Typical usage scenarios of LocTag for indoor localization are shown in Fig. 1. LocTags are attached to surfaces of walls or objects indoors. When a user wants location service, she starts the localization applet on her smartphone. The smartphone then reads backscattered signals from several LocTags nearby, and provides location information to the user by using a localizing algorithm. Where there are APs, LocTags are triggered by APs as in the left in Fig. 1. Where there are not APs (e.g., underground parking lots), LocTags are triggered by smartphones nearby as in the right scenario. Therefore, LocTag provides a robust localization solution for complex indoor environments, independent of AP deployment.

However, the design of LocTag for indoor localization is very challenging. Traditional passive WiFi tags cannot be used directly. Most of them are designed for low-cost communications, requiring either specialized hardware to trigger tags or modifications to WiFi devices to receive tag's signal [2]. Therefore, we propose several techniques both in hardware and in software to make LocTag suitable for localization. We prototype LocTag and deploy a localization system in a 7.4 m $\times$ 5 m area in an office building. The average localization error is 0.75 m, achieving sub-meter level accuracy.

In summary, our contributions are two-fold:

- Unlike prior works aiming to low-cost communications, we design a novel passive WiFi tag LocTag for indoor localization. To the best of our knowledge, this is the first passive WiFi tag that localizes smartphones robust to complex indoor environments.

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- We prototype LocTag and deploy it in a typical indoor environment. Experiment results show that sub-meter localization accuracy is achieved via LocTags.

II. LocTag Design

The functional architecture of LocTag is shown in Fig. 2. Unlike conventional passive tags, LocTag adds several new functions, including triggering source selection, WiFi compatible modulation, and random MAC (Multiple Access Control) protocol, which enable LocTag suitable for indoor localization.

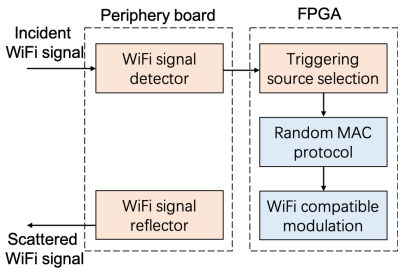

Fig. 2. Functional architecture of LocTag.

Triggering source selection. LocTag is triggered by ambient WiFi signals from APs or smartphones. To avoid backscattering too many signals, we add an ADC (Analog-to-Digital Converter) to enable ambient WiFi sources selection as shown in Fig. 3. The ADC measures signals with strength higher than a threshold and then inputs them to the FPGA (Field Programmable Gate Array). The FPGA decides to backscatter the signal according to the MAC protocol. In this way, only a few ambient WiFi sources are chosen to trigger tags.

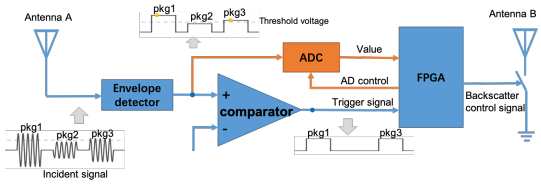

Fig. 3. LocTag hardware diagram.

WiFi compatible modulation. LocTag modulates signals by on-off frequency shifting subframes in an A-MPDU (Aggregated-MAC Protocol Data Unit) packet available in IEEE 802.11n/ac. Frequency shifting is a technique to avoid self-interference [3]. In particular, the receiver works in an adjacent non-overlapping WiFi channel with the triggering source. LocTag transmits "1" by backscattering a subframe with frequency shifting, and "0" by not reflecting a subframe. Thereby, the receiver can decode the data by checking the status of subframes received. This enables standard compliant communication using 802.11n/ac networks without hardware modifications to smartphones (i.e., receivers).

Random MAC protocol. If multiple LocTags backscatter the same signals simultaneously, a collision will be caused at a smartphone. To avoid the collision, we design a random MAC protocol under the constraints of hardwares. Particularly, LocTag decides whether to backscatter a signal according to a random variable p, which depends on the voltage value of triggering sources measured by the ADC. Therefore, LocTags backscatter signals at different time with high probability.

III. Implementation and Evaluation

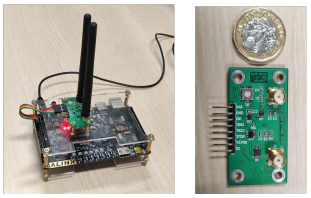

Fig. 4. Pictures of LocTag.

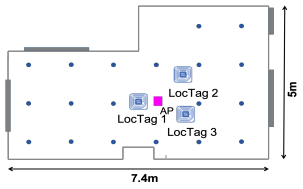

Fig. 5. Experiment scenario.

We build a prototype of LocTag shown in Fig. 4. The left is LocTag in working, and the right is the periphery board. Following the design in Fig. 3, the ADC uses an AD7478. The envelop detector uses a LT5534. The voltage comparator uses a LMV7239. LocTag modulation and MAC protocol are implemented in a XILINX Zynq xc7020 FPGA evaluation kit.

We carry out experiments in an office building on our campus. The floor plan is shown in Fig. 5. Three LocTags are placed in the office. Currently, we adopt 1 AP as a triggering source, and a DELL laptop equipped with an Intel 5300 NIC (Network Interface Card) to simulate a smartphone. We will exploit smartphones as triggering sources and receivers in our future work.

We put the laptop on each spot shown in Fig. 5, and collect CSI (Channel State Information) there. Then a CSI fingerprint-based localization algorithm is employed to estimate the location. The average localization error is 0.75 m. In our future work, other localization algorithms will be studied to make full use of LocTags and to improve localization accuracy as well.

IV. Conclusion

We have designed a novel passive WiFi tag LocTag for robust indoor localization with high accuracy. LocTag has been prototyped and deployed in a typical indoor environment. Experiment results show that sub-meter level accuracy is achieved based on LocTag. Although our work is still at its early stage, we believe that LocTag provides a promising smartphone indoor localization solution robust to complex indoor environments yet with high accuracy.

References

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