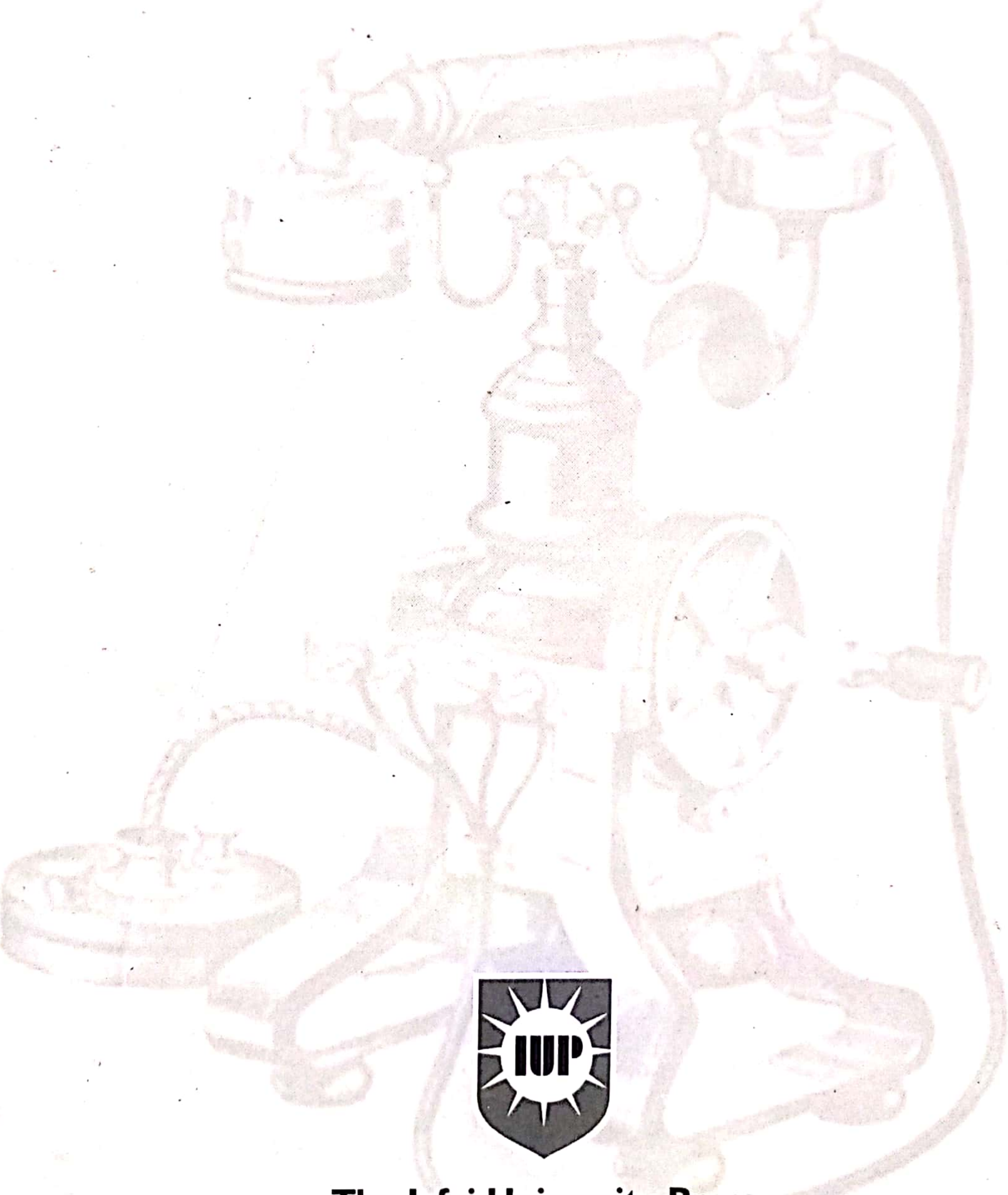
Vol. V No. 1 February 2013

The IUP Journal of Telecommunications



The Icfai University Press
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The IUP Journal of Telecommunications

Vol. V No. 1 February 2013

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IJTC

Vol. V No. 1 February 2013

ISSN 0975-5551

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The IUP Journal of Telecommunications is published four times a year in February, May, August and November.

