Open Research issues in Cognitive Radio

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Abstract— **Cognitive Radios have been receiving increasing attention in academia, industry, and government. This has come after several studies indicating that up to 90% of the allocated radio spectrum less than 3GHz is idle most of the time [1]. As a result, spectrum regulation around the world is in progress to allow unlicensed access on a non-interfering [2] [3]. Current researches are investigating different techniques of using cognitive radio to reuse more locally unused spectrums to increase the total system capacity. However, there are many issues across all layers of a cognitive radio system design. In this paper we address cognitive radio issues for enabling cognitive radio including more spectrums sensing, protocol, hardware, security and algorithmic challenges that could limit their performance or even make them infeasible. We also give some insight into the evolution of cognitive radios and characteristics. We conclude highlighting open research challenges in this exciting area.**

Key words: **Cognitive radio, radio environment, spectrum sensing.**

I. Introduction

A driving feature of future network architectures will be the mobile user. Users increasingly will access information resources while on the move, whether when in a vehicle etc. Wireless technology is necessary to support the mobile user and adaptive and efficient use of radio spectrum is an important aspect of developing future network architectures. Observing that in some locations or at some times of day, 70 percent of the allocated spectrum may be sitting idle, the FCC [4] has recently recommended that significantly greater spectral efficiency could be realized by deploying wireless devices that can coexist with the primary users, generating minimal interference while taking advantage of the available resources. Thus, the discrepancy between spectrum allocation and spectrum use suggests that this spectrum shortage could be overcome by allowing more flexible usage of a spectrum. Flexibility would mean that radios could find and adapt to any immediate local spectrum availability. A new class of radios that is able to reliably sense the spectral environment over a wide bandwidth detects the presence or absence of users and use the spectrum only if the communication does not interfere with primary users is defined by the term cognitive radio [5]. Cognitive Radios integrate radio technology and networking technology to provide efficient use of radio spectrum. The cognitive radio wireless network is intended as an advanced technology integration environment with focus on building adaptive, spectrum-efficient systems with emerging programmable radios. The emerging cognitive radio scenario is of current interest to both policy makers and technologists because of the potential for order of magnitude gains in spectral efficiency and network performance. The idea of a cognitive radio extends the concepts of a hardware radio and a software defined radio from a simple, single function device to a radio that senses and reacts to its operating environment. The promise of cognitive radios is improved use of spectrum resources, reduced engineering and planning time, and adaptation to current operating conditions. Cognitive radios have been proposed as a mean to implement efficient reuse of the licensed spectrum [6] [7]. The main feature of cognitive radios is their ability to recognize their communication environment and independently adapt the parameters of their communication scheme to maximize the quality of service for the secondary users while minimizing the interference to the primary users [8]. Figure.1 [9] and figure.2 illustrate cognition radio cycle and cognitive radio scenario respectively. In cognitive radio cycle a cognitive radio monitors spectrum bands, captures their information, and then detects the spectrum spaces .The characteristics of the spectrum spaces that are detected through spectrum sensing are estimated. Then, the appropriate spectrum band is chosen according to the spectrum characteristics and user requirements. Once the operating spectrum band is determined, the communication can be performed over this spectrum band. Cognitive radio scenario consists of two-user cognitive radio are shown in figure , we assume that each user knows only his channel and the unused spectrum through adequate sensing, The cognitive user will listen to the channel and, if sensed idle, will transmit during the voids.

