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From Blindness to Foraging to Sensing to Sociality: an Evolutionary Perspective on Cognitive Radio Networks

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Abstract Wireless communication is an increasingly important aspect of the digital ecosystem. The Internet of Things reached 4+ billion devices in 2014, and is expected to exceed 25 billion by 2020. In this paper, we formalize the notion of evolutionary pressures in Cognitive Radio (CR) societies, and show how it can be expected to drive the emergence of more advanced sensing capabilities, and correspondingly more sophisticated models of resource sharing. We put forth four evolutionary stages for CR societies, based on well-established biological analogs, and demonstrate that at each stage of CR evolution, a subpopulation that is able to engage more advanced sensing capabilities and co-use strategies is able to better extract greater utility from spectrum resources. In this manner, we see that each stage of CR evolution prepares the way for the next: the present societies of non-foragers facilitate the emergence of foragers; foragers give way to contention-sensing rational CR societies; these, in turn, will likely facilitate the emergence of sociality. We find this progression to depend crucially in population size, and to be robust to consideration of primary user activity. We use a sensitivity analysis to isolate salient factors most likely to accelerate or inhibit the anticipated natural evolutionary trajectory.

Keywords Internet of things · Cognitive radio networks · Dynamic spectrum access · Behavioral-ecological networks · Self-coexsitence

1 Introduction

Opportunities afforded by cheaper hardware, wireless services, and increased demand for end-user applications, have led to rapid population growth in the Internet of Things (IoT). As wireless devices become more sophisticated, Dynamic Spectrum Access (DSA) networks [15] using Cognitive Radio (CR) technology offers a potential solution to relieve over-crowded wireless channels as has been argued by many [14, 40, 45, 66].

Current spectrum assignment policies have resulted in suboptimal use of spectral resources [55]—over-use in some bands and under-utilization in others [3, 23, 24]. Few segments of spectrum remain unassigned, and yet, the licensed spectrum is underutilized because licensed ("primary") users are often idle [22] and "spectrum holes" [31] arise. This has motivated DSA policy by the U.S. Federal Communications Commission (FCC), as well as **Cognitive Radio** (CR) [1, 39] wherein nodes dynamically identify unused spectrum bands [1, 7, 15, 16, 25, 29].

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