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Published by E N Murthy on behalf of IUP Publications, # 52, Nagarjuna Hills, Panjagutta, Hyderabad 500082, Andhra Pradesh, India, and printed at M/s. Mahathi Print Creations, H. No. 1-1-379/290/A, Jawahar Nagar, Chikkadpally, Hyderabad 500020.

Focus

The last (November 2012) issue featured some research papers related to emerging trends of programmable radio module-based SDR systems incorporating spectrum sensing and adaptive reconfigurability to exploit multiband and multi-standard facility of the deployed networks. These remarkable developments in emerging wireless telecommunication involve efficient RF system enabling 4G technologies providing ubiquitous mobile seamless link at data rate beyond 100 Mbps at spectral efficiency of 10bits/s/Hz under Internet-based mobility with IPv6. Obviously, orthogonal frequency division multiple access or combined with CDMA or TDMA employing intelligent antenna and MIMO system have extensively been refined and innovated to improve link speed, performance and spectral efficiency. The new trends in emerging wireless technologies are based on software defined radio, cognitive radio, multi input multi output system, adaptive modulation and coding techniques to use various frequency bands more intelligently and efficiently.

The papers contained in the present issue also address some of the research problems related to cognitive radio, low power VLSI for mobiles, adaptive beamforming in smart antenna and data retrieving via image watermarking for improved channel utilization.

The Dynamic Spectrum Access (DSA) is a technology that senses the unused 'free' spectrum and allocates such spectrum on a non-interfering basis to the secondary users on a time-varying and flexible usage basis under consideration of appropriate regulatory restrictions. In the first paper, "Dynamic Spectrum Access (DSA) in Wireless Cognitive Radio Networks (WCRN)", the authors, Johnson Adegbenga Ajiboye, Yinusa Ademola Adediran and Mary Adebola Ajiboye, have presented a review of the techniques that can be deployed for DSA reliably in a Wireless Cognitive Radio Network (WCRN) and also have proposed models of network architecture-based DSA for such networks.

In the second paper, "A Self-Sustained RO Design for Low Power Multimedia Processing Blocks in Mobile Handsets", the authors, Saurabh Chaubey and Vinita Tiwari, have presented a novel self-sustained, self-start and low voltage ring oscillator as a frequency generation block used in the mobile instruments. A unique combination of DC-DC converter and a ring oscillator is proposed to fulfil the needs of high speed, power hungry multimedia digital/analog blocks of the mobile processors both in terms of clock frequency and power transfer. The paper reports a significant reduction in power consumption for a typical ring oscillator used in the frequency generation block.

In wireless technology, the smart adaptive antenna technology offers a superior solution to reduce interference levels and to improve the system capacity. The authors V E Idigo, A C O Azubogu, C O Ohaneme and O S Oguejio, in the paper, "Evaluation of

Beamforming Algorithms for Smart Antenna System", have presented an experimental test-bed of a smart antenna system for the comparative performance evaluation of various adaptive beamforming algorithms. The smart antenna technology suggested offers a significantly improved solution to reduce interference levels to achieve an increase in the capacity.

In the fourth paper, "Robust Semi-Reversible Watermarking Using Pixel Averaging Method Against Geometric Attack", the authors, Rajendra D Kanphade and Navnath S Narawade, have proposed a new watermarking method based on pixel averaging technique for copyright protection or military applications. The proposed method is robust and semi-reversible, and also gives exact recovery of a watermark with a compromising quality. Simulation results indicate that the proposed watermarking method is highly robust against various kinds of attacks such as rotation, scaling and translation attacks.

