Ph.D. Research Proposal

Doctoral Program in "Department Name"

Cooperative and Synchronized Spectrum Sensing and PAPR Aware Resource Allocation in Cluster based CRN-CSS 5G

by

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1. Introduction

Cognitive Radio (CR) is a Software Defined Radio (SDR) which is employed with cognitive engine to sense the environment and adapts to environment [1]. Due to sensing ability, CR becomes promising technology which can be integrated with future fifth generation (5G) network in order to improve spectrum efficiency [2]. To improve transmission in Multiple Input Multiple Output (MIMO) system Orthogonal Frequency Division Multiplexing (OFDM) scheme is incorporated in CRN based 5G network [3]. OFDM provides enhanced spectrum sensing and resource allocation in CRN and supports MIMO system. To enable spectrum sensing, optimal channel assignment and scheduling strategies were presented to avoid interference [4]-[6]. In [4], author presents two algorithms such as CSBUA and BUACS for channel assignment. But these algorithms increase waiting time for SUs for sensing. SUs were divided into free riders and contributors to sense the channel in [5]. Here channels are not utilized since channels for sensing are selected by SUs and if number free riders are increased then sensing is not efficient. Coalitional game theory was presented for channel assignment in CRN-CSS [6]. Here interference is introduced among SUs during spectrum sensing.

After sensing channel assignment, SU sense the channel to detect available spectrum. To improve sensing efficiency, Virtual Clustering Distributed Coordination (VCDC) method uses CSMA/CA technology for data transmission [7]. But this method is not able to support large network with multiple users. Reporting time was reduced in clustered CRN by providing fixed Time Division Multiple Access (TDMA) frame for each cluster [9]. Here fixed TDMA allocation for different size cluster reduces sensing efficiency. For efficient spectrum sensing, multiple Spectrum Agents (SAs) were incorporated in [11]. This method is not able to handle multiple SUs and managing multiple SAs become difficult. After sensing was completed, CH sends aggregated sensing reports to FC sequentially in specified order [10]. This sequential order increases reporting time and minimizes transmission time. In Fusion center (FC) decision on PU presence was made using OR rule [8]. Involvement of OR rule degrades the spectrum utilization.

Cognitive Radio was integrated with MIMO-OFDM based system to improve spectrum sensing and transmission [12] [13]. But major problem in OFDM system is it provides high Peak-to-Average power ratio (PAPR). If sensing process detect idle channel (i.e.) PU is inactive in that channel, then next step is to allocate spectrum and required transmission power for SUs in CRN [14].

2. Problem Definition

2.1 Overall Problem Statement

In CRN-CSS, interference is the major issue that occurs during spectrum sensing and also data transmission. In order to resolve this issue, sensing channel assignment and resource allocation is followed in prior works. However, the following research problems are still not yet addressed,

- How to mitigate the interference in sensing and data transmission?
- How to improve spectrum sensing techniques for wide-band 5G transmission since the conventional methods only support narrow band sensing?
- What is the best way to reduce PAPR in OFDM based 5G transmission?
- How to achieve high throughput and low power consumption in CRN-CSS?

2.2 Detailed Research Problems

A game theoretic approach was employed to utilize available spectrum during real time transmission for non-real time transmission [15]. Here spectrum utilization is poor while non-real time user requires more spectrum than available spectrum. Artificial Bee Colony (ABC) algorithm with eight crossover operators was introduced for power allocation in OFDM based CRN [16]. This method increases complexity and provide only power allocation (i.e. channel allocation is not considered). Interference Alignment (IA) method was involved in resource allocation which degrades the performance in low SNR [17]. Location aware spectrum access method was presented for resource allocation in overlay and underlay CRN [18]. Here resource allocation introduces interference between SU and PU. By considering channel uncertainty and

sensing error, Robust Power Allocation (RPA) method allocates resource to SU [19]. But this method only supports single user resource allocation in CRN. To increase data rate, interference and power were maximized by a controller that follows Lyapunov stability theory was employed in [20]. This method increases interference between PU and SU which degrades the overall network performance. Hence it is necessary to design a CRN architecture that supports efficient spectrum sensing and spectrum utilization.

