Demo Abstract: Accessible WiFi sensing leveraging Robot Operating System

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ABSTRACT

RF signals can be effectively leveraged to fill in the gaps left by visual sensors like Cameras or Lidars [1]. Despite the advantages to leveraging WiFi sensing modality, there are no accurate, versatile, and tractable WiFi sensors available for the systems community to use. We develop WiROS to address this immediate need, furnishing many WiFi-related measurements as easy-to-consume ROS topics. Specifically, WiROS is a plug-and-play WiFi sensing toolbox allowing researchers to access coarse-grained WiFi signal strength (RSSI), fine-grained WiFi channel state information (CSI), and other MAC-layer information (device address, packet id's or frequency-channel information). Additionally, WiROS open-sources state-of-art algorithms to calibrate and process WiFi measurements to furnish accurate bearing information for received WiFi signals. The open-sourced repository is:

WiROS:https://github.com/ucsdwcsng/WiROS.

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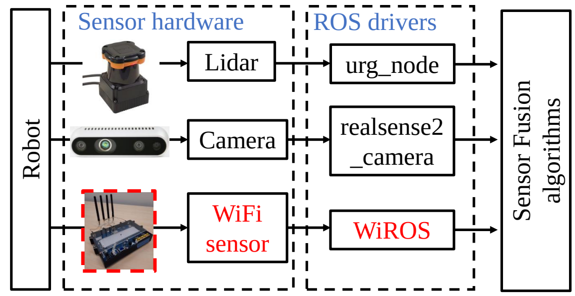

Figure 1: The sensor hardware, like cameras and Lidars have widely supported ROS nodes. This work releases WiROS, a similar ROS node compatible for WiFi sensors.

1 INTRODUCTION

Incorporating wireless sensing into a robotics sensor stack allows robots to better handle the failure cases of visual sensors like cameras or Lidars. Many recent works [1] have shown that integrating wireless signals helps to overcome common failure cases like visual occlusion, dynamic lighting or perceptual aliasing [10]. Among the various wireless-sensing modalities explored, leveraging WiFi sensing is particularly attractive. It is widely deployed in many indoor environments, most robots already have WiFi chipsets for communication purposes and it provides a long sensing range (over 10 m). With this in mind, many recent papers [1, 7] explore using WiFi signals.

However, leveraging the advantages of WiFi sensing is challenging as there are no easy solutions for integrating WiFi sensors into an existing robot's sensor stack. Popular cameras [6] and Lidars [5] have clear documentation and are widely supported within the Robot Operating System (ROS) framework. ROS support allows for quick integration and easy operation of these sensors. The same, unfortunately, does not exist for WiFi sensors, inhibiting their adoption in the wider robotics community. In this work, we present WiROS to fill in this gap. WiROS develops a set of ROS nodes that furnishes raw and processed WiFi measurements as ROS topics (CSI Node), provides an easy-to-perform wireless calibration framework and provides visualization, verification, and debugging toolkits (Processing Node).

WiROS's broad goal is to provide an accessible WiFi sensor within robot sensor stacks to allow roboticists to leverage the advantages of WiFi signals, as can be done for Cameras and Lidars (Fig. 1). In this vein, we follow three design principles. A WiFi sensor should be

(1) **Accurate**: accurate and consistent in diverse indoor scenarios
(2) **Tractable**: quick to bring up and easy to calibrate
(3) **Versatile**: widely usable wherever indoor WiFi networks exist and on common robot platforms

Prior Works: Many existing systems that furnish WiFi measurements at the robot application layer fail to meet one or a few of these requirements, making them unsuitable for robot integration. Two widely used open-source WiFi measurement toolkits [4, 11] support the IEEE 802.11n protocol. However, this protocol is outdated and consequently not as widely supported in current WiFi deployments. Alternatively, toolkits that leverage more recent protocols [3, 8] exist. Unfortunately, these systems do not expose WiFi measurements in real time. They instead store the WiFi measurements on the device in specialized files, requiring additional post-processing and time-synchronization, precluding real-time robot operations. To alleviate this problem, a recent work [7] looked at providing ROS support for the 802.11n chipsets [4, 11] mentioned previously.