The last paper, "Retrieving of Image Based on Histogram Modification", by M Ramesh Reddy and K Yateendranath, reports an efficient algorithm to retrieve the data to reconstruct the image. The proposed model is an extension of the histogram modification technique by considering the differences between adjacent pixels instead of simple pixel value. The proposed scheme can hide and retrieve data without any loss in the quality of the image and is useful in image transmission through wireless channels.

V K Chaubey
Consulting Editor

Dynamic Spectrum Access (DSA) in Wireless Cognitive Radio Networks (WCRN)

Johnson Adegbenga Ajiboye, Yinusa Ademola Adediran** and Mary Adebola Ajiboye****

Dynamic Spectrum Access (DSA) is a technology that senses the unused 'free' but allocated portion of the radio frequency spectrum on a non-interfering basis. These unused bands are also known as 'holes' or 'white spaces'. DSA also refers to the time-varying, flexible usage of parts of the radio spectrum under consideration of regulatory and technical restrictions. This type of spectrum access is due to the dynamic behavior that the Secondary User (SU) must employ in order to access the spectrum, while avoiding interfering with a Primary User (PU). Intelligent or Cognitive Radio (CR) is a platform on which the DSA can be implemented. CRs are radio systems that autonomously coordinate the usage of spectrum. They utilize radio spectrum when it is not being used by incumbent (primary) radio systems. Underutilized spectrum can be exploited with the concepts of DSA and CR. This paper reviews the techniques that can be deployed for DSA reliably in a Wireless Cognitive Radio Network (WCRN) and models of network architecture-based DSA in Cognitive Radio Networks (CRN).

Keywords: Cognitive, Primary User, Secondary User, CR, SDR, QoS, WCRN, WRAN, DSA, FCC

Introduction

The need for intelligent radios capable of efficiently utilizing the wireless resource cannot be overemphasized. Certainly, the current traditional method of command-and-control in the usage of the scarce resource is becoming unacceptable. Recently, because of the increase in spectrum demand, the static spectrum allocation policy is faced with spectrum scarcity, in particular spectrum bands (Akyildiz *et al.*, 2008). Also, the design of radio that is to perform only a single task is becoming outdated. A robust radio capable of intelligent decision is a new concept and technology being envisioned in the current wireless networks.

There is an urgent need to manage the wireless resource due to the stringent demands being placed on it because of the increase in both applications and complexity of devices (Rondeau and Bostian, 2009). Dynamic Spectrum Access (DSA)

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is a new technology that senses the unused spectrum and permits devices to temporarily use this spectrum in a non-injurious basis. Radios that dynamically share the spectrum and other wireless resources are known as Cognitive Radio (CR). CR is capable of monitoring the wireless network and then using intelligent algorithms to optimize its behavior. According to Razavi (2009), CRs offer an approach to alleviate the congestion: they continually sense the spectrum, detect and utilize the unoccupied channels. Certainly, CRs dramatically improve the efficiency of the utilization of radio frequency spectrum. It is expected that CRs require new protocols and algorithms for spectrum sharing. According to the FCC, CR is defined as radio systems that continuously perform spectrum sensing, dynamically identify unused (white) spectrum, and then operate in this spectrum at times when it is not used by incumbent radio systems (Mangold *et al.*, 2005).

CR is a radio designed and also built on a software-defined radio. It is a wireless communication system that is aware of its environment. It is expected that CRs improve the quality of service of future radio networks and radically enhance and improve the efficiency of spectrum usage. According to Mahmud *et al.* (2009), CR can be defined as an intelligent wireless system that is aware of its surrounding environment through sensing and measurements; a system that uses its gained experience to plan future actions and adapt to improve the overall communication quality and meet user's needs. The CR should, in an attempt to minimize interference to Primary Users (PUs), while making the most out of the opportunities, keep track of variations in spectrum availability and also make predictions (Yucek and Arslan, 2009).

