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BY

MR.HUSSEIN TUAMA HAZIM

SEAT NO. 7989

UNDER THE GUIDANCE OF

PROF.MRS.S.A.SHIRSAT

SINHGAD TECHNICAL EDUCATION SOCIETY, PUNE

तमसो मा ज्योतिर्गमय

Sinhgad Institutes

DEPARTMENT OF ELECTRONICS & TELECOMMUNICATIONS ENGINEERING

SINHGAD COLLEGE OF ENGINEERING

S.NO.44/1,OFF SINHGAD ROAD,
VADGAON BK, PUNE - 411041

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Certificate

This is to certify that the dissertation report entitled

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Submitted By

Mr. Hussein Tuama Hazim

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This dissertation work has not been earlier submitted to any other institute or university for the award of degree or diploma.

Prof.S.A.Shirsat
Guide
(Department of E&TC)

Prof.V.V.Dixit
PG Coordinator(CN)
(Department of E&TC)

Dr. M. B. Mali
HOD
(Department of E&TC)

3/10

(External Examiner)

SINHGAD COLLEGE OF ENGINEERING PUNE-41

Dr.S.D.Lokhande
Principal
S.C.O.E Pune

Place: PUNE
Date: 30/06/2015

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Hussein Tuama Hazim
M.E. (Communication Networks)

ABSTRACT

Recently major research is going on various problems in dynamic spectrum access (DSA) in cognitive networks due to its growing use all over world. One of the problems is energy efficient bandwidth allocation or resource allocation in IEEE 802.22 cognitive LTE networks. IEEE 802.22 standard is based on cognitive radio network (CRN).It allows opportunistic use of TV white space as spectrum holes by secondary user. The existing methods used for spectrum access in cognitive third generation partnership project (3GPP) long term evaluation (LTE) network based on IEEE 802.22 standard are not power efficient.

In this dissertation Hybrid Queue Balancing Control (HQBC) is implemented to improve the performance of parameters such as transmission power, delay and packet loss and it is compared with existing methods.

The NS2 simulation results show that the proposed (HQBC) technique achieved better performance of transmission power, packet loss and end to end delay than existing methods such as power control and spectrum access (PCSA). queue balancing control (QBC-1) and (QBC-2).

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List of Abbreviations

CR	Cognitive Radio
3GPP	Third Generation Partnership Project
MIMO	Multi Input Multi Output
LTE	Long Term Evaluation
DSA	Dynamic Spectrum Access
GSM	Global System for Mobile Communications
EDGE	Enhanced Data rates for GSM Evolution
HSPA	High Speed Packet Access
UMTS	Universal Mobile Telecommunications System
SAE	System Architecture Evolution
EPC	Evolved Packet Core
EPS	Evolved Packet System
DL	Downlink
UP	Uplink
ITU	International Telecommunication Union
IoTs	Internet of Things
CPS	Cyber Physical Systems
FCC	Federal Communications Commission
NTIA	National Telecommunications and Information Administration
WSs	White Spaces
PCSA	Power Control Spectrum Access
QBC	Queue Balancing Control
HQBC	Hybrid Queue Balancing Control
PU	Primary User
SU	Secondary User
MIMO	Multi Input Multi Output
MAC	Medium Access Control
QOS	Quality of Service

E2E	End to End
BS	Base Station
CRDS	Cell Request Distribution Scheme
CSC	Channel Sharing Community
D2D	Device-to-Device
WRAN	Wireless Regional Area Network
DC	Data Channel
DCD	Downstream Channel Descriptors
DCSS	On-Demand inter-cell Channel Sharing Scheme
DFH	Dynamic Frequency Hopping
DFHC	Dynamic Frequency Hopping Community
ECMA	European Computer Manufacturers Association
EOCSA	Enhanced One Column Striping with non-increasing Area first mapping
FCH	Frame Control Header
FDD	Frequency-Domain Duplex
FE	Fairness Element
P2M	Point-to-Multipoint
PHY	Physical layer
PHYME	Physical Layer Management Entity
QAM	Quadrature Amplitude Modulation
QPSK	Quaternary Phase Shift Keying
SBS	Seamless Backup Strategy
SM	Spectrum Management
SSF	Spectrum Sensing Function
UHF	Ultra High Frequency
VHF	Very High Frequency