3. Proposed Work

To overwhelm above problems exist in previous works, we integrate OFDM based CRN-CSS with 5G network. Our proposed OFDM based CRN-CSS supports Multiple Input and Multiple Output (MIMO) technology in order to increase the network throughput and OFDM is incorporated to enhance transmission in network. OFDM based CRN-CSS architecture is comprised with Primary Base Station (PBS), Primary Users (PUs), Secondary Users (SUs), Fusion Center (FC) with MIMO, and Spectrum Agent (SA).

3.1 Cluster Formation and Channel Assignment

Initially network is divided into multiple clusters with equal size by using **BRICK Clustering (BRICK) algorithm**. In each cluster, Cluster Head (CH) is selected based on distance between SU and FC. Sensing channel assignment and scheduling is performed by a novel **Two-Stage Killer Whale Optimizer (TSKWO)** method. In this method, each cluster is provided with channel set for sensing at each round and each SU in group sense the channel in left circular shift order. Then the channel sets are rotated between clusters in each round. Hence TSKWO assures that each SU sense every channel which improves sensing efficiency.

3.2 Spectrum Sensing

SU sense the assigned channel at given time slot by **Wide-Band Energy and Power Spectral Density based Energy Detection (WBEPSD-ED)** method. In this method, energy spectral density is computed over a frequency of sensed channel and decision threshold includes noise uncertainty factor to improve spectrum sensing in low SNR. SA is involved to work only for FC to provide accurate report about channel state. SA schedules channel sets based on CH and

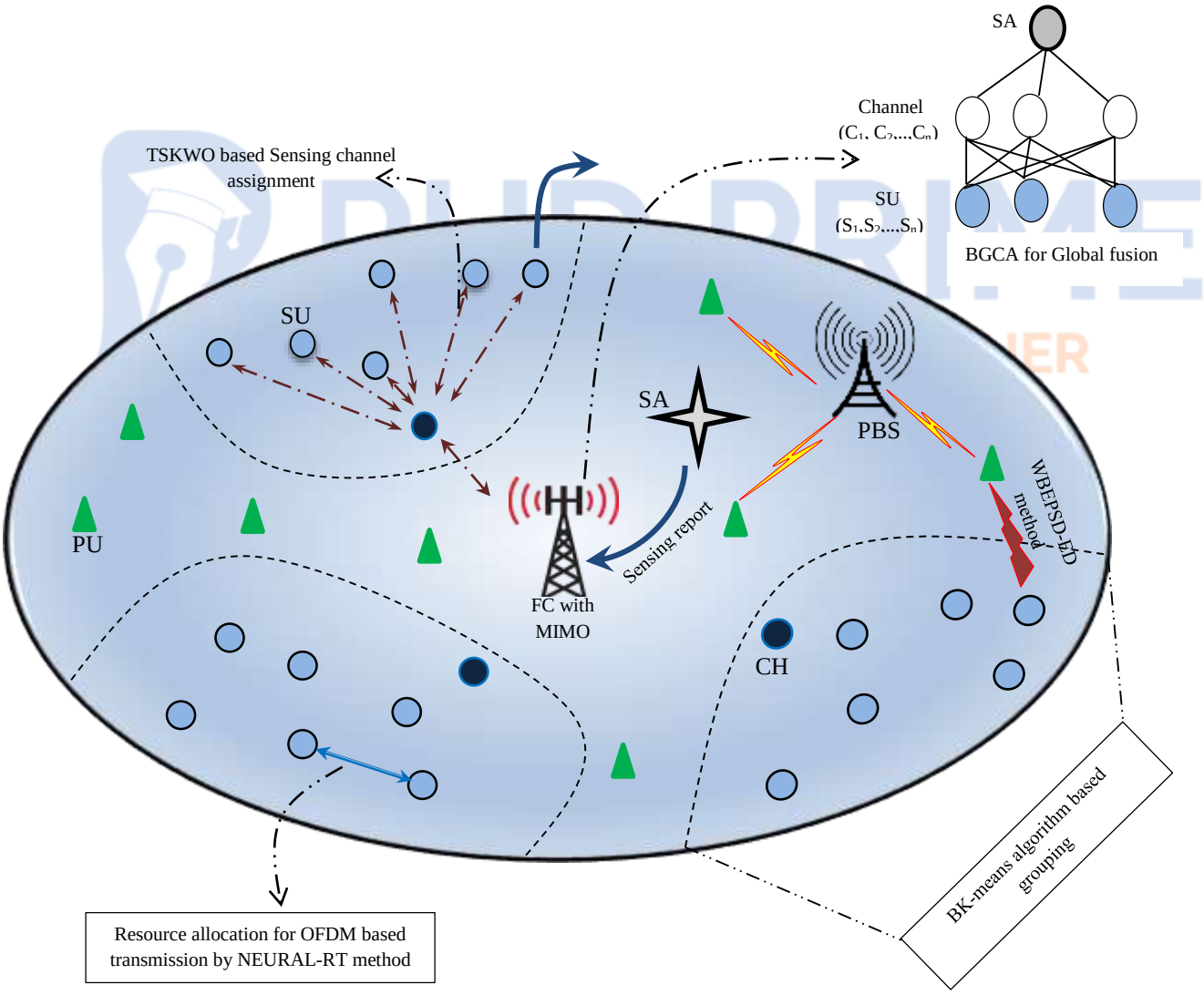
reports to FC. In FC, global decision making is carried out through **Bipartite Graph based Channel Assignment (BGCA)** in which undirected graph is constructed for all sensing reports of SUs in each group. Then the report is compared with SA report to overcome sensing errors.