Recent studies by the Federal Communications Commission (FCC) highlight that many spectrum bands allocated through static assignment policies are used only in bounded geographical areas or over limited periods of time, and that the average utilization of such bands varies between 15% and 85% in the band below 3 GHz (FCC, 2002). According to Kamal *et al.* (2010), the fixed spectrum assignment policy is based on static long-term exclusive rights of spectrum usage and is shown to be inflexible. Some licensed bands such as TV bands are known to be grossly underutilized. Therefore, spectrum sharing in unused portions of these licensed bands can effectively reduce, to a large extent, the problem of spectrum scarcity.

Spectrum-Policy Task Force under the FCC released a report in November 2002. The report considered how the spectrum can be judiciously managed and utilized in the US (Cesana *et al.*, 2011). They recommended that significant greater spectral efficiency could be realized by deploying wireless devices that can coexist with the PUs, generating minimal interference, while taking advantage of the available resources (Hayar *et al.*, 2007).

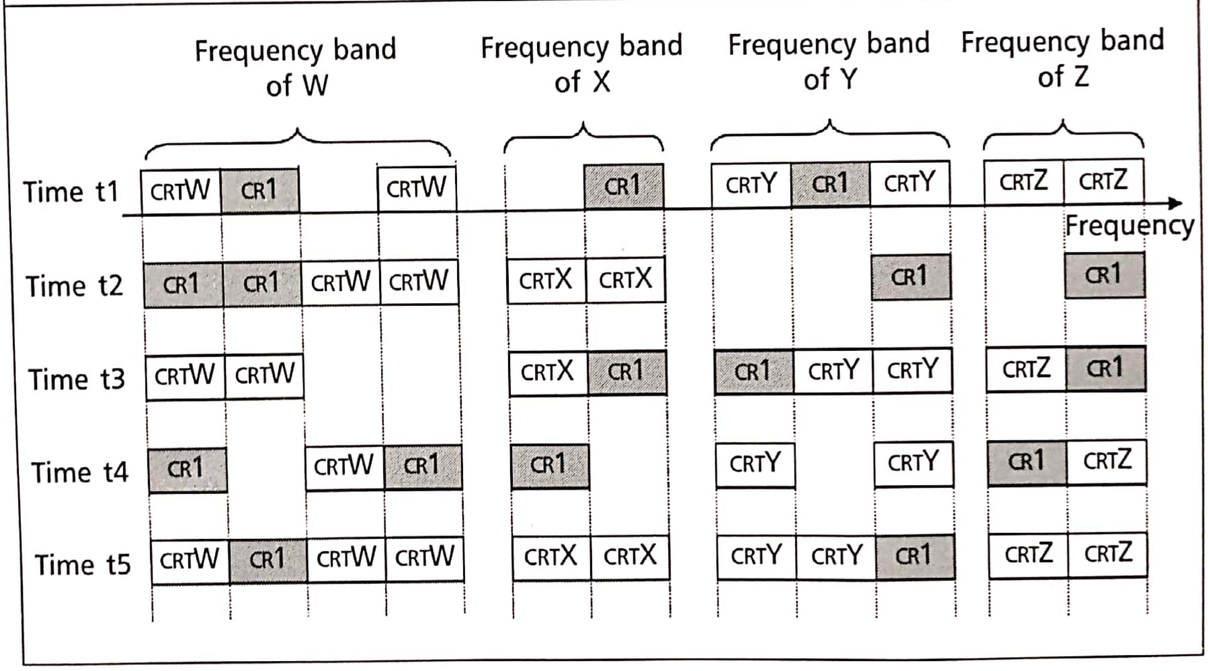
Cognitive Radio Network (CRN) is defined as composed of cognitive, spectrum-agile devices capable of changing their configurations on the fly based on the spectral environment (Cesana *et al.*, 2011).

CRNs Concept

There are two major concepts of the CRN. The first is the concept of the multiple system, in which wireless communication systems are switched depending on the prevailing radio condition. The second concept is based on DSA. In DSA, the unused spare frequencies of a primary licensed user are discovered and are temporarily allocated to the unlicensed Secondary User (SU) for its communication, i.e., to either receive or send data. However, this must be done in such a way that interference to the primary legacy user is minimal.