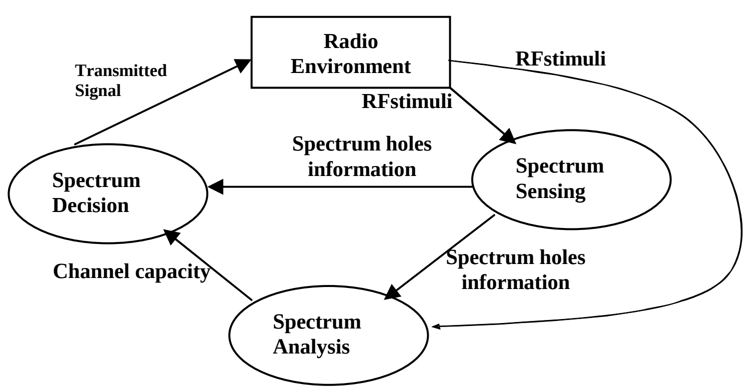

Figure.1,Cognitive radio cycle

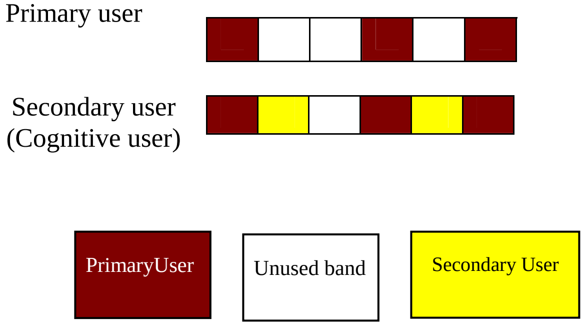

Figure.2, cognitive radio scenario

II. Features of Cognitive Radio Networks

Firstly, sensing the current radio frequency spectrum environment this includes measuring which frequencies are being used, when they are used, estimating the location of transmitters and receivers, and determining signal modulation [6]. Results from sensing the environment would be used to determine radio settings. Cognitive radios measure and react to the environment they are operating in. This environment is multi-dimensional; including cooperative and non-cooperative emitters turning on and off, Cognitive radios adapting to their local changes, and traffic loads; and rapidly varying. Cognitive radios must rapidly adapt to this changing environment and communicate their changing operation settings to other wireless devices in the network. The mechanisms and techniques to sense, adapt, and communicate operation state are necessary in Cognitive radio networks and applicable to networks in general. Secondly, policy and configuration databases, policies specifying how the radio can be operated and physical limitations of radio operation can be included in the radio or accessed over the network. Policies might specify which frequencies can be used in which locations [6]. Configuration databases would describe the operating characteristics of the physical radio. These databases would normally be used to constrain the operation of the radio to stay within regulatory or physical limits. Thirdly, self-configuration, radios may be assembled from several modules. For example, a radio frequency front-end, a digital signal processor, and a control processor. Each module should be self-describing and the radio should automatically configure itself for operation from the available modules [10].Fourthly, mission-oriented configuration, software defined radios can meet a wide set of operational requirements. Configuring a software defined radio to meet a given set of mission requirements is called mission oriented configuration. Typical mission requirements might include operation within buildings, substantial capacity, operation over long distances, and operation while moving at high speed. Mission-oriented configuration involves selecting a set of radio software modules from a library of modules and connecting them into an operational radio [6].Fifthly, adaptive algorithm, during radio operation, the cognitive radio is sensing its environment, adhering to policy and configuration constraints, and negotiating with peers to best utilize the radio spectrum and meet user demands by using adaptive communications [6] [11]. An adaptive algorithm optimizes performance by choosing various cooperative sensing methods.

Sixly, collaboration, cognitive radios will exchange current information on their local environment, user demand, and radio performance between themselves on regular bases. Radios will use their local information and peer information to determine their operating settings. The radio spectrum is a distributed resource. Use of the spectrum in one location affects the availability of that spectrum in other network locations. Allocation of the radio spectrum resource must be carried out in a cooperative manner and balanced between local decisions and global allocation [6] [9].Finally, robust communications services with unreliable links, the radio links, by their nature, have intermittent outages. A link outage may result from the temporary location of the receiver, transmitter, and other objects in the environment [6]. Cognitive radios, by their design, must deal with these very short term link outages, and do so through a variety of techniques. It is through this large set of techniques and mechanisms that wireless networks implement a robust and reliable communications service with unreliable links, the techniques and design patterns used in wireless architectures are applicable to the larger network architecture [12] [13].