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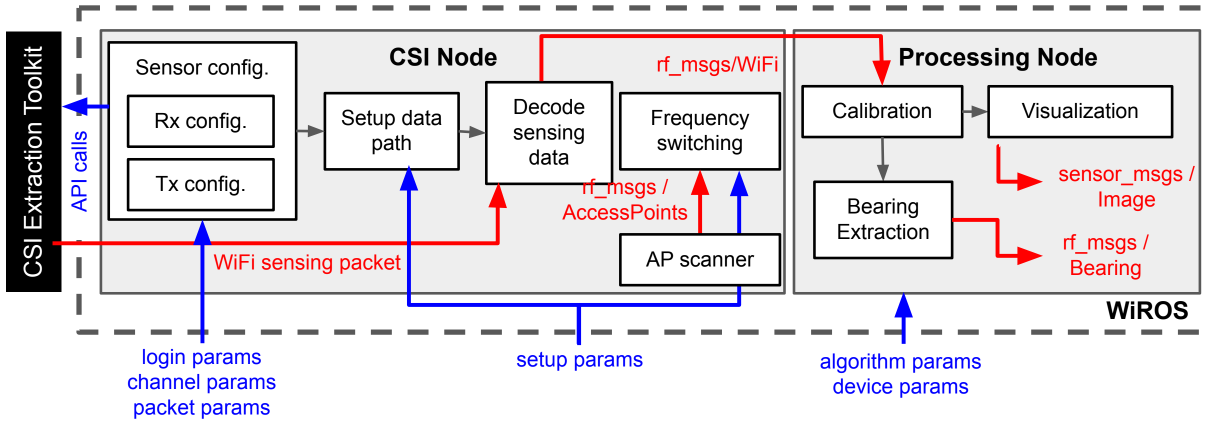

Figure 2: WiROS's Block Diagram: An inside look at the WiROS's box from Fig 1. Showcases the two main blocks - CSI Node and Processing Node to extract raw WiFi measurements and to calibrate and process these measurements. The blue text indicates the control plane parameters, whereas the red text indicates the exposed measurements. WiROS extends the functionality of the underlying black box 'CSI Extraction Toolkit'.

However, this system requires active collaboration with the WiFi infrastructure, requires deployed WiFi AP's to perform 'round-robin' measurements, and as of this writing, does not provide ready integration to ROS, precluding versatile deployments.

2 DESIGN GOALS

WiROS instead leverages widely used 802.11ac WiFi protocol and builds on prior work [3] to provide accurate, tractable, and versatile WiFi measurements. In developing WiROS, we make the following key contributions:
1. Scalable framework for Wi-Fi sensing: We provide a ROS layer as a simple abstraction over the hardware used to collect CSI to allow for simple integration and leverage ROS-based time synchronization via the CSI Node (see Fig. 2).
2. Easy calibration and setup: Commercial AP's come with unique hardware biases which can skew the signal measurements [2]. These biases must be measured and calibrated to estimate various physical parameters, including the bearing of the transmitted signal or Doppler. We provide a tool for automatically calibrating phase offsets on-robot by extending the work in [2]. This allows for hassle-free wireless calibration and validation of the hardware bias.
3. Algorithms for sensing: Finally, we provide a ROS node that estimates bearings using state-of-the-art techniques [9]. Providing this node serves two key purposes. First, it allows researchers to use out-of-the-box WiFi measurements for SLAM and other navigation purposes. Second, it provides a blueprint for using WiFi CSI to perform wider tasks like Doppler estimation or time-of-flight measurements [12].

3 DEMO SETUP

For the demo, we would like to showcase the setup, working, and calibration of WiROS. Additionally, WiROS's WiFi module can be deployed on a robot to localize various WiFi IOT sensors in the environment. We would like to showcase this via video submission.

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