In Figure 1, CR is described both in time and frequency domains. The frequency bands of four communication systems W, X, Y and Z are shown. System W with CR terminal CRTW can communicate using a maximum of four channels, system X with CR terminal CRTX has a maximum of only 2 channels for communication, system Y with CR terminal CRTY has 3 channels, while system Z with CR terminal CRTZ has only 2 channels. However, not all the channels are utilized in all the time epochs for communication. Therefore, as seen in Figure 1, CR1 dynamically explores the unused time slots for its own communication. For example, at time epoch t1 the CR terminal communicates using the frequency band of systems W, X and Y, etc.

Figure 1: CRN Concept



CRNs and DSA

DSA was initiated with the intention of addressing the problem of spectrum underutilization. DSA describes how the frequency bands assigned to RF networks are used. A frequency band can be shared by several RF networks and distributed spectrum managers analyze the information from the DSA algorithms and dynamically make spectrum access decisions based on regulations and policies (Hayar *et al.*, 2007). DSA may be done with or without negotiation.

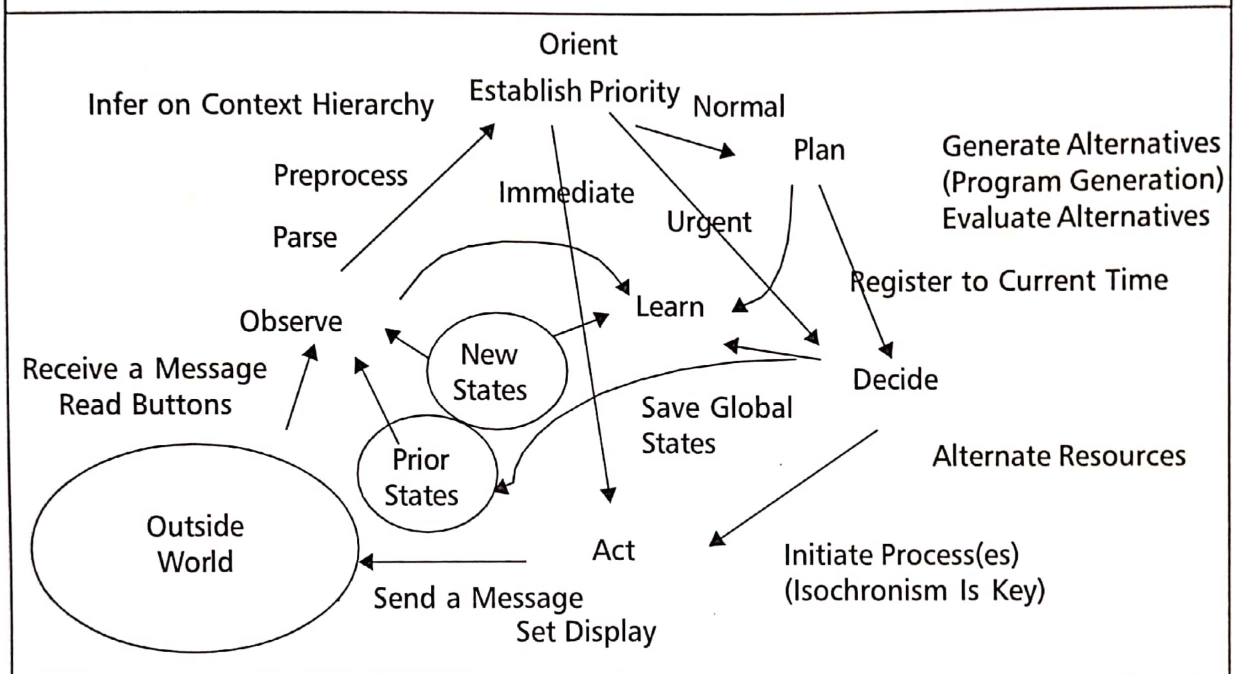
In DSA, CRN identifies and utilizes unused portions of the spectrum, also known as white space, dynamically. The white space is the unused portion of frequency or time in a particular location. DSA is at the cutting edge of future wireless communication. With DSA, unlicensed SUs are allowed access to licensed PUs spectrum bands opportunistically and in a non-interfering and non-intrusive manner. The Software-Defined Radios (SDRs), a core platform on which CRs are designed and built have made this possible. SDRs have enabled the design of spectrum-agile devices that are being programmed and have the ability to operate on a very wide spectrum range. These devices can be tuned to any frequency band in that range with very minimal delay. The CR transceivers have the ability and capability of completely changing transmitter parameters such as operating spectrum, modulation, communication technology and transmission power. The CR can sense a wide spectrum range and dynamically discover unused spectrum blocks for the purpose of data communication. It can also intelligently access the unoccupied spectrum. The unoccupied spectrums are known as spectrum opportunities.

