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COGNITIVE RADIOS FOR DYNAMIC SPECTRUM ACCESS

Accessibility to spectral bandwidth affects everyone in modern society. With each passing day, more people are subscribing to one of the plethora of wireless services currently available on the market. As a result of this rapid growth in the wireless services industry, the demand for additional bandwidth is steadily increasing despite the fact that frequency spectrum is a finite natural resource. Thus, to avoid a potential spectrum scarcity problem, both spectrum policy makers and wireless technology specialists are united in seeking solutions that would help increase the amount of available frequency spectrum in order to accommodate this rapid growth.

To provide the necessary spectral bandwidth required by both current and future wireless services and applications, a critical rethinking of the spectrum regulatory requirements is currently underway, led by organizations such as the Federal Communications Commission (FCC). With the knowledge that a majority of licensed spectrum is underutilized in both time and frequency, the concept of dynamic spectrum access (DSA) has been proposed as a solution to the potential spectrum scarcity problem, where unlicensed users temporarily "borrow" frequency bands from spectrum licensees while simultaneously respecting the rights of the incumbent license holders.

Cognitive radios have been identified as a key enabler for DSA networks, where the operating parameters of the unlicensed device can be rapidly reconfigured to the changing requirements and conditions of the transmission environment. Based on software-defined radio (SDR) technology, cognitive radios are the product of a multidisciplinary effort involving experts in wireless networks, digital communications, systems engineering, artificial intelligence, and other fields. As a result of these activities, it is hoped that these systems can simultaneously respect the rights of the incumbent license holders while providing greater flexibility and access to spectrum.

Given the demand for more bandwidth and the amount of underutilized spectrum, DSA networks employing cognitive radios are a solution that can revolutionize the telecommunications industry, significantly changing the way we use spectrum resources, and design wireless systems and services. Thus, the purpose of this Feature Topic is to provide all members of the wireless technology community with insights into the various DSA networks and cognitive radios research activities currently underway. Each of the articles appearing in this Feature Topic focuses on a different aspect of this complex and multifaceted area.

Understanding how spectrum opportunities behave over time and frequency in reality is the first important step toward being able to efficiently exploit those opportunities. The focus of the first article, entitled "Dynamic Spectrum Access in the Time Domain: Modeling and Exploiting Whitespace," by Stefan Geirhofer, Lang Tong, and Brian M. Sadler, is the presentation of a mathematical model that accurately describes the behavior of a DSA environment. As a result, it provides useful insights into a very important tool for DSA research.

Although it has been widely advertised that the potential for a DSA network to increase overall data throughput is substantial, an accurate quantitative assessment of the potential gains is needed. The second article, "The Potential of Cognitive Radio: A Theoretical Perspective" by Sudhir Srinivasa and Syed Jafar, provides such an analysis for a wide range of operating scenarios and radio configurations. In particular, this article focuses on the design trade-offs and their impact on system data throughput.

Currently, one of the most active standardization activities in the IEEE is the cognitive radio-based IEEE 802.22, a wireless regional area network (WRAN) standard. The importance of developing a standard based on cognitive radio technology is that it will help introduce this technology into mainstream wireless products, thus fueling greater research and development in this area. The third article, entitled "Dynamic Frequency Hopping Communities for Efficient IEEE 802.22 Operation," by Wendong Hu, Daniel Willkomm, Liwen Chu, Mario Gerla, and Adam Wolisz, provides us with an overview of dynamic frequency hopping, which is an important component of the IEEE 802.22 standard.

Knowing how to effectively share unoccupied spectrum between several unlicensed devices is of prime importance in achieving greater spectrum efficiency. Although there are several approaches to defining the DSA behavior of a number of unlicensed users, game theory is receiving significant attention for its ability for specifying flexible, efficient, and fair spectrum usage among DSA network users. The focus of the fourth article, "Dynamic Spectrum Sharing: A Game Theoretical Overview" by Zhu Ji and K. J. Ray Liu, provides an overview of a game theoretical approach to dynamic spectrum sharing from several perspectives.

Dynamic spectrum access and cognitive radio ideas and solutions abound within the wireless communication networks community. However, knowing how these solutions will evolve and integrate into the existing wireless services market involves understanding the prime mover of any wireless technology: economics. As a result, the fifth article, entitled "The Path to Market Success for Dynamic Spectrum Access Technology," by John M. Chapin and William H. Lehr, examines the relationships between the technical and economic aspects of cognitive radios and DSA networks. Based on these relationships, several recommendations are made that will support the commercial success of this area.

Although there is a substantial amount of cognitive radio research activity, the majority of work published in the open literature focuses on issues related to the physical layer of the radio and above. Consequently, the challenges associated with circuit-level designs for cognitive radios have not received the important attention they deserve. As a result, several circuit-level design issues for cognitive radios are the focus of the sixth article, "Polyphase Multi-Path Radio Circuits for Dynamic Spectrum Access" by Eric A. M. Klumperink, Rameswor Shresta, Eisse Mensink, Vincent J. Arkesteijn, and Bram Nauta. In this article the radio design for a DSA-capable transceiver employing a polyphase multipath technique is discussed. This is a very important issue since it helps the system avoid the use of frequency selective dedicated filters, thus more readily enabling DSA.

With all the DSA and cognitive radio ideas being published in the open literature, it is vitally important to evaluate the feasibility and performance of these ideas using an experimental testbed. However, the construction of a testbed and its associated components is a huge nontrivial undertaking. As a result, the seventh and final article, entitled "An Agile Radio for Wireless Innovation," by Gary J. Minden *et al.*, highlights the challenges and design methodologies of building a cognitive radio experimental testbed completely in house in order to evaluate new ideas in DSA networks.

In conclusion, this Feature Topic introduces the general communications community to developments in the way we handle spectrum, highlights technologies that will enable access to this spectrum, and outlines policy issues that will affect the design decisions of implementing these networks. The articles cover many different layers of the dynamic spectrum access network (e.g., physical, network, application) from different viewpoints (government, industry, academia). Thus, we feel that this Feature Topic has something for everyone within the communications community.

BIOGRAPHIES

WILLIAM KRENIK [F'05] (w-krenik@ti.com) is a senior director of advanced technology of the Wireless Terminals Business Unit at Texas Instruments. He manages TI's advanced wireless research team, and studies wireless technologies and system architectures. His efforts include serving on several academic and professional boards. He has been employed by TI since 1984, and has held roles in analog circuit design, design management, business management, and technology development. He received a doctorate in electrical engineering from the University of Texas, Dallas in 1993. He also holds a Master's degree in electrical engineering from Southern Methodist University and a Bachelor's degree in electrical engineering from the University of Minnesota. He is a registered professional engineer in the state of Texas and holds 38 U.S. patents. He speaks frequently at professional industry and technical events, and has published numerous articles and technical papers.

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