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Spectrum Handoff Schemes and Optimum Utilization of Spectrum Holes in Cognitive Radio Network

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Abstract: *Cognitive Radio (CR) was proposed as a brain empowered wireless communication system. It uses the software defined radio (SDR) to use and dynamically share the spectrum in an opportunistic manner. In this paper, we have defined a priority assignment technique (CR+) so that spectrum can be used effectively and dynamically and there would be much heavily reduction in the forced termination of a handoff request.*
Keywords: *Cognitive Radio (CR), Handoff*

I. Introduction

Current wireless networks are characterized by a static spectrum allocation policy, which assigns a fixed block of spectrum to each new wireless service for its exclusive use. Over the years, the remaining useful spectrum available for new wireless services is being exhausted. Studies show that many allocated spectrum blocks are used only in certain geographical areas and are idle most of the time. These frequency bands are called the spectrum "white space."[1]. Hence, dynamic spectrum access techniques were recently proposed to solve these spectrum inefficiency problems.

The key enabling technology of dynamic spectrum access techniques is Cognitive Radio (CR) technology, which provides the capability to share the wireless channel with licensed users in opportunistic manner. The idea of cognitive radio was first presented officially in an article by Joseph Mitola III and Gerald Q. Maguire, Jr in 1999. It was a novel approach in wireless communications that Mitola later described as:

The point in which wireless personal digital assistants (PDAs) and the related networks are sufficiently computationally intelligent about radio resources and related computer-to-computer communications to detect user communications needs as a function of use context, and to provide radio resources and wireless services most appropriate to those needs. It was thought of as an ideal goal towards which a software-defined radio platform should evolve: a fully reconfigurable wireless black-box that automatically changes its communication variables in response to network and user demands.

This paper is organized for the issues like opportunistic usage of limited available spectrum, optimal utilization of available spectrum, requirement fulfillment of licensed and unlicensed users, reduction in probability of unsuccessful handoff, improvement in spectrum allocation policy in order to provide seamless communication.

II. Problem Definition

The problems that are tackled using the concept of CR or Dynamic Spectrum Access are:

a) Limited available spectrum.
b) Inefficiency in the spectrum usage and allocation policy.
c) Blocking of handoff call.
d) Providing seamless communication for the mobile users across different wireless architectures.

Since there is scarcity of available spectrum and mis-utilization of available resources there always exists a conflict between an initial attempt call and a handoff call. A handoff can occur with primary user as well as secondary user.

Handoff with primary user: when quality deteriorates and also when a spectrum band with better QOS is available.

Handoff with secondary user: when the licensed user of the spectrum, which is being utilized by secondary user appears and also when a better spectrum as per the user's requirement becomes available.

It will not be desirable to forcefully terminate an ongoing call and to provide the resources that were occupied by the handoff call to an initial attempt call to originate.

III. Cognitive Radio

A. *Definition*

CR was proposed as a brain empowered wireless communication system and is defined as " a radio that has, in some sense, awareness of changes in its environment, in response to these changes adapt its operating characteristics in some way to improve its performance or to minimize a loss in performance."

In simpler terms, a CR is a transceiver device that is able to understand and react to its operating environment.

"A radio that can change its transmitter parameters based on the environment in which it operates".

The term cognitive radio is derived from "cognition."[2] Cognition is referred to as

a) mental processes of an individual, with particular relation
b) mental states such as beliefs, desires and intentions
c) information processing involving learning and knowledge
d) Description of the emergent development of knowledge and concepts within a group.

Resulting from this definition, the cognitive radio is a self-aware communication system that efficiently uses spectrum in an intelligent way. It autonomously coordinates the usage of spectrum in identifying the unused radio spectrum on the basis of observing spectrum usage.

CR uses the software defined radio (SDR) to use and dynamically share the spectrum in an opportunistic manner. CR offers the promise of intelligent radio that can learn from and adapt to their environment. Dynamic spectrum access technique can allow the user to operate in the best available channel in terms of the application requirement and available spectrum pool characteristics, like channel capacity, BER, possible interference, path loss, possible channel holding time etc.

CR technology is the key technology that enables an XG network to use spectrum n a dynamic manner. Two main characteristics of the Cognitive Radio are:

1) Cognitive Capability: Cognitive Capability refers to the ability of the radio technology to capture or sense the information from its radio environment.

2) Re-configurability: The Cognitive capability provides spectrum awareness whereas re-configurability enables the radio to be dynamically programmed according to the radio environment.

The ultimate objective of the Cognitive Radio is to obtain the best available spectrum through cognitive capability and re-configurability.