It is possible to network devices that have cognitive capabilities. Such networks are known as CRNs. In CRNs, there are basically two types of users sharing a common spectrum portion. The PUs or the licensed users adopt the traditional wireless communication systems with static spectrum allocation, while the SUs or the unlicensed users are merely equipped with CRs and exploit unused spectrum to enable them sustain their communication activities. This they do without interfering with the PUs transmissions. IEEE 802.22 is a potential candidate for the CR technology. The goal of IEEE 802.22 standard is to make use of the advantage of unused frequency spectrum for Wireless Regional Area Network (WRAN) and they are designed to operate in the TV broadcast bands while ensuring that no harm interference is caused to the incumbent operation (i.e., digital TV and analog TV broadcasting) and low-power licensed devices such as wireless microphones (Stevenson *et al.*, 2009). Four key components to DSA are spectrum opportunity identification, spectrum opportunity detection, spectrum opportunity tracking and spectrum opportunity exploitation (Zhao and Sadler, 2007).

CRNs and Cognition Cycle

An ideal Cognitive Radio (iCR) can be defined as a wireless communication system with the ability and potential for sensing, perceiving, orienting, planning, decision making and autonomous learning. Through direct observation, a radio accepts information about its operating environment or the outside world. The received information is evaluated or oriented with the aim of knowing its relevance or importance. The evaluation determines the 'plan' and chooses an alternative 'decide' in a way that would improve the evaluation. In a situation when change in waveform is necessary, the radio then implements the alternative 'act' by adjusting its resources and performing the appropriate signaling. These changes are then reflected in the interference profile presented by the CR in the outside world (Figure 2). As part of this process, the radio uses these observations and decisions to improve the operation of the radio 'learn', perhaps by creating new modeling states and generating new alternatives. According to Piasecki (2009) and Stevenson *et al.* (2009) CRNs use a cognition cycle that includes radio scene analysis, channel state estimation and predictive modeling and transmit power control and spectrum management commands.

Figure 2: The Cognition Cycle



Source: Mitola III (2000)

Techniques for DSA in CRNs

The implementation of CRNs is based on DSA by the unlicensed SUs. When spectrum is intelligently shared in this way, it can greatly improve the efficiency of the scarce finite resource. There are several techniques which can be adopted. The techniques can be based on network architecture, spectrum allocation behavior and spectrum access technique.

Network Architecture-Based DSA in CRNs

In this model, there are two approaches: the centralized approach and the distributed approach. In the centralized approach, the central server is responsible for managing the frequency spectrum by collecting information from the SUs attached to it and it keeps a database of the spectrum access and its availability (Figure 3). There is a well coordinated and efficient spectrum sharing in this model.

In the distributed model of spectrum sharing, each communication node is in charge of its own spectrum allocation. Access to the spectrum is allowed or disallowed depending on the transmission of the PU in its immediate environment. In this model, the SUs are empowered to sense the PU and to share the spectrum (Figure 4).

