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Local and Low-Cost White Space Detection

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***Abstract*—White spaces are portions of the TV spectrum that are allocated but not used locally. If accurately detected, white spaces offer a valuable new opportunity for high speed wireless communications. We propose a new method for white space detection that allows a node to act locally, based on a centrally constructed model, and at low cost, while detecting more spectrum opportunities than best known approaches. We leverage two ideas. First, we demonstrate that low-cost spectrum monitoring hardware can offer "good enough" detection capabilities. Second, we develop a model that combines locally-measured signal features and location to more efficiently detect white space availability. We incorporate these ideas into the design, implementation, and evaluation of a complete system we call Waldo. We deploy Waldo on a laptop in the Atlanta metropolitan area in the US covering 700 km^2. Our results show that using signal features, in addition to location, can improve detection accuracy by up to 10x for some channels. We also deploy Waldo on an Android smartphone, demonstrating the feasibility of real-time white space detection with efficient use of smartphone resources.**

1. Introduction

In 2008 the FCC issued a ruling that allows the unlicensed opportunistic usage of unused portions of the UHF and VHF spectrum [6], referred to as TV *white spaces.* This ruling triggered research and development of white space standards, protocols, and prototypes [12], [23], [46] due to the good propagation characteristics of signals at those frequencies, and the abundance of white space bandwidth in many settings [12]. When using white spaces, it is critical to keep spectrum incumbents *safe,* by avoiding interference with licensed transmissions from the primary spectrum incumbents. When safety is assured, *efficiency* becomes important, so that as many white spaces can be detected as possible.

The approach preferred by the FCC for white space detection is the use of a spectrum occupancy database. These databases are trusted, centralized entities that store information about the location of primary incumbents and use propagation models to infer geographic regions that are within incumbent transmission range. Users querying the database are given permission for opportunistic use of white space spectrum only in locations that are outside

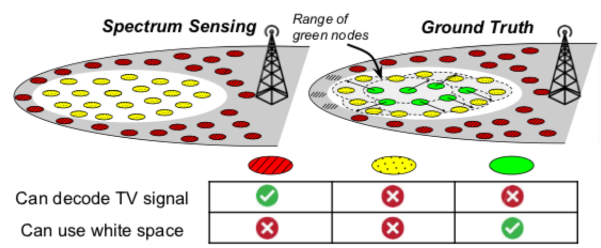

Figure 1. A "pocket" of white space represented by the white area with the grey area representing places where TV signal is decodable. Spectrum sensing dismisses the pocket by considering all nodes in it to be hidden nodes. The ground truth is that green (solid) nodes, that are far enough from red (striped) nodes not to cause harmful interference, should be able to use the white space.

all estimated incumbent regions. The spectrum databases approved by the FCC all use the same propagation model (R6602 [24]) and are subjected to rigorous testing to ensure they avoid interfering with incumbents. While this approach ensures safety, spectrum databases constructed using this propagation model have significant *overprotection* errors that limit coverage and reduce efficiency, meaning they deem locations to be within incumbent range when they are not. This overprotection reduces the opportunities for white space use, reportedly up to 71% [52].

A second approach to white space detection involves local sensing to determine whether the desired spectrum is used by an incumbent, without relying on a database. As depicted in Figure 1, local sensing has the potential to improve efficiency by detecting "pockets" of channel availability , produced by terrain variations and obstacles, that can be missed by generic propagation models. The problem with this approach, however, is that local sensing at a device is subject to *underprotection* errors when the device falls in a hidden node scenario. This can happen, for example, if an obstacle prevents the device from detecting the full-strength TV transmission signal, yet the channel is in use within the region. To reduce the risk of such errors, the FCC requires that devices using local spectrum sensing avoid channels they detect at a lower power (-114 dBm) than the minimum decodable TV signal power (-84 dBm) [9]. With this low power requirement, local spectrum sensing also results in overprotection, up to 2x of the actual

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