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CHAPTER-1

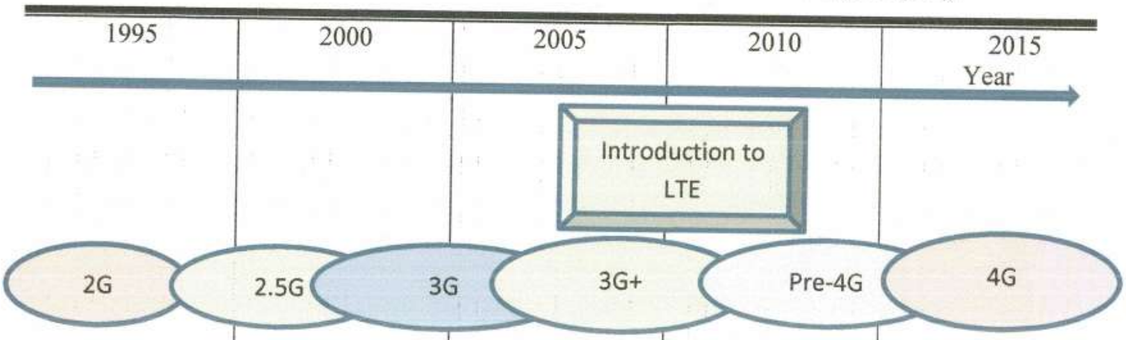
INTRODUCTION

1. INTRODUCTION

1.1. Background

With the development of the highly advanced mobile devices, the demands for higher data rates and better QoS increased rapidly. Therefore, the Third Generation Partnership Project (3GPP) has specified new standards for the mobile communications based on the GSM (Global System for Mobile Communications)/ EDGE (Enhanced Data rates for GSM Evolution) and UMTS (Universal Mobile Telecommunications System)/HSPA (High Speed Packet Access) network technologies in 2004: LTE and the System Architecture Evolution (SAE), which define the radio access network and the core network (CN) of the system, respectively.

The SAE is called the Evolved Packet Core (EPC), and LTE, together with the SAE, are known as the Evolved Packet System (EPS). LTE supports high data rates of up to 300 Mbit/s in the downlink (DL) and 75 Mbit/s in the uplink (UL). A brief illustration of the evolution of the mobile networks is shown in the figure (1.1).



Max. data rate	64 kbps	2 Mbps	200 Mbps	1Gbps
Spectral efficiency (bps/Hz)	0.15_0.3	0.3_1	3_4	Up to 16

Figure1.1:The Evolution of Mobile Networks[1]

Applications of wireless networking technologies are experiencing a tremendous growth. New techniques, protocols, devices and applications have constantly been introduced to the users, creating opportunities for new ways of interacting and increased productivity in the professional sphere. The number of wireless devices has been growing exponentially.

Over 7 billion mobile phone subscriptions (excluding other wireless devices such as Wi-Fi devices) were reported at the end of 2014 according to the International Telecommunication Union (ITU) report - Measuring the Information Society. According to the same report, around 85.7% of the world's populations have their own mobile phone subscriptions.

Recently, the booming of the Internet of Things (IoTs) and Cyber Physical Systems (CPS) is offering opportunities for context-aware intelligent services. With IoTs and CPS, a massive number of devices can be networked to offer new services [1].

These developments, however, have also introduced new challenges with respect to the management of spectrum, which is not an abundant resource. The management of radio frequencies in different countries and regions, each with their own regulators, is governed by treaties under the umbrella of the ITU. For example, the Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA) in the United States manage the use of spectrum by non-government and government users, respectively.

In Europe, the European Conference of Postal and Telecommunications Administration is in charge of the radio frequency allocation. The spectrum is allocated for different services and technologies by these regulators. The allocated spectrum is for exclusive use by a certain technology or service and these bands are called licensed bands and the rest are unlicensed bands. The users that are authorized to use these frequencies are called the licensed users or primary users (PUs).

An imbalance with respect to the spectrum availability can be easily seen in this centrally controlled spectrum management. On the one hand, most of the frequencies are already allocated, which means that not many unlicensed bands are left for new technologies. For example the industrial, scientific and medical (ISM) bands are unlicensed and have to be shared by many wireless standards and applications, e.g., IEEE 802.11 (Wi-Fi), IEEE 802.15.1 (Bluetooth), and IEEE 802.15.4 (Zigbee).

The coexistence of these technologies and devices is already turning into a critical issue [2]. On the other hand, the licensed bands can be expensive, e.g., the Dutch 4G mobile spectrum auction raised a total of 3.8 billion Euros according to the Dutch spectrum agency Agents chap Telecom report in December of 2014 [3].

However, many licensed bands have a very low utilization. A recent study on 20MHz to 6GHz by Vinod Kone [4] shows that on average 54% of the spectrum is never used and about 26% is not frequently used. Another study indicates that only an average 5% of the total capacity of the licensed bands is used [5]. More spectrum utilization results can be found, for instance, on the website of the Shared Spectrum Company [6].

Cognitive radio (CR) and cognitive radio networks (CRNs) are providing a solution to resolve or at least ease this imbalance [7]. The basic idea of the CR concept, in this thesis, is to let unlicensed users (also called secondary users or SUs) occupy licensed bands when the PUs are not using them. The unused licensed bands in time and frequency domains are called white spaces (WSs); the SUs try to use WSs without causing any interference to the PUs. Therefore, when a PU appears, SUs should stop using that particular WS immediately. An example of WSs and a SU using these WSs is shown in figure (1.2).