Figure 3: Centralized Sharing in CRN

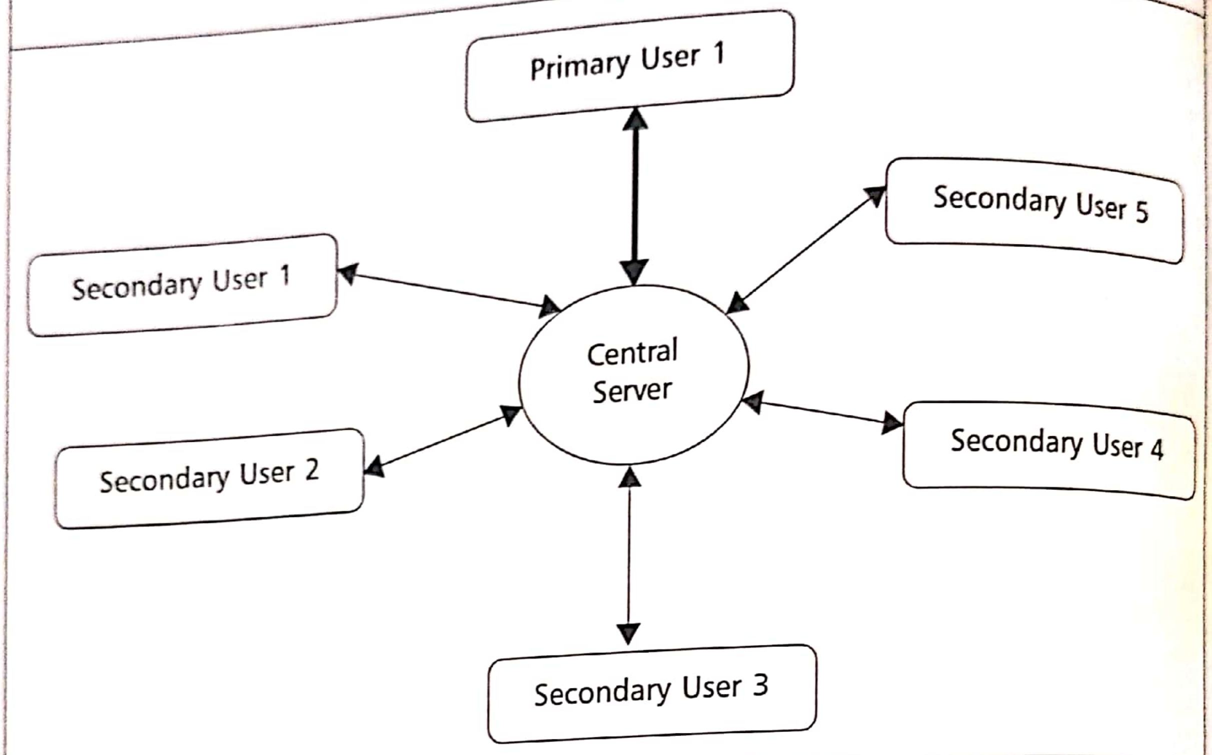
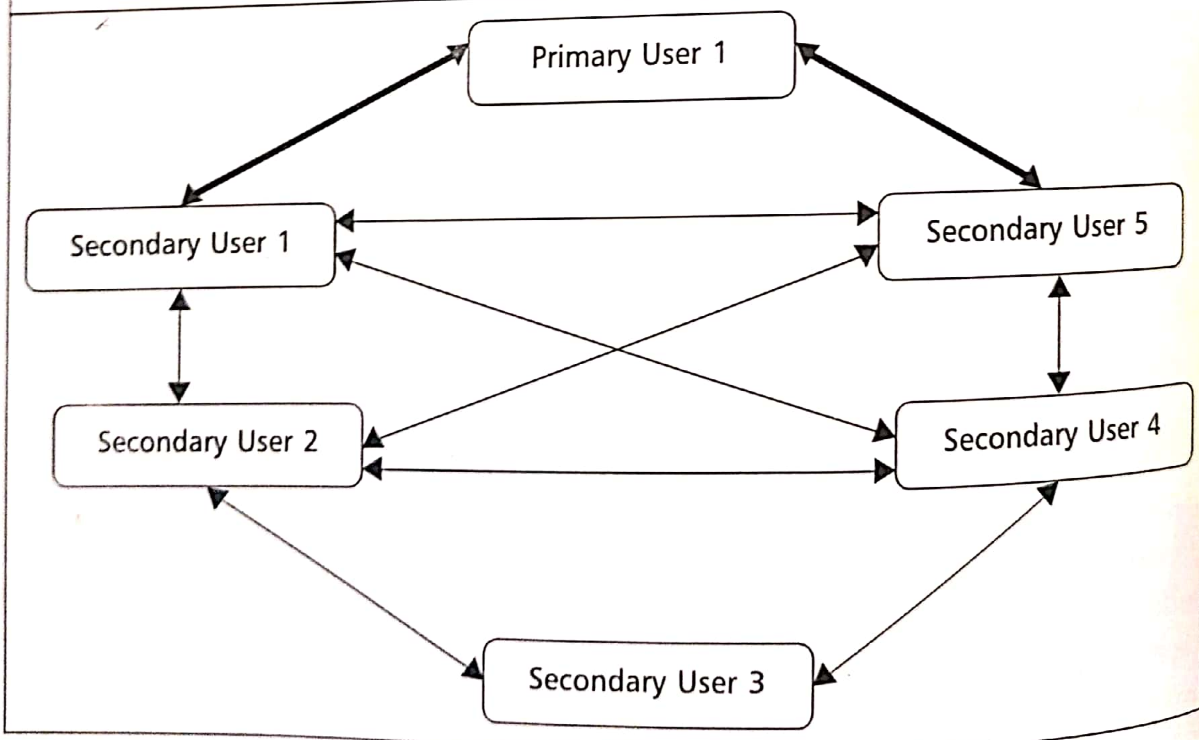