B. *Opportunistic spectrum access*

Cognitive Radio has been considered as an efficient means to opportunistic spectrum sharing between primary (licensed) users and cognitive users. In this scheme [3], CR networks consist of a multiple cells and the system throughput is defined as the total number of subscribers that can be simultaneously served. Here, CR network is considered as self organizing network

Dynamic Spectrum Allocation: CR uses CORVUS {CR Virtual Unlicensed Approach) [4] that uses allocated spectrum in an opportunistic manner to create "virtual unlicensed bands" i.e. bands that are shared with the primary users on a non-interference basis. Spectrum Pooling is a resource sharing strategy that organizes the available spectrum into a spectrum pool which is then optimized for a given application. Once a primary user appears, secondary users need to cease transmission if they will cause interference.

C. *Spectrum Sensing and Primary Users Detection*

Since CR (Secondary Users) are considered lower priority of spectrum allocated to a Primary User, a fundamental requirement is to avoid interference to potential primary users in their vicinity. Therefore, cognitive radios should be able to detect unoccupied spectrums and the presence of primary users through continuous sensing. Stringent requirements on the probability of detection is 99.9% at a given false alarm probability. A variety of techniques had been proposed to increase the probability of primary user detection like detection using pilot signal and cyclo-stationary feature detection [5]

D. *Requirement fulfillment of licensed and unlicensed users*

Cognitive Radios have been proposed as a means to implement efficient use of the licensed spectrum. The key feature of a CR is its ability to recognize the primary users and adapt its communication strategy to minimize the interference that it generates. CR allows both primary and secondary users to use the channel effectively.

Functions: Main functions for Cognitive Radios in XG networks are:

Spectrum Sensing: Detecting unused spectrum and sharing the spectrum without harmful interference with other users.

Spectrum Management: Capturing the best available spectrum to meet user communication requirements.

Spectrum Mobility: Maintaining seamless communication requirements during the transition to better spectrum.

Spectrum Sharing: Providing the fair spectrum scheduling method among coexisting XG users.

E. *Applications*

Mobile multimedia downloads (for example, download of music/videos files to portable players) which require moderate data rates and near- ubiquitous coverage. Emergency communication services that require a moderate data rate and localized coverage. Broadband wireless networking (for example: using nomadic laptops), which needs high data rates, but where users may be satisfied with localized "hot spots" services. Multimedia wireless networking services (e.g. audio/ video distribution within homes) requiring high data rates.

F. Advantages

The main specific benefits of CR are that it would allow systems to use their spectrum sensing capabilities to optimize their access to and use of the spectrum. From a regulator's perspective, dynamic spectrum access techniques using CR could minimize the burden of spectrum management whilst maximizing spectrum efficiency. Additional benefits from the development of SDR, coupled with basic intelligence, are: optimal diversification enabling better QOS for users and reduced cost for radio manufacturers. So, key points are: expansion in the capacity of critical communication network in emergency scenarios offer enhanced coverage to user make higher data rate services available to users increase in utilization of radio spectrum

IV. Proposed Method

Here we proposed the dynamic way of spectrum sensing to find unused frequencies or spectrum holes or white spaces [6]. "A Spectrum Hole is a band of frequencies assigned to a primary user, but, at a particular time and specific geographic location, the band is not being utilized by that user." Then to utilize these white spaces in the unlicensed zone with the condition that unlicensed users should

1) not interfere with the primary users
2) release the resources on the occurrence of license holders

Here approach is to assign different priority levels to handoffs as well as initial access requests. This priority assignment treatment can be extended to the limit where the reduction in the overall traffic due to the insufficient weight to the initial access request can be afforded.

Here each incoming request will be classified based on four existing classes

1) Primary Handoff request (*PH*)
2) Primary initial request (*PI*)
3) Secondary handoff request (*SH*)
4) Secondary initial request (*SI*)

The priority assigned to each request is as follows

$PH > PI > SH > SI$

Calls are categorized into four streams:

1) A primary handoff call: occurs when either quality deteriorates or a band of spectrum with better quality of service is available.
2) A primary initial call: is generated from a licensed user.
3) A secondary handoff call: may appear due to mobility of the user after the communication has been started, when the owner of the band which an unlicensed user was utilizing appears, when quality deteriorates or when a spectrum band with better quality of service becomes available.
4) A secondary initial call: an initial access request from an unlicensed user.

Primary handoff is given highest priority as it's a request that comes from a licensed user of the cell and also the communication for which the request is made ongoing. Second highest priority is given to primary initial, though it's a request to initiate a communication, but this request is made by a licensed user. Thus to support this call is more important in comparison of secondary handoff and secondary initial because later two are the request made by the unlicensed user.

Opportunistic spectrum access help unlicensed user only in the condition when it does not interfere with the primary user. Third higher priority is allocated to the secondary handoff, though this request is from unlicensed user but is for an ongoing communication.

Last comes secondary initial, it has the lowest priority as it is a request from an unlicensed user and it is to initiate a communication. The technique that we used here to use spectrum effectively and dynamically is called CR+. The switching from one spectral band to another should be smooth without any interruption and quick.

