

Surveying of Energy Efficient Methods for Cognitive Radio

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Abstract - Cognitive Radio (CR) is a innovative technology that aims for significant improvements in efficiency of spectrum usage. CR will change the way the radio spectrum is regulated, but also requires new enabling methods such as improved spectrum sensing and dynamic spectrum assignment. Cognitive radio (CR) networks are clever networks that can automatically sense the environment and adapt the communication parameters accordingly. These kind of networks have applications in dynamic spectrum access, co-existence of various wireless networks, interference management. They are touted to drive the next generation of devices and applications. Visibly, the cognitive radio network paradigm poses many new technical challenges in protocol designs, power efficiency, spectrum management, spectrum detection, environment consciousness, new distributed algorithm aim, distributed spectrum measurements, Quality of services guarantees, and security. Overcoming these issues becomes even more challenging due to non-uniform spectrum and other radio resource allocation schemes, economic considerations, the inherent transmission impairments of wireless links, and user mobility. Cognitive radio is an emerging technology that enables the flexible development and deployment of highly adaptive radios that are built upon software defined radio technology. Cognitive radio has been considered as a key technology for future wireless communications and mobile computing. We notice that the cognitive radios can form cognitive radio networks (CRN) by extending the radio link features to network layer functions and above.

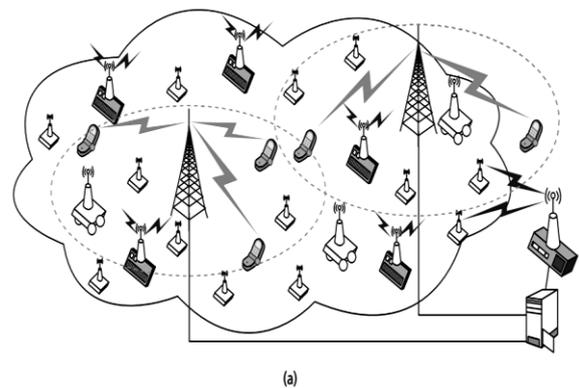
Keywords : Cognitive Network, QoS, Wireless Communication, Spectrum Usage.

I. INTRODUCTION

A typical architecture of a Cognitive Radio Sensor Network is illustrated in Fig. 1a. Depending on various spectrum availability, sensor nodes transmit their readings in an opportunistic manner to the next hops and ultimately to the sink. The sink may also be equipped with cognitive radio capability (i.e., a cognitive radio sink). In addition to the event readings, sensors may exchange additional information with the sink including control data for group formation, spectrum allocation, and spectrum- handoff-aware route determination depending on the specific topology.

Traditional communication system design is based on allocating fixed amounts of resources to the user. Adaptive design methodologies, typically identify the

requirements of the user, and then allocate just adequate resources, thus enabling more efficient utilization of system resources and consequently increasing capacity. Pushing the adaptive system design further by introducing advanced attributes such as multidimensional awareness, sensing, as well as learning from its experiences to reason, plan, and decide future plans to meet user needs leads to the cognitive radio concept. Ignited by the earlier work of Mitola, cognitive radio is a novel concept for future wireless communications, and it has gained significant interest among the academia, industry, and regulatory bodies [12].



Even though there is no consent SUs on the formal definition of cognitive radio, the concept has evolved recently to include various meanings in several contexts. One of its main aspects is related to autonomously exploiting locally unused spectrum to provide new paths

to the spectrum access. Different aspects includes:

- Inter-operability across various networks,
- Roaming across borders, while being able to stay in compliance with local regulations, adapting the system transmission, and reception parameters.
- Having the ability to understand and follow actions and choices of the users,
- Learning over time to become more responsive and to anticipate the user needs.