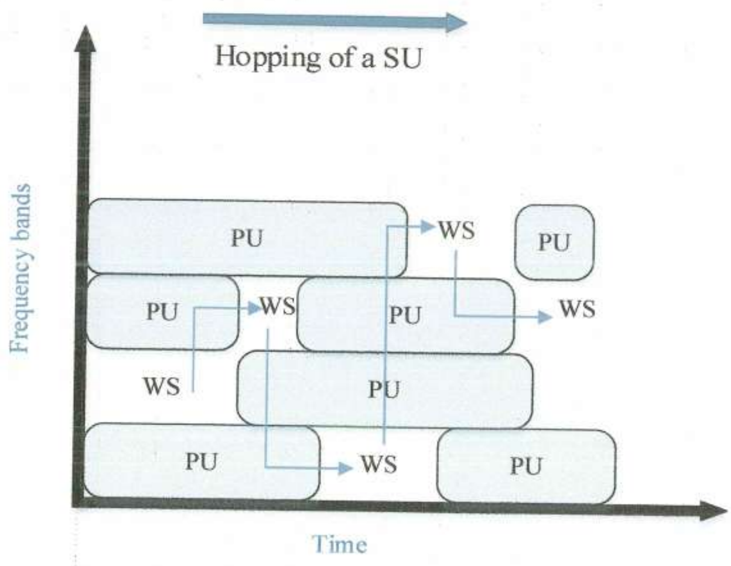


Figure 1.2: Frequency Reuse in CRN [8].

The secondary user SU in figure (1.2) hops from WS to WS in order to get access without causing any interference to the PUs. In the last decade, there has been a large interest in CR technology. It has encouraged many standardization groups, such as IEEE 802.22, IEEE 802.11af, IEEE 802.16h, IEEE 802.19.1 and IEEE Dynamic Spectrum Access Networks (DySPAN) [8].

IEEE 802.22 is the first world-wide wireless network standard about CR technology. It is applicable to many scenarios, especially to provide broadband services in rural areas. The main drawback of an IEEE 802.22 network is its limited network capacity. In this dissertation, the main objective is to enhance the network capacity via advanced spectrum management techniques and resource allocation strategies.

While developing strategies, found that fairness is an important issue that needs to be addressed first in order to use the spectrum more efficiently and increase the network capacity. Fairness is a prevalent issue in almost all resource allocation scenarios when two or more entities have to share the resource. Even though it is difficult to define fairness precisely, its goal is to treat all individuals equally with respect to some criteria, for example, the priority of a request. Unfairness in resource allocation will lead to starvation and reduction in Quality of Service (QoS) or performance experienced by particular users.

1.2. Overview of IEEE 802.22 Standards

In 2004, the FCC gave permission to use TV channels in both very high frequency (VHF) and ultra-high frequency (UHF) bands for fixed broadband services [9]. Based on this ruling, the IEEE 802.22 standard was developed for wireless regional area networks (WRANs).

IEEE 802.22 operates on TV channels from 2 to 69 (54MHz to 862MHz) with a bandwidth of 6, 7 or 8MHz depending on the country [10]. The typical radius of a WRAN cell is 32 km but it can go up to 100 km or even more [11]. Wireless Regional Area Networks (WRANs) are formed in a point-to-multi-point (P2M) fashion with one base station (BS) and multiple customer premises equipment (CPE) in a cell.

The differences between IEEE 802.22 and other wireless standards are illustrated in figure (1.3) [10].