III. Cognitive radio issues

A. Advance spectrum management: Cognitive radios have a great potential to improve spectrum utilization by enabling users to access the spectrum dynamically without disturbing licensed primary radios. A key challenge in operating these radios as a network is how to implement an efficient medium access control mechanism that can adaptively and efficiently allocate transmission powers and spectrum among Cognitive radios according to the surrounding environment. Most existing works address this issue via suboptimal heuristic approaches or centralized solutions [14].

B. Unlicensed spectrum usage: It is this discrepancy between FCC allocations and actual usage, which indicates that a new approach to spectrum licensing is needed [15].What is clearly needed is an approach, which provides the incentives and efficiency of unlicensed usage to other spectral bands, while accommodating the present users who have higher priority (primary users) and enabling future systems a more flexible spectrum access

C. Spectrum sharing strategies: Spectrum sharing is allocation of an unprecedented amount of spectrum that could be used for unlicensed or shared services. Opportunistic communication with interference avoidance faces a multitude of challenges in the detection of sharing in multi-user cognitive radio systems. Because of the presence of user priority (primary and secondary), they pose unique design challenges that are not faced in conventional wireless systems. A major issue in a multiple secondary user environment is sharing, a topic that has generated a lot of research interest in the recent past [11] [16]

D. Hidden node and sharing issues: Cognitive radio sensitivity should outperform primary user receivers by a large margin in order to prevent what is essentially a hidden node problem of cognitive radios to ensure cognitive radios do not interfere with each other [17].

E. Trusted access and security: With increased focus over the past few years on system security and survivability, it is important to note that distributed intelligent systems, such as cognitive radio, offer benefit in the event of attacks. Intelligence and military application require application-specific secure wireless systems [18] [19].

F. Complexity issue: Cognitive radio is being proposed as a future way of tackling the problem of increasingly radio spectrum. To achieve this it requires that the communications nodes themselves are intelligently capable of sensing, and dynamically selecting, the appropriate spectral resources without causing excessive interference on other users. To achieve this researchers are proposing a variety of increasingly complex methods of implementing cognitive radio, which incorporate software defined radio, dynamic spectrum management, and intelligence[6][11][15][16]. The drawback of this complexity is that it is predicted that Cognitive Radio is still years away from implementation. The challenge is to understand whether such complexity is justified, and what benefits it brings to overcome the current regulatory constrained spectral assignment process. It is foreseen that it should be possible to develop reduced complexity strategies that will deliver much of the functionality of proposed systems, enabling more rapid adoption, and wider use in systems where cognitive radio is currently not being considered due to prohibitive complexity.

G. Cross-layer design: The flexibility of cognitive radios has significant implications for the design crosslayer algorithms which adapt to changes in physical link quality, radio interference, radio node density, network topology or traffic demand may be expected to require an advanced control and management framework with support for cross-layer information [20][21]. Spectrum handoff and mobility management will face some new challenges which are required to do a cross-layer design, especially when required providing the necessary capabilities in terms of quality of service at the same time.

H. Hardware and software architecture: The potential for Cognitive radio is a novel efficient methodology, extension of software-defined radio, to transmit and receive information over various wireless communication devices [22]. According to the existing operators in the environment, Cognitive radio choses the best available option based on performance for each application. The different performance measuring parameters include frequency, power, antenna, transmitter bandwidth, modulation and coding schemes etc. This means that the radio has to deal with different radio frequencies spectrum and baseband varieties at the same time, thus requiring a more robust, efficient and reconfigurable hardware and software architecture.

IV. Conclusion

The limited spectrum for dense wireless communications and inefficient spectrum utilization necessitate a new communication paradigm cognitive radio which can exploit the unutilized spectrum opportunistically. This paper presents some of the cognitive radios issues used to determine the effectiveness in wireless communication. These characteristics are crucial when applying the cognitive radios in order to determine the effectiveness and reliability of wireless networks. Spectrum management, unlicensed spectrum usage, spectrum sharing, hidden node and sharing issues, security, complexity, cross-layer design hardware and software architecture are introduced. Many researchers are currently engaged in developing the communication technologies and protocols required for cognitive radio networks .The recent and evolving research efforts have made big progress on cognitive radios both in theory and in practical implementations. Thought there are methods available in cognitive radios, none is considered to be the most reliable method in a wide ranging wireless environment, and so more research is needed along the lines introduced in this paper.

