Towards Ubiquitous Sensing Using Wi-Fi Beamforming Feedback

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1 Overview

Wi-Fi sensing systems benefit from widely deployed Wi-Fi devices and thus enable sensing across a diverse range of applications such as mobile healthcare, security monitoring, Human-Computer Interaction (HCI), etc. However, existing Wi-Fi sensing systems rely on Channel State Information (CSI), and the accessibility of CSI is significantly constrained. The process of capturing and recording the CSI is currently not supported by the IEEE 802.11 standard. Consequently, custom-tailored firmware modifications and specific Wi-Fi Network Interface Cards (NICs) are required for the extraction of CSI. Whereas, in reality, current Wi-Fi devices are equipped with a wide range of NICs that operate with the original firmware provided by manufacturers. Therefore, this project proposes to enable ubiquitous Wi-Fi sensing with Beamforming Feedback Information (BFI) which is transmitted in clear text and can be easily recorded using most Wi-Fi NICs without any firmware modification. This project will develop a generalized BFI-based Wi-Fi sensing framework under realistic communication scenarios. This project will be evaluated using real-world test beds.

2 Intellectual Merit

This proposal will construct a generalized BFI-based Wi-Fi sensing framework that can enable ubiquitous sensing capabilities utilizing current Wi-Fi infrastructures without the need for special NICs and firmware modifications. We will propose three modules to build the framework.

First, in *Wi-Fi Signal Probing* module, the access point communicates with multiple stations using Wi-Fi signals and the signals also probe human subjects, objects, and the physical environment. The human bodies or objects will interact with the signals. Another Wi-Fi device (i.e., sniffer) can sniff ambient traffic to collect the BFI of the Wi-Fi links.

Next, the collected BFI will go through *Signal Processing* module, where this project will address several research challenges: (i) This project will extract BFI from real-world Wi-Fi communication involving multiple stations and the contention-based medium access mechanism, resulting in bursty and intermittent traffic patterns. Hence, this project will recover continuous channel variations from a BFI time series with sparse samples. (ii) In theory, the AoA and AoD are contained in the antenna domain of BFI, and DFS and ToF are contained in the frequency and time domains of BFI, respectively. However, in the wireless sensing community, the full potential of the BFI-based estimation of multidimensional information has not been investigated. This project will customize estimation algorithms, such as the MUSIC algorithm and maximum likelihood estimation, to achieve multidimensional information estimation for BFI. (iii) In this project, the fine-grained spatial information provided by AoA, AoD, and ToF will enable BFI to distinguish and separate multiple targets within the 3D space.

Finally, this project will develop *Application-orientated Model Construction* module which can leverage both modeling-based and learning-based methods to achieve different applications including HCI, mobile healthcare, smart home, and security.

3 Broader Impacts

This project can facilitate interdisciplinary research by fostering collaboration across fields such as wireless communication, deep learning, human-computer interaction, mobile healthcare, privacy, and security. Additionally, it is anticipated to introduce innovative methods for developing a variety of mobile and wireless applications such as activity recognition, localization, user authentication, etc. The research and outreach activities will be integrated into the university educational programs which will involve curriculum development, participation of undergraduate and graduate students, engagement of female and minority students, and initiatives to enhance K-12 education.