Cognitive radio proposes to furnish the radio systems with the ability to measure and be aware of parameter related to the radio channel characteristics, accessibility of spectrum, power, interference and noise temperature, available

networks, nodes, and infrastructures, also local policies and other operating restrictions. The primary advantage targeted with these features is to enable the cognitive systems to utilize the available spectrum in the most efficient way.

i. Spectrum Regulation Changes

Cognitive radio means not only improving technology, it also requires basic changes in the way radio spectrum is regulated. Figure 1 illustrates the relation of horizontal and vertical sharing, which are some main levels of spectrum sharing we are focusing on. Depending on the regulatory status of the radio systems that operate in the similar spectrum, cognitive radios share spectrum with radio systems that are designed to access spectrum with various priorities. To reflect this priority, licensed and unlicensed radio systems are sometimes referred to respectively as primary and secondary radio systems. The licensed radio systems designed to operate in exclusively assigned bands, unlicensed radio systems designed to live with some interference from dissimilar radio systems may share spectrum with cognitive radios. Figure 1 indicates that sharing with primary radio systems is referred to as vertical sharing and contribution with secondary radio systems is referred to as horizontal sharing. It appears that, dissimilar cognitive radios that are not designed to communicate with each other may also share the similar spectrum. This is another common example of horizontal sharing, due to the dissimilar cognitive radio systems have the similar regulatory significance, i.e. similar rights to access the spectrum. Vertical and horizontal sharing, a cognitive radio ought to be capable of detecting underutilized spectrum, i.e. spectrum opportunities, also referred to as “white space” spectrum.

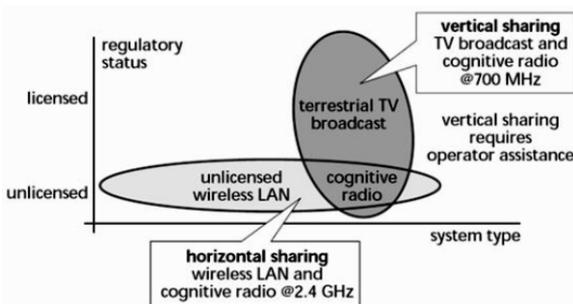


Figure. 1. Horizontal sharing and vertical sharing.

Typically, spectrum opportunities change over time and vary depending on the location of the cognitive radio. To shield the licensed radio systems and their services in vertical sharing scenarios, other radio systems such as operated by Swiss com may assist cognitive radios in identifying spectrum opportunities. Hence, regulation will be changed towards dynamic spectrum assignment. Even more flexibility and a higher rank of freedom could be envisioned for horizontal sharing, ultimately with less

predictable result. Here, the cognitive radios would identify opportunities originally. To avoid chaotic and unpredictable spectrum usage as in today’s unlicensed bands, advanced approaches such as “spectrum etiquette” and “value-orientation” are supportive. Spectrum etiquette is today already discussed for existing unlicensed bands in various regulatory bodies and standardization groups.

Depending on the regulatory status of the incumbent radio systems, cognitive radios share spectrum with various types of systems.

II. PHYSICAL ARCHITECTURE OF THE COGNITIVE RADIO

A generic architecture of a cognitive radio transceiver is shown in Fig. 2. The main components of a cognitive radio transceiver are the radio front-end and the baseband processing unit. Each component could be reconfigured via a control bus to adapt to the time-varying RF environment. The RF front-end, the received signal is amplified, mixed and A/D converted. The baseband processing unit, the signal is modulated /demodulated and encoded and decoded. The baseband processing unit of a cognitive radio is essentially similar to existing transceivers. The novelty of the cognitive radio is the RF front-end. Therefore, next, we focus on the RF front-end of the cognitive radios.

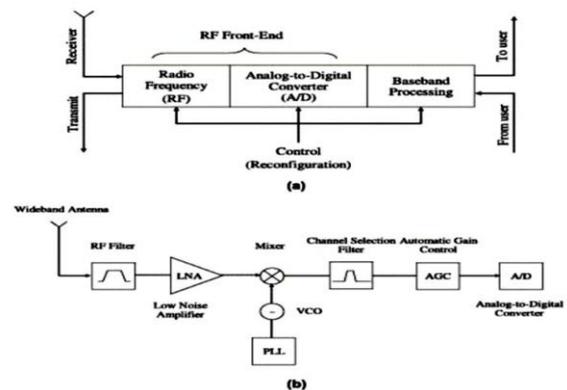


Figure. 2 Physical architecture of the cognitive radio (a) Cognitive radio transceiver and (b) wideband RF/analog front-end architecture