3.3 Resource Allocation

If channel is idle, then FC performs resource allocation process with the help of **Neural Roughset Theory (NEURAL-RT)** conditions by considering power, channel assignment, and interference constraints into account. NEURAL-RT method allocates both transmission power and spectrum jointly to improve spectrum utilization. In NEURAL-RT, optimal SU is allocated with optimal channel with reasonable transmission power. To reduce Peak-to-Average-Power Ration (PAPR) during transmission using OFDM, transmission signal is selected with high SNR and Quadrature Phase Shift Keying (QPSK) scheme is employed for modulation. Finally our proposed OFDM based CRN-CSS system shows better performance in terms of following performance metrics,

- Throughput
- Channel Utilization
- Capacity
- Network utility
- Transmission power
- Transmission rate
- Bit Error Rate

Overall Architecture



Reference Explanation-

Reference: 1

Title: *Software-Defined Radio—Basics and Evolution to Cognitive Radio*

Concept:

This paper provides a brief overview about Software Define Radio (SDR) and Cognitive Radio (CR) with their advantages and disadvantages. In SDR, communication functions of transceiver are realized as software programs instead of hardware components as in traditional radio. SDR transceiver consists of radio frequency element, Analog to Digital Converter (ADC), Baseband processing, and data processing units. CR is a redefined SDR which has ability of sensing environment through cognitive engine. CR has many advantages due to its sensing ability.

Reference: 2

Title: *5G Based on Cognitive Radio*

Concept:

This paper discuss about the integration of CR with 5G network. CR and 5G standards are considered as promising future technologies. To overcome evolving spectrum scarcity, CR network is integrated with 5G network. Cognitive terminal is able to choose proper network from all existing system at a given time and adapt to its requirement to access the network. This capability of CR probes researchers to use CR in 5G network. Because 5G network is integrated with multiple wireless networks which requires terminals has ability of adaption. Hence CR is the best solution for 5G network and provides large connectivity.

Reference: 3

Title: *OFDM for Cognitive Radio: Merits and Challenges*

Concept:

In this paper integration of Orthogonal Frequency Division Multiplexing (OFDM) scheme in CR network is discussed. OFDM is employed in CRN to overcome problem of data rates in communication. OFDM has many advantages such as high spectral efficiency, robustness against narrow band interference, scalability and so on. The major requirement of CR with 5G network is to support MIMO system. Since OFDM works well with MIMO antennas and smart antenna, OFDM is adapted as communication technology in CRN. But integrating OFDM and CRN introduces new challenges such as transmission parameter requirements, mutual interference, and spectrum allocation.

