AirPress: Towards Scalable Spectrum Inventory

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An accurate, timely inventory of spectrum occupancy is critical for the advancement of Dynamic Spectrum Access (DSA) technologies and legislation. Creating such inventory at scale requires ubiquitous spectrum scans, which poses challenges related to cost, storage, transmission bandwidth and analysis. To be scalable and effective, a spectrum inventory needs to minimize the amount of data it stores and transmits, while maximizing the utility of that data. To this end, we design AirPress (Figure 1), a spectrum inventory system that consists of (i) scanners, (ii) a database (DB) and (iii) a querying and analytics engine (QAE). AirPress utilizes USRP software-defined radio and general purpose PCs to implement the sensors and run the DB and QAE. In software, AirPress makes use of *wavelet decomposition* to perform scalable *spectrum scan compression* at the sensors and *transmitter characterization* in the QAE.

Wavelet decomposition of spectrum scans. We adopt a one dimensional wavelet decomposition applied to a scan of signal power $p_t(f)$ over a range of frequencies at a given time instant t, where p is a function over n discrete frequency values. Spectrum scans are characterized with local regularities, as transmissions correspond to contiguous frequency regions of constant power modulo noise and empty bands correspond to noise-level power. The *Haar* wavelet transform is well suited for decomposition of such signals, and hence we focus on this basis. The wavelet decomposition of spectrum traces enables two key operations on these traces, namely compression and characterization.

Spectrum scan compression. The wavelet decomposition of a power scan $p_t(f)$ is a mapping from the n-dimensional original signal $p_t(f)$ to a n-dimensional set of coefficients w_t. The full decomposition w_t can be used to reconstruct the original signal $p_t(f)$ exactly. Spectrum scans, however, are characterized with local regularities, thus many of the coefficients are close to zero and can be dismissed, which will reduce the spectrum scan size and will result in lossy reconstruction of the original signal.

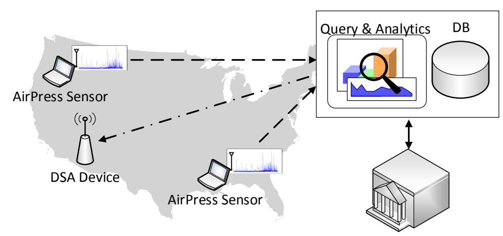

Figure 1: AirPress Overview. Geographically diverse sensors upload spectrum measurements to the spectrum inventory database. A query and analytics engine characterizes these traces. DSA devices and policymakers query the spectrum inventory in order to understand spectrum occupancy.

Spectrum characterization. The ultimate goal of a spectrum inventory is to provide deep insight into spectrum utilization by characterizing the time and frequency properties of spectrum occupants. Previous work in this domain develops mechanisms that are either limited in the types of transmitters they can detect or too computationally complex. AirPress enables unsupervised, real-time characterization of arbitrary transmitters that is not sensitive to the noisy nature of spectrum scans. Our characterization technique exploits inherent properties of the structure of the wavelet coefficient tree and is thus able to detect the time-frequency signatures of observed transmitters. This, in turn, can serve in shaping policy decisions and characterize the DSA opportunity across frequency bands.

Opportunities. We see two major directions to advance the state of spectrum sensing with our proposed methodology. First, we plan to design adaptive compression techniques that fine-tune the level of compression depending on the dynamicity of observed spectrum and are thus better able to optimize spectrum scans storage requirements. Second, we explore opportunities for characterization of spectrum occupancy directly in the compressed coefficient domain, which will allow for robust and real-time transmitter characterization using low volume of spectrum data.

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