Chapter 1

History and Foundation

Alagan Anpalagan
Ryerson University
E-mail: alagan@ee.ryerson.ca

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1.1. History and Foundation

The unprecedented development in wireless communication over the last decade has changed the human life in many ways for good. It has brought about many changes in social interactions, business operations, safety applications, multimedia video gaming and many more areas. There have been generational shifts in service offerings over many years, from analog rudimentary voice services to digital voice and low rate data applications, and then to high quality multimedia services. Keeping up with the wider societal acceptance and higher demand for wire-free communication, the industry is looking for enabling technologies for next generation wireless communication and networking.

The term cognitive radio (CR) first coined by J. Mitola III [1] has been widely identified as one of the key enabling technologies to increase efficiency of the current wireless communication. The ideal CR envisioned in the early stage of its conception included highly integrated and sophisticated active operational entities such as environmental sensing, reasoning, learning and acting based on the built knowledge and prevalent operating conditions. The later research focused more on pragmatic approach to CR operations with special emphasis on highly reliable sensing of the presence of the licensed users [2], dynamic opportunistic spectrum access by the CRs and to autonomously adjust transceiver parameters [3] to exploit the under-utilized radio resources. There are significant spectrum opportunities available for a range of indoor and outdoor applications and services that include wireless home networks, mobile broadband, rural broadband and femtocells [4] through the use of cognitive radios. This book discusses enabling technologies for a good understanding of the cognitive radios.

1.2. Introduction

Radio spectrum—the segment of the electromagnetic continuum containing waves in the radio-frequency range (RF)—is a valuable and scare resource. The demand for wireless communication is continuously increasing with more and more users wanting the services anywhere and anytime. New applications that require higher data rates and better quality of service are emerging. While some were calling for more spectrums to be released for personal communication services, the Federal Communication Commission (FCC) reported the under-utilization of the already allocated spectrum in various locations, in frequency bands and at different times [5]. Measurements in the 30-300 MHz band showed that the average utilization over all the frequency channels in this band was less than 10%. It was an interesting and eye-opening revelation for many while the findings provided many opportunities to innovate technologies to efficiently utilize the spectrum. The call for more spectrums shifted to call for disruptive technology in wireless communication.

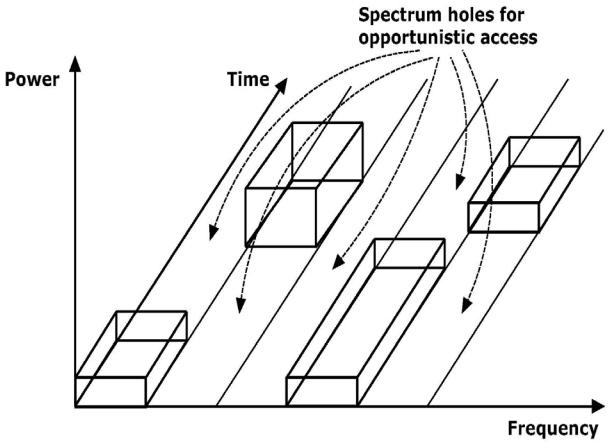

Figure 1. Availability of spectrum holes that can be used opportunistically.

The idea of utilizing the unused spectrum of the licensed bands by the unlicensed users temporally and spatially was proposed. In doing so, any licensed user who has the exclusive access and usage privilege to the licensed bands has to be protected yet allowing unlicensed users to access and utilize the spectrum dynamically. **Figure 1** shows the spectrum holes (also known as white spaces) with time in different bands which can poten-

tially be used opportunistically by the unlicensed users until the licensed users signal to use them.

A promising solution to efficiently exploit the underutilized spectrum was the development of cognitive radio (CR) - an innovative conceptual proposal first originated in [1]. There are many definitions of cognitive radio in the literature. One such definition is *a radio that is adaptive, autonomous, learns from its environment and experiences to reason, plan and decide actions to meet user needs by being multi-dimensionally aware* [6]. The unlicensed users are known as cognitive radio users and they form a cognitive radio network for communication. In the literature, cognitive radio users are also referred to sometimes as secondary users (SUs), and licensed users as primary users (PUs). As such, these terminologies are used interchangeably.

Some consider cognitive radio as to revolutionize wireless world just as the PC did in computer world with the expectation that cognitive radio will exploit the full potential of wireless system capabilities including software, hardware and firmware, for better service and pricing. The cognitive radio also capitalizes on latest technological advances in signal processing, RF technology and embedded system development as well as changes in the spectrum policy by the regulatory bodies [7]. **Figure 2** shows a hybrid network consisting of primary and cognitive radio network where *CR1* uses licensed band *f2* and, *CR2* and *CR3* use unlicensed bands for their communication need.

The architecture for cognitive radio network (CRN) falls into two main categories, centralized CRN and distributed CRN. Centralized CRN has an access point (or base station) that manages the data transmission of users in the network and a type of spectrum broker which is responsible for allocating the radio resources to users. Here, the spectrum access by secondary users is coordinated. In a distributed CRN, the secondary users access the spectrum based on each user's decision that can be arrived individually (non-cooperatively) or cooperatively by sharing information with other users.

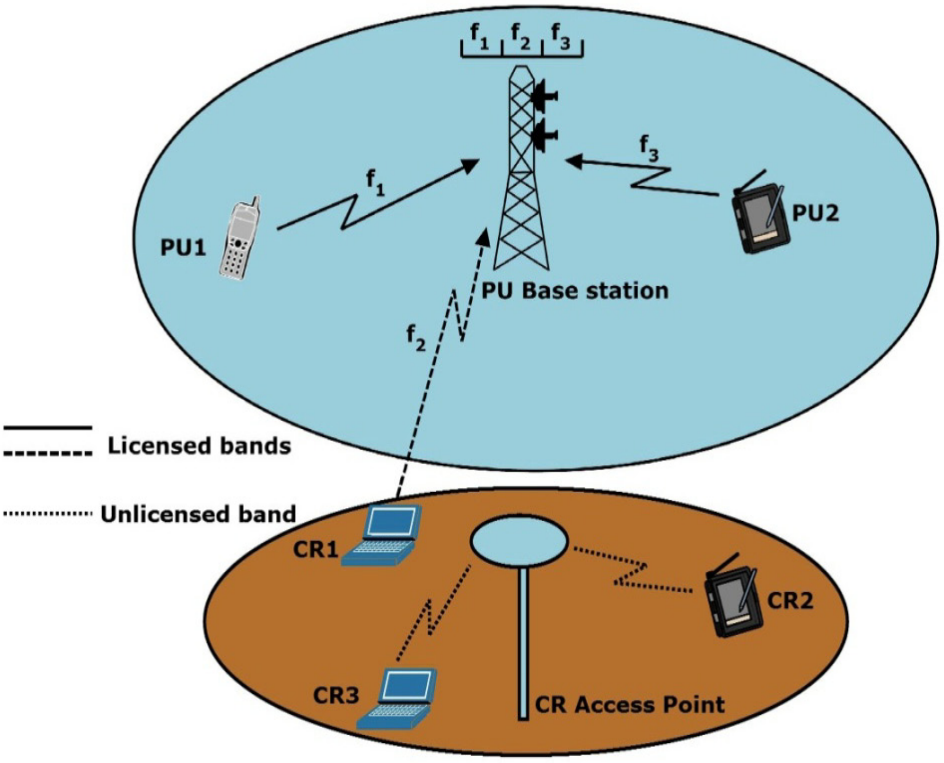

Figure 2. An example of cognitive radio network.