Social Deference and Hunger as Mechanisms for Starvation Avoidance in Cognitive Radio Societies

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***Abstract*—Wireless communication is an increasingly ubiquitous and important resource substrate of the digital ecosystem. In the face of the rapid growth in the population of Internet of Things (IoT), however, uncoordinated access to limited resources of radio spectrum is likely to lead to mass starvation. Here we put forward a new bio-social paradigm for cognitive radio, extending previous models in which the secondary users of spectrum alternate stochastically between foraging and consuming behaviors. In this paper, we ask and resolve two questions: (1) What costs and benefits does social deference to the group yield for each of the *individuals* therein? and (2) Can a notion of individual "hunger" form the basis of a distributed social deference scheme that is free of group coordination costs? Through a series of simulation experiments grounded in a well-specified formal model, we show that social deference improves both the fairness and the reliability of spectrum resource allocation, and moreover, that the concept of individual "hunger" can be used to implement social deference with minimal group coordination overhead. The results have consequences both in suggesting potential improvements for distributed spectrum access, and in understanding the evolutionary pressures on the behaviors of individual devices within emerging digital IoT societies.**

***Index Terms*—Cognitive radio networks, bio-social networking, Internet of Things, self-coexsitence, dynamic spectrum access, contention-sensing.**

I. Introduction

Ubiquitous wireless service together with decreasing hardware costs have led to rapid population growth in the Internet of Things (IoT). Although the present IoT consists largely of primitive low power sensors, the demand to support richer data streams is unquestionable. As the population and sophistication of IoT devices increases, it is widely expected that they will engage Dynamic Spectrum Access (DSA) networks [3] as secondary users (SUs) of radio spectrum, using Cognitive Radio (CR) technologies [12], [14], [2].

Unfortunately, the FCC's frequency assignment policies over the years have resulted in suboptimal use of spectral resources. Few segments of spectrum remain unallocated, and yet spectrum is underutilized because licensed ("primary") users are frequently idle. To address this, the FCC proposed DSA within the CR paradigm. However, although the FCC reforms "allow unlimited numbers of unlicensed [secondary] users to share frequencies", they do "not provide any right to protection from interference" [7]. Since there are many secondary users, each SU's selection of band and decision to transmit, potentially impacts other secondary users, whose channel bandwidth degrades when greater numbers of SUs share a channel. Taken together, bandwidth scarcity and "no right to protection from interference" present serious challenges to performance for SUs in CR and DSA environments. In short, DSA can "kick the can further down the road" but the problem remains looming.

Prior research on resource allocation in networks recognizes the potential relevance of our knowledge on resource co-use in human and animal societies; for a recent survey of bio-socially inspired approaches, see [6], [13]. In particular, since SUs in CR and DSA environments are potentially capable of sensing, learning, and adaptation, there has been considerable prior work seeking to apply models of animal foraging strategies to the design of protocols in CR networks [1], [5], [11].

In their previous work [17] the authors considered cognitive radio societies in which secondary users (SUs) of radio spectrum can alternate stochastically between two distinct behavioral modes: searching for spectrum holes ("foraging") and transmitting in a band ("consuming"), rather than always consuming. They showed that if, while in foraging mode, SUs measure ("sense") congestion (i.e. number of other SUs transmitting) in a band, and then use this measurement to bias the individual decisions to start consuming the band, such **social contention avoidance** behaviors significantly improve channel utilization metrics (28%).

Here, we continue to extend the above bio-social model to leverage prior understanding of resource conflict/sharing in the context of humans and other social animals [8], [9], [18]. Specifically, we consider **social deference**, by which we mean

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