Figure 4: Distributed Sharing in CRN



Spectrum Allocation Behavior-Based DSA in CRNs

There are two types of models in this technique of spectrum sharing. These are cooperative and non-cooperative spectrum sharing approaches. In the cooperative sharing model, the PU and the SU are expected to share the spectrum occupancy information with each other. In this way spectral efficiency is enhanced. This model can either be in a centralized manner, where a central server maintains a database of the spectral usage or in a distributed manner where each user has a knowledge of spectral usage and therefore shares this knowledge with its neighbors with a view to enhancing spectrum utilization.

In the non-cooperative spectrum sharing approach, information exchange and sharing between the PUs and the SUs is kept to the barest minimum. As expected, this will greatly affect the spectral efficiency as communication nodes may behave in a greedy and self-centered manner.

Spectrum Access Technique-Based DSA in CRNs

There are two approaches for opportunistic spectrum access: spectrum underlay and spectrum overlay. In the underlay model, when communication signal is in frequency, power and time domain mode, the signal transmission is done at a low power level, therefore the spectrum underlay approach constrains the transmission power of SUs. The underlay systems utilize the wideband and low power signals for simultaneous transmission with the PUs. However, in the overlay model, the system utilizes the unused portion of the spectrum, i.e., the white spaces but with reasonable amount of guard bands for transmission by the SUs. Spectrum measurements must be done constantly by the SUs to gain knowledge of the PUs' activity.

Conclusion

In this work, the CRN concept was discussed with a focus on the DSA, a mechanism that adjusts the spectrum resource usage in a near-real-time manner in response to the changing environment and objective. Network architecture-based techniques, spectrum allocation-based techniques and spectrum access-based technique for DSA implementation in CRN were discussed and models for the implementation of these techniques were proposed. With opportunistic spectrum access, SUs are able to exploit unused in-band segments without causing any severe interference to the active PUs. Models that achieve this QoS level were presented in this paper.

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Reference # 70J-2013-02-01-01