Delay-Doppler Domain Feature Extraction for Explainable Activity Recognition via SVM: Extending to IEEE 802.11be and mmWave Experimental Testbeds

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Abstract

Recent joint communication and sensing (JCAS) research shows that channel state information (CSI) extracted from commercial off-the-shelf Wi-Fi devices can support accurate human activity recognition. In [1], we propose an explainable sensing methodology based on the extraction of physically grounded features from the delay-Doppler (DD) representation of CSI sequences. Coupled with a linear support vector machine (SVM)-based classifier, the feature extraction process enables low-complexity activity recognition with comparable performance to that of a black-box approach leveraging neural networks (NNs). The sensing tool was validated on two independent IEEE 802.11ax datasets collected with commercial Asus RT-AX86U and RT-AX82U access points (APs) operating at $5.775\,\mathrm{GHz}$. This poster presents an experimental extension of [1] to evaluate the robustness and portability of the proposed methodology across different hardware, frequencies, and environmental setups.

First, we replicate the experimental configuration of the ANS dataset of [1] in a different indoor environment, using Ettus X410 universal software radio peripherals (USRPs) instead of Asus APs. The software-defined radios (SDRs) operate with a $500\,\mathrm{MHz}$ master clock rate. The transmitted waveform is IEEE 802.11ax-compliant, with $5\,\mathrm{ms}$ inter-frame spacing over an $80\,\mathrm{MHz}$-wide channel centered at $5.775\,\mathrm{GHz}$. This setup allows direct comparison with the original dataset, while providing environment and hardware varibiality.

Second, we extend the analysis to IEEE 802.11be-compliant waveforms transmitted on a $320\,\mathrm{MHz}$-wide channel with central frequency of $6.105\,\mathrm{GHz}$, keeping the $5\,\mathrm{ms}$ inter-frame. Transitioning from Wi-Fi 6 to Wi-Fi 7 enables us to evaluate whether the features extracted from the DD domain representation of the CSI samples maintain their discriminative characteristics across different Wi-Fi generations and frequency allocations.

Finally, we explore the method's applicability to an entirely different scenario, in the $28\,\mathrm{GHz}$ band. The experimental testbed consists of the aforementioned Ettus X410 USRPs, synchronized through an OctoClock CDA-2990 clock distribution system. The mmWave frontends are two TMYTEK BBox Lite 5G modules, while a UD Box 5G performs the IF/RF frequency conversion. The setup includes three XRifle passive non-reconfigurable reflecting surfaces (NRRSs) (TMYTEK), featuring 51×51 element arrays, operating at $28\,\mathrm{GHz}$ with a radar cross-section gain of approximately $70\,\mathrm{dB}$. Again, the transmitted waveform is IEEE 802.11be-compliant and the channel is $320\,\mathrm{MHz}$ wide. A thorough description of the dataset is presented in [2].

Across all experimental configurations, we maintain the same processing pipeline: the Symplectic Fourier transform (SFT) transposes blocks of N_C consecutive CSI samples to the DD domain, creating the elementary sensing units we call *cast*; from each cast, the same set of statistical and energy-based features proposed in [1] is extracted and processed by the same linear SVM classifier.

The results show that the proposed methodology maintains consistently high activity recognition accuracy despite significant variability in the experimental setup, reaching performances up to 100% of classification accuracy. The selected features remain discriminative across sub-$6\,\mathrm{GHz}$ and mmWave frequencies, confirming that the extracted information is linked to propagation physics rather than to hardware or dataset-dependent properties.

The results strengthen the claim that explainable DD-based sensing techniques can keep up with the same performances across heterogeneous wireless systems, supporting the development of explainable JCAS applications for deployment scenarios extending beyond Wi-Fi.

REFERENCES

[1] E. Tonini, R. Lo Cigno, and E. Viterbo, "Delay-Doppler Domain Feature Extraction for Explainable Wi-Fi Activity Recognition via SVM," in *24th Mediterranean Artificial Intelligence and Networking Conference (MAIN)*, 2026.

[2] J. Angjo, E. Tonini, F. Dressler, and R. Lo Cigno, "mmWave CSI-based Sensing: a Feasibility Study," in *31st ACM International Conference on Mobile Computing and Networking (MobiCom 2025), Poster Session*. Hong Kong, China: ACM, 11 2025, pp. 1353–1355.