Reference: 4

Title: *Adaptive Assignment of Heterogeneous Users for Group-Based Cooperative Spectrum Sensing*

Concept:

This paper presents an adaptive channel assignment strategy in multi-channel CRN with Cooperative Spectrum Sensing (CRN-CSS) network. In this scheme, Secondary Users (SUs) are initially grouped and each group is responsible for sensing different channels. Two algorithms such as Channel Selection then Best User Assignment (CSBUA), Best User Assignment then

Channel Selection (BUACS) are introduced for sensing channel assignment. Spectrum sensing is performed in assigned channel using energy detection method.

Problem:

- SU is allowed to sense only one channel at each round.
- Waiting time of SU for next sensing round is high.

Proposed:

- Proposed *TSKWO* method allows SU to sense multiple channels at each round.
- Since SU sense multiple channels at each round, waiting time is relaxed.

Reference: 5

Title: *Utility-Based Cooperative Spectrum Sensing Scheduling in Cognitive Radio Networks*

Concept:

In this paper, author focuses on CRN-CSS with multiple Primary Users (PUs). Here each SU is allowed to make decision about spectrum sensing (i.e.) whether participated in sensing or not participated in sensing. If a SU is participated in CSS then it is called as contributors otherwise it is called as free riders. Free riders utilize sensing results of contributors without sensing in order to save energy. The sensing channels are selected by contributors based on channel uncertainty.

Problem:

- Sensing is not efficient if numbers of free riders are higher than contributors.
- Since channels are selected by SUs for sensing some channels are not sensed.

Proposed:

- All channels are sensed by every SU without any interference by *TSKWO* method.

Reference: 6

Title: *A distributed solution for cooperative spectrum sensing scheduling in multiband cognitive radio networks*

Concept:

In this paper, author formulates CSS scheduling as Inter Linear Programming (ILP) problem. Then the ILP problem is solved by distributed algorithm based on coalitional game theory. SUs form a coalition for each channel and each coalition consist of Cluster Head (CH). CH is selected based on probability of false alarm and probability of detection. For a channel, eligible SUs which have minimum probability of false alarm and maximum detection probability are selected by CH and form coalition. Similarly best channel for sensing is determined by CH based on number of SUs are present in coalition for that channel.

Problem:

- Interference occurs among SUs which are assigned for same channel.

Proposed:

- Multiple time slots are employed in *TSKWO* method to avoid interference.

Reference: 7

Title: *Cooperative OFDM-based Virtual Clustering Scheme for Distributed Coordination in Cognitive Radio Networks*

Concept:

A distributed group-based spectrum aware coordination scheme is presented in this paper. For this purpose Virtual Clustering Distributed Coordination (VCDC) method in which the neighbor CR nodes are grouped based on spectrum opportunities is employed. Inter cluster communication and broadcasting is performed by Discrete OFDM (D-OFDM) technique to reduce neighbor discovery time. Communication in network is carried out through Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) technique.

Problem:

- CSMA/CA is not suitable for large network and transmission is relatively slow.

Proposed:

- OFDM based CRN supports large network and fast transmission.

Reference: 8

Title: *Approach for cluster-based spectrum sensing over band-limited reporting channels*

Concept:

In this paper, author proposes a cluster-based spectrum-sensing approach that minimizes the bandwidth requirements by reducing the number of terminals reporting to the FC to a minimal reporting set. The secondary base station is replaced by local fusion center. The location of local fusion center is found by general center scheme. In this scheme the decision making is done by using OR rule in fusion center.

Problem:

- OR rule incorporated for decision making. If anyone of the user report is erroneous then spectrum utilization is degraded.

Proposed:

- SA is involved for accurate spectrum sensing and global decision is made by *BGCA* in FC.