The novel characteristic of cognitive radio transceiver is a wideband sensing capability of the RF front-end. This function is related to RF hardware technologies such as wideband antennas, power amplifiers, and adaptive filters. RF HW for the cognitive radio should be capable of tuning to any part of a large spectrum of frequency spectrum. Also this spectrum sensing enables real-time measurements of spectrum information from radio environment. Normally, a wideband front-end architecture for the cognitive radio has the following structure as shown in Fig.2. The components of a cognitive radio RF front-end are as follows:

1. RF filter: The RF filter selects the desired band by band pass filtering the received RF signal.
2. Low noise amplifier (LNA): The LNA amplifies the desired signal while simultaneously minimizing noise component.
- 3 Mixer: Mixer, the received signal is mixed with locally generated RF frequency and converted to the baseband or the intermediate frequency (IF).
4. Voltage-controlled oscillator (VCO): The VCO generates a signal at a specific frequency for a given voltage to mix with the incoming signal. This process converts the incoming signal to baseband or an intermediate frequency.
5. Phase locked loop (PLL): The PLL ensures that a signal is locked on a specific frequency and can also be used to generate precise frequencies with fine resolution.
6. Channel selection filter: The channel selection filter is used to select the desired channel and to reject the adjacent channels. There are two kinds of channel selection filters present. The direct conversion receiver uses a low-pass filter for the channel selection. On the other hand, the superheterodyne receiver adopts a band pass filter.
7. Automatic gain control (AGC): The AGC maintains the gain or output power level of an amplifier constant over a wide spectrum of input signal levels. In this architecture, a wideband signal is received through the RF front-end, sampled by the high speed A/D converter, and measurements are performed for the detection of the licensed user signal. There exist some limitations on developing the cognitive radio front-end.

The wideband Radio Frequency antenna receives signals from various transmitters operating at various power levels, bandwidths, and locations. Accordingly, the RF front-end should have the capability to detect a weak signal in a large dynamic spectrum. However, this capability requires a multi-GHz speed A/D converter with high resolution. Necessitates the dynamic The requirement of a multi- GHz speed A/D converter spectrum of the signal to be reduced before Analog to Digital (A/D) conversion. This reduction can be achieved by filtering strong signals. As strong signals can be located anywhere in the wide spectrum, tuneable notch filters are required for the reduction. Another approach is to use multi antennas such that signal filtering is performed in the spatial domain rather than in the frequency domain. Multiple antennas can receive signals selectively using beam forming method . The key challenge of the physical architecture of the cognitive radio is an accurate detection of weak signals of licensed users over a wide spectrum. Therefore, the implementation of RF wideband front-end and A/D converter are critical issues in

Cognitive Radio Networks.

III. COGNITIVE RADIO NETWORK AS WIRELESS SENSOR NETWORK AND ITS APPLICATIONS

A. Cognitive Radio Networks could be applied to the following cases:

1. Leased network: The primary network can provide a leased network by allowing opportunistic access to its licensed spectrum with the agreement with a third party without sacrificing the service quality of the primary user. As the primary network can lease its spectrum access right to a mobile virtual network operator (MVNO). Also the primary network can provide its spectrum access rights to a regional community for the purpose of broadband access.
2. Cognitive mesh network: Wireless mesh networks are emerging as a cost-effective technology for providing broadband connectivity. As the network density increases and the applications require large throughput, mesh networks require large capacity to meet the requirements of the applications. The cognitive radio technology enables the access to larger spectrum, CR networks can be used for mesh networks that will be deployed in dense urban areas with the possibility of significant contention.

For example, the coverage area of CR networks can be increased when a meshed wireless backbone network of infrastructure links is established based on cognitive access points (CAPs) and fixed cognitive relay nodes.

The capacity of a CAP, connected via a wired broadband access to the Internet, is distributed into a large area with the help of a fixed CRN. CR networks have the capacity to add temporary or permanent spectrum to the infrastructure links used for relaying in case of high traffic load.

3. Emergency network: Public safety and emergency networks are another area in which CR networks can be implemented. In case of natural disasters, which may temporarily disable or destroy existing communication infrastructure, emergency personnel work in the disaster areas need to establish emergency networks. Since emergency networks deal with the essential information, reliable communication should be guaranteed with minimum latency. In addition, emergency communication requires a significant amount of radio spectrum for handling huge volume of traffic including voice, video and data (information). CR networks can enable the usage of the existing spectrum without the need for an infrastructure and by maintaining communication priority and response time.