References

[1]Kevin Werbach, “Toward a Unified Theory of Wireless Communication”, Super commons, Texas Law Review, 2004.

[2]J.Scott, Lorenz Nett, Mark scanlan, Ulrich Stumpf, Martin Cave, Gerard Pogorel “Towards more flexible spectrum regulation”, study for federal network agency December 2005.

[3]Ovum, Indepen, Aegis, “Spectrum Framework Review”, ofcom, 28 June 2005.

[4] Federal Communications Commission, Cognitive Radio Technologies Proceeding

[5] J. Mitola,”Cognitive radio: integrated agent architecture for software defined radio”,

[6] Joe Evans, U. Kansas, Gary Minden, U. Kansas Ed Knightly, Rice,”Technical Document on Cognitive Radio Networks “, September 15, 2006.

[7] Fredric Pujol,”Regulatory and Policy Implications of Emerging Technologies to Spectrum Management”, ITU workshop, Geneva, 22-23 January 2007.

[8]Hsiao-Hwa Chen, Dr. Mohsen Guizani, “Next Generation Wireless Systems and Networks”, 2006 John Wiley & Sons, Ltd

[9]Ian F. Akyildiz, Won-Yeol Lee, Mehmet C. Vuran , Shantidev Mohanty,” NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey”, Elsevier ,Computer Networks Journal, PP 2127-2159, May 2006.

[10]Adam D. Ross,” Configuration and Optimization in Self-Managing Networks”, Tutorial, University of Northern Iowa.

[11] Nie Nie, Cristina Comaniciu,”Adaptive Channel Allocation Spectrum Etiquette for Cognitive Radio Networks” Springer Science Business Media, 2006

[12] Andrew Michael James,” A Link-quality-aware Graph Model for Cognitive Radio Network Routing Topology Management”, thesis, Rochester,October 2007

[13] European Cooperation in the field of Scientific and Technical Research-COST,“Pervasive Mobile & Ambient Wireless Communications “, 2006

[14] G.Dimitrakopoulos, P.Demestichas, D.Grandblaise, K. J.Hoffmeyer, J.Luo, “Cognitive Radio, Spectrum and Radio Resource Management”, Wireless World Research Forum, 2004.

[15] R.W. Brodersen, A. Wolisz, D. Cabric, S.M. Mishra, D. Willkomm, “Corvus: a cognitive radio approach for usage of virtual unlicensed spectrum”, Berkeley Wireless Research Center (BWRC) White paper, 2004.

[16] Raul Etkin, Abhay K. Parekh, David Tse, “Spectrum Sharing for Unlicensed Bands,” IEEE Journal on Selected Areas in Communications, vol. 25, pp. 517–528, April 2007.

[17] A.Shukla, P.Hall, J.Bradford, D.Chandler, M.Kennett, P.Levine, A.Alptekin,” Cognitive Radio”, QINETIQ/06/00420 Issue 1.1, November 2006.

[18] Kwang-Cheng Chen, Irving T. Ho,” Cognitive Radio Networks”, CTiF Workshop 2007.

[19] William Krenik, Anuj Batra, “Cognitive Radio Techniques for Wide Area Networks”, ACM, Anaheim, California, USA, June 2005.

[20] Dipankar Raychaudhuri , Narayan B. Mandayam, Joseph B. Evans, Benjamin J. Ewy, Srinivasan Seshan, Peter Steenkiste ,”CogNet - An

Architectural Foundation for Experimental Cognitive Radio Networks within the Future Internet", MobiArch'06, San Francisco, CA, USA. December 1, 2006
[21] IMEC research group," Cross-layer performance-energy modeling and optimization for wireless multimedia systems", scientific report 2006.
[22] Mark Scoville, Stephen Berger, Richard C. Reinhart, Jeffrey E. Smith," The Software -Defined Radio and Cognitive Radio Inter-Consortia Affiliation", Military Communications Conference (MILCOM), Washington, USA, 2006.