Reference: 9

Title: *Sensing-Throughput Tradeoff in Cluster-Based Cooperative Cognitive Radio Networks with A TDMA Reporting Frame Structure*

Concept:

This paper presents a clustering scheme to reduce sensing throughput trade off problem. They proposed a framework for reduce reporting time and increasing transmission time using centralized cluster based cooperative spectrum sensing model. Time Division Multiple Access (TDMA) is used as reporting framework. Clustering is performed to increase transmission time for SUs. K-means clustering scheme is adapted for clustering based on SU location.

Problem:

- Each cluster has different number of CR users and provided with fixed length TDMA frame. Hence sensing is not efficient for various clusters.

Proposed:

- *BK-means clustering* forms clusters with equal size. Hence clusters formed in the network are balanced.

Reference: 10

Title: *A Reliable spectrum sensing method in presence of malicious node in cognitive radio network*

Concept:

The main concept of this paper is to find malicious node in the network. For this purpose network is clustered into small groups. And Cluster Head (CH) reports the sensing results sequentially to fusion center to detect the malicious node. Based on this sensing information, FC finds the distance between cluster and PU using ML estimator. Then the FC finds error distance (i.e.) difference between true distance and estimated distance. If the error distance of cluster is less than certain threshold value then the cluster is considered as trusted cluster which has no malicious node.

Problem:

- CH reports the sensing results to fusion center in specified order. When one CH reports to fusion center, all other CH should wait for their time. This leads to increase in waiting time.

Proposed:

- FC is configured with MIMO to support multiple users simultaneously and reduce waiting time significantly.

Reference: 11

Title: *Cognitive Radio Spectrum Sensing Framework Based on Multi-Agent Architecture For 5G Networks*

Concept:

This paper concept involves with the major goal of reducing the spectrum sensing capacity of SUs. So a Spectrum Agent (SA) is a device used for the purpose of sensing spectrum, the SUs requests SA for sensing and then the SA performs sensing for that particular secondary user and replies with the sensing result. SA first detects the presence of PU spectrum, and then the sensing information is sent to FC. As per the result of FC the spectrum is allocated for each requested Secondary User.

Problem:

- Difficult to manage multiple spectrum agents
- Since SAs are sensed for SUs and FC, if number of SUs increased, then the network is not able to perform spectrum sensing efficiently.

Proposed:

- Achieves high sensing efficiency with the help of single SA.
- SA is working for only FC and each SU sense PU signal by own. Hence sensing efficiency is high.

Reference: 12

Title: *Evaluating Performance of Cognitive Radio Users in MIMO-OFDM based Wireless Networks*

Concept:

In this paper the authors have concentrated on evaluating the spectrum sensing and Mean Square Error and Successful Reconstruction Rate. Here Cyclostationary detection method is involved for the detection of primary signals whether it is present or absent. The signals are reconstructed if the intended signal is obtained from Cognitive Radio User.

Problem:

- Higher computational cost
- PAPR is high

Proposed:

- Complexity is reduced
- PAPR is reduced by QPSK modulation

Reference: 13

Title: *On Multiple-Input Multiple-Output OFDM with Index Modulation for Next Generation Wireless Networks*

Concept:

This paper focused on MMSE detectors of MIMO-OFDM-IM which shows tradeoff between error performance and spectral efficiency. It involves with Maximum Likelihood (ML), near-ML, simple Minimum Mean Square Error (MMSE) and Ordered Successive Interference Cancellation based on MMSE detectors

Problem:

- Provide high PAPR

Proposed:

- Involvement of QPSK scheme reduces PAPR significantly.