4. Military network: One of the most interesting potential applications of a CR network is in a military radio environment. CR network can allow the military radios choose arbitrary, intermediate frequency (IF) bandwidth,

modulation technique, and coding methods, adapting to the variable radio environment of battlefield. Also military networks have a strong need for security and protection of the communication in hostile environment. CR networks could allow military personnel to perform spectrum handoff to find secure spectrum band for themselves and their allies.

B. Vision and Challenges

COGNITIVE RADIO NETWORK and wireless sensor network have been extensively studied separately. However, our vision is to use COGNITIVE RADIO NETWORK as wireless sensor network. In other words, we would like to embed wireless sensor network into COGNITIVE RADIO NETWORK which acts as a backbone. Sensing and communication will be explored simultaneously. Because of network, sensing coverage and sensing performance will be improved. Because of cognition, machine learning can be applied for the high level decision making. Meanwhile, dynamic spectrum access, the key feature of cognitive radio, will be used to make the smooth coexistence of sensing and communication. COGNITIVE RADIO NETWORK will be built based on the commercial communication components. Thus, our vision is also to push the capability of the communication components to the limit.

The sensing task is performed with these communication components instead of the sophisticated equipment's or the dedicated radar sets. Meanwhile, these communication components will be the programmable SDRs which are well suitable for building multifunction system at least including sensing, computation, and communication [1] [2]. Take wireless tomography [3] [4] as an example. Multiple Universal Software Radio Peripheral 2 (USRP2) will be used to set up a close-in wireless sensor network [11] the goal of which is to form the image of the target in the scene by wireless tomography.

Optimization theory, machine learning, real-time adaptive signal processing, and graph theory will be applied. An integrated sensing/communication cognitive network should have the capabilities of cognition, waveform diversity, network resource management, dynamic network topology, multi-level synchronization, and cyber security. In terms of wireless sensor network, the following functions should be supported: (1) interference mitigation; (2) detection and estimation; (3) classification, discrimination, and recognition; (4) tracking; (5) sensing and imaging.

B. Though the vision is very promising, we still have to face the inevitable challenges before we touch the goal. Because of the commercial communication components, even with the capability of programmability, the transmitted power and the signal bandwidth are limited.

Thus, COGNITIVE RADIO NETWORK with a large amount of radio nodes is needed to compensate the sensing performance loss due to the limitation of power and bandwidth. Meanwhile, in order to improve sensing resolution, high-precise synchronization is a must. However, the accurate measurement of phase rotation and time delay needs advanced hardware, precise timing information, and real time signal processing; especially for the case the transceiver is not collocated. Thus, COGNITIVE RADIO NETWORK should try its best to coordinate its radio nodes to carry out sensing task. Besides, spectrum, sometimes, is not available due to the usage of primary users. COGNITIVE RADIO NETWORK should have a quick response to the dynamic working radio environment.

IV. LITERATURE REVIEW

Comparison of Linear and Polynomial Classifiers for Co-operative Cognitive Radio Networks Yasmin Hassan Electrical Engineering Dept., UAE, 2010[5] In this research work the Cognitive Radio nodes collaborating in making the decision about spectrum availability. Simulation result indicates that both polynomial and linear classifiers provide high detection rate of primary users with a constant false alarm rate at very small signal to noise ratio conditions. For instance, the proposed method can achieve above 90% detection probability at $E_b/N_0 = -7$ dB with observation window of 50 bits and 10% false alarm rate. It is additionally indicated that the performance improves as we increase the sensing time for both methods.

Spectrum Sharing Based on Spectrum Heterogeneity and Multihop Handoff in Centralized Cognitive Radio Networks, Guoqin Ning, Jiaqi Duan, Jian Su, Duo Qiu, 2011[6] Here a prediction model of channel usage time is

proposed, which is based on the mobility of Cognitive Radio users and spectrum transmission spectrum. The channel predicted usage time is main metrics for the spectrum sharing. In sequence to decrease channel handoffs resulting from short channel usage time, a usage threshold time is set for the channel allocation. When channel handoff cannot be implemented in a single hop, the multi-hop routing will be established to keep the communication.