Flowchart describing with 3 pools but can be extended to N pools:
Total frequencies available in Pool 1 = N1
Frequencies allocated to Pool 1= n1
Free frequencies in Pool 1= N1-n1
Total frequencies available in Pool 2 = N2
Frequencies allocated to Pool 2= n2
Free frequencies in Pool 2= N2-n2
Total frequencies available in Pool 3 = N3
Frequencies allocated to Pool 3= n3
Free frequencies in Pool 2= N3-n3

Accept new user with priority PH=4, PI=3, SH=2, SI=1
Threshold= 70% of total channel available in Pool 1 (Pool 2 and Pool 3)
Step 1: If new user belongs to pool 1 than repeat step 2 to step 4 else if user belongs to pool 2 and repeat step 5 to step 7 and else user belongs to pool 3 and repeat step 8 o step 10.
Step 2: If n1< N1 then allocate frequency to new user and set n1= n1+1 else go to step 3.
Step3: If number of free channel >= threshold of pool 2 then check the user.If it is primary user it will now act as secondary user and channel will be allocated to the user on the basis of priority else if number of free channel >= threshold of pool 3 then check the user again. If it is primary user it will now act as secondary user and channel will be allocated to the user on the basis of priority else call will be dropped.
Step4: If number of free channel < threshold of pool 3 then check the new user priority. If new user priority is equal to1 then wait for 30 seconds else if new user (i) priority =1 then user(i)= new user else if user(i)priority =2 and < new user priority then user(i)= new user else if user(i)priority =3 and < new user priority then user(i)= new user else wait for 30 seconds and go to step 2.
Step5: If n2< N2 then allocate frequency to new user and set n2= n2+1 else go to step 6.
Step6: If number of free channel >= threshold of pool 1 then check the user. If it is primary user it will now act as secondary user and channel will be allocated to the user on the basis of priority else if number of free channel >= threshold of pool 3 then check the user again. If it is primary user it will now act as secondary user and channel will be allocated to the user on the basis of priority else call will be dropped.
Step7: If number of free channel < threshold of pool 3 then check the new user priority. If new user priority is equal to1 then wait for 30 seconds else if new user (i) priority =1 then user(i)= new user else if user(i)priority =2 and < new user priority then user(i)= new user else if user(i)priority =3 and < new user priority then user(i)= new user else wait for 30 seconds and go to step 5.
Step8: If n3< N3 then allocate frequency to new user and set n3= n3+1 else go to step 9.
Step9: If number of free channel >= threshold of pool 1 then check the user. If it is primary user it will now act as secondary user and channel will be allocated to the user on the basis of priority else if number of free channel >= threshold of pool 2 then check the user again. If it is primary user it will now act as secondary user and channel will be allocated to the user on the basis of priority else call will be dropped.
Step10: If number of free channel < threshold of pool 2 then check the new user priority. If new user priority is equal to1 then wait for 30 seconds else if new user (i) priority =1 then user(i)= new user else if user(i)priority =2 and < new user priority then user(i)= new user else if user(i)priority =3 and < new user priority then user(i)= new user else wait for 30 seconds and go to step 5.
This is basically the assignment module. In allocation module we will allocate priority to the users (primary and secondary).

V. Conclusion And Results

CR+ is a promising technology that can significantly enhance the utilization of radio spectrum. It has the potential to facilitate new spectrum trading approaches and business models. CR+ is an immature but rapidly developing technology area that should, in time, offer great benefits to all members of the radio community from regulators to users. In terms of spectrum regulation, the key benefit of CR+ is more efficient use of spectrum, because CR+ will enable new systems to share spectrum with existing legacy devices, with managed degrees of interference

The theory behind the spectrum band allocation policy and reduction in the forced termination of a handoff request is the assignment of different priority levels to different calls.
Primary handoff call > primary initial call > secondary handoff call > secondary initial call.
The ultimate objective of the CR+ is to obtain the best available spectrum through cognitive capability and reconfigure ability.
CR+ implies intelligent signal processing (ISP) at the physical layer of a wireless system, i.e. the layer that performs functions such as communication resource management, access to the communication medium, etc.

usually it is accompanied by ISP at higher layers of the open system interconnection (OSI) model. If ISP is not implemented at these higher layers then a CR+ will be restricted in what it can do. Because a communication exchange uses all seven OSI layers, ideally all seven layers need to be flexible if the CR+ intelligence is to be fully exploited. Without optimization of all the layers, spectrum efficiency gains may not be optimized. This level of complexity, required for the full CR may not be achievable for many years.
Surely this new spectrum allocation policy will fill the gaps of wireless spectrum and will satisfy the needs of both licensed as well as unlicensed users without any compromise.

VI. Future Work

In this paper, we have worked on new scheme called CR+ that significantly enhances the utilization of radio spectrum by assigning different priority levels to handoffs as well as initial access requests for both primary as well as secondary users. The future work includes designing an allocation module that allocates priority to both primary and secondary users.

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