Reference: 14

Title: *Radio Resource Allocation Techniques for Efficient Spectrum Access in Cognitive Radio Networks*

Concept:

This paper provides an overview of resource allocation techniques in CRN. Transmission power and spectrum are major resources of SUs in CRN. To allocate these resources in an efficient way, many techniques are presented. These techniques are mainly focused on Signal-to-Interference-and-noise Ratio (SINR), transmission power in centralized are in decentralized manner. The common drawback in those methods is poor spectrum utilization/

Reference: 15

Title: *Optimized Secondary User Selection for Quality of Service Enhancement of Two-tier Multi-User Cognitive Radio Network: A Game Theoretic Approach*

Concept:

In this paper they discussed about the secondary user selection to utilize the spectrum by using game theory. The secondary users are classified into two categories namely, real time SU (voice) with higher priority and non-real time SU (text) with lower priority. The spectrum is allocated to real time SU using auction game. Since the real time SU transmits packets as VoIP the aim is to utilize the intervals in the VoIP packet transmission for non-real time SU transmission.

Problem:

- If non-real time user require more spectrum than available spectrum, then spectrum utilization is not efficient.

Proposed:

- Optimal SU is allocated with optimal power and channel for transmission by *EKKD method.*

Reference: 16

Title: *Using artificial bee colony algorithm with crossover for power allocation in cognitive MIMO-OFDM system*

Concept:

In this paper, author studies the impact of cross over operators on Artificial Bee Colony (ABC) algorithm and ABC algorithm with best cross over operator is applied for power allocation problem in MIMO-OFDM cognitive system. Here eight crossover operators are used and performance of ABC with each crossover operator is evaluated. Finally optimal crossover rate for ABC algorithm is found over multiple trials and ABC with optimal crossover rate is adapted for power allocation.

Problem:

- Complexity and computational time are high due to eight crossover operators.

Proposed:

- Complexity is minimized by NEURAL-RT method.

Reference: 17

Title: *Interference Alignment with Frequency-Clustering for Efficient Resource Allocation in Cognitive Radio Networks*

Concept:

This paper presents a resource allocation method based on Interference Alignment (IA) to improve spectral efficiency. IA enables cooperative spectrum sensing among SUs and spectrum sharing between SUs. Resource allocation problem is solved in two-phases in which frequency clustering is performed in first phase and available power is allocated to SUs in second phase.

Problem:

- IA method is relatively depends upon SNR and channel state information (CSI). Hence resource allocation is not efficient in low SNR.

Proposed:

- Proposed method uses E*KKD method* which performs better in low SNR.

Reference: 18

Title: *Resource Allocation Strategy for Multi-user Cognitive Radio Systems: Location-Aware Spectrum Access*

Concept:

This paper investigates the resource allocation in underlay and overlay region in CRN. Hereby, initially network is divided into underlay and overlay regions based on network coverage area. SUs present in overlay region are adopted to use overlay spectrum access techniques while SUs present in hybrid region are adopted to use underlay spectrum access or sensing free spectrum access techniques.

Problem:

- Interference constraint is not considered.

Proposed:

- Power, assignment, and interference constraints are considered in NEURAL-RT method for resource allocation.

Reference: 19

Title: *Optimal resource allocation for cooperative orthogonal frequency division multiplexing based cognitive radio networks with imperfect spectrum sensing*

Concept:

In this paper, author investigate Sensing based Spectrum Sharing Access (SSSA) and Sensing based Opportunistic Sharing Access (SSOA) in OFDM based CRN. Here resource allocation is performed by a Robust Power Allocation (RPA) method which considers both channel uncertainty and imperfect sensing error. In this approach, amplify-and-forward relay protocol is employed for spectrum sensing and average interference power in each hop is considered for relay selection.

Problem:

- This method only supports single user power allocation process in CRN.

Proposed:

- *EKKD method* supports multiple users and multiple channels simultaneously for resource allocation.

Reference: 20

Title: *Robust Power Allocation for OFDM-Based Cognitive Radio Networks: A Switched Affine Based Control Approach*

Concept:

In this paper, author presents a resource allocation scheme to maximize data rate in channel uncertainties. To achieve this, a controller for a switched affined system with state constraint is presented by author. Data rate is increased by maximizing allowable interference constraint and total power budget of network. The controller follows Lyapunov stability theory for resource allocation.

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Problem:

- Increases interference between PU and SU.

Proposed:

- Optimal resource allocation avoids interference between SU and PU.

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