Simulation results reveal that the amount of channel handoffs can be considerably reduced after using the predicted channel usage time and channel utilization is enhanced and the handoff blocking probability is also dramatically decreased simultaneously. In addition, the further simulation results show that apart from the PU activity, CR node's mobility is also vital to the channel handoffs and link available time. Co-operative Spectrum Sensing: Implementation and Benchmarking on ANRC

Cognitive Radio Testbed Ramachandra Budihal, Aerospace Network Research, 2012[7]

Co-operative Spectrum Sensing: Implementation and Benchmarking on ANRC Cognitive Radio Testbed Ramachandra Budihal, Aerospace Network Research, 2012[7] In this paper, taking cue from our earlier implementation work on simple Snapshot ED and CUSUM based algorithms for single node spectrum sensing, explained the implementation of Sequential change detection algorithm in co-operative method, the Dual-CUSUM. Single node sensing is not reliable, particularly, when the nodes are subjected to shadow fading due to obstacles (hidden node problem). This is relieved by using co-operative sensing that exploits the inherent spatial diversity and it is seen that with certain fusion rules, Co-operative CUSUM (Dual- CUSUM) is better than its counterpart Co-operative Snapshot ED, mainly, under low SNR regimes. Spectrum Handover with Queues and Guard Channels in Cognitive Radio Networks, Shun-Fang Yang, Jung- Shyr Wu and Jian-Wei Huang, 2012[8] In this research work the markov chain model is proposed to evaluate the performance of the proposed handoff spectrum technique.

The proposed scheme can reduce the blocking rate and dropping rate of real-time and non-real-time SUs in order to enhance service quality with seamless spectrum handover in multi-cell cognitive radio networks, thus improving overall system performance. Dynamic Channel Allocation-based Call Admission Control in Cognitive Radio Networks Zhifeng Ni , Hanguan Shan, 2013[9] In this research work, a slotted call admission control method integrated with dynamic channel allocation is proposed to address the issue. In the proposed method , admitting user only occurs at the beginning of a new slot; thus, new SUs arriving between two slots ought to first enter a waiting queue until the next slot arrives. By imposing a compulsory so far limited waiting time on new SUs, the proposed method offer an opportunity to allow admitted SUs to fully utilize the available primary spectrum. An analytical framework using a 3D discretetime Markov chain is developed to analyze the impact of the proposed method on both the call-level and packetlevel performances of SUs. Simulation result verifies that the accuracy of the analysis and show the effectiveness of the proposed method in terms of reducing blocking and dropping probabilities, lowering packet queuing delay, and improving spectrum utilization efficiency. Improved Spectrum Mobility using Virtual Reservation in Collaborative Cognitive Radio Networks, Zhifeng Ni, Hanguan Shan, Wei Shen t, Jian Wang, 2013[10] In this paper propose and analyze the performance of virtual reservation in collaborative cognitive networks. Virtual reservation is a narrative link maintenance strategy that aims to maximize the throughput of the cognitive network

through full spectrum utilization. Performance evaluation shows significant improvements not only in the SUs blocking and forced termination probabilities but also in the throughput of cognitive users.

V. CONCLUSION AND FUTURE WORK

In this paper we concludes that the vision and challenge for the convergence of the wireless sensor network to cognitive radio network. The goal of the conceptual design is utilize the key features of the cognitive radio network as possible as it can, like the efficient spectrum utilization, software defined radio, etc. This creates new challenges for the network design which have been addressed applying varies approaches as has been discussed in the previous sections. The fundamental problems in detecting the spectrum holes are naturally mostly related to signal processing at the physical layer. There are significant regulatory, scientific and application challenges that need to be addressed and CR will not suddenly emerge. Cognitive radio networks are being studied intensively. In the future the major motivation for this is the currently heavily underutilized frequency spectrum some works need to be exploited more. Extending the availability of today's radio spectrum is a natural interest of nationwide operators. With a more flexible regulatory framework, cognitive radios will improve coverage, capacity, and quality of service of future radio networks.

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