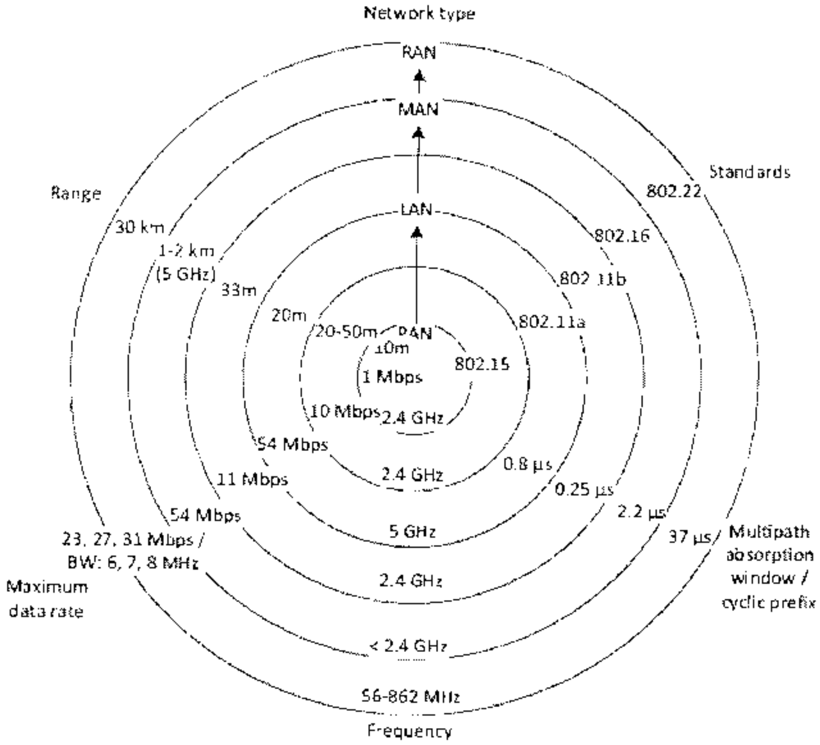


Figure 1.3: Comparison of IEEE 802.22 Standards to Other Wireless Network Standards [10].

So far three official standards have been published by the IEEE 802.22 working group. They are IEEE 802.22-2011, IEEE 802.22.1-2010 and IEEE 802.22.2-2012 [10].

The BS of an IEEE 802.22 cell manages the channel allocation amongst CPEs and aims at coexistence with the PUs and the neighboring IEEE 802.22 cells. The BS also schedules Quiet Periods (QPs) for spectrum sensing to ensure that no harmful interference is caused to the PUs.

The CPEs are equipped with two antennas: a directional one for communication with the BS and an omni-directional one for sensing and geo-location. Orthogonal frequency-division multiple access (OFDMA) is used in IEEE 802.22 to enable multiple CPEs to access the BS simultaneously in a cell. Time-domain duplexing (TDD) is used to split a frame into downstream and upstream subframes.

The IEEE 802.22 WRAN standard is aimed at supporting license-exempt devices on a non-interfering basis in spectrum that is allocated to the TV Broadcast Service. With operating data rates comparable to those offered by many DSL / ADSL services it can provide broadband connectivity using spectrum that is nominally allocated to other services without causing any undue interference. In this way IEEE 802.22 makes effective use of the available spectrum without the need for new allocations.

There are still two ongoing standardization projects, viz., IEEE 802.22a and IEEE 802.22b as in figure 1.4[11].

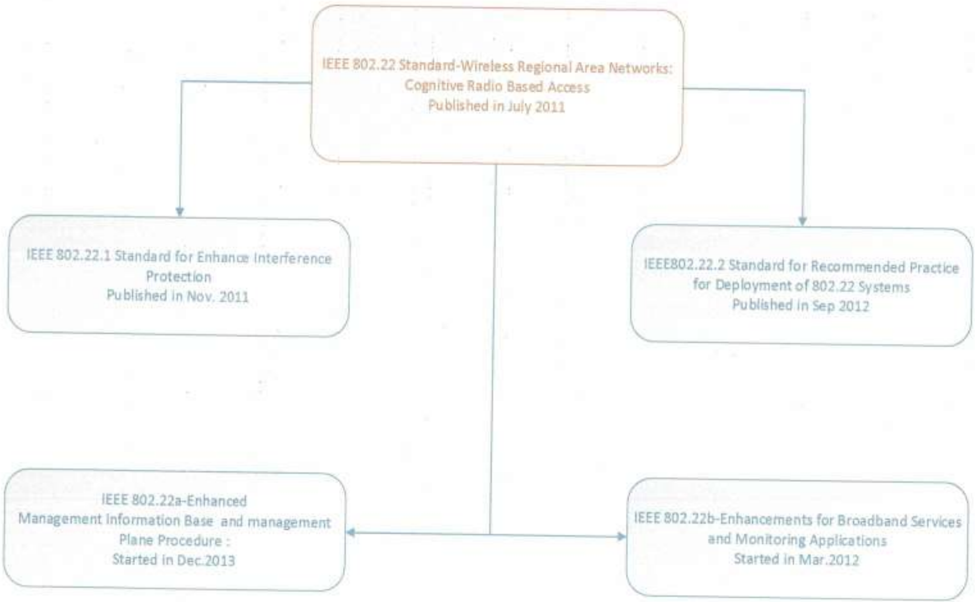


Figure 1.4: The Projects of IEEE 802.22 Working group [11]

Therefore by organizing other services around these constraints it is possible to gain greater spectrum utilization without causing interference to other users. Despite the fact that the impetus for 802.22 is coming from the USA, the aim for the standard is that it can be used within any regulatory régime. One particular technology that is key to the deployment of new services that may bring better spectrum utilization is that of cognitive radios technology.

1.3. Motivation

Along with the fairness in IEEE 802.22 wireless networks; there is another performance metrics which is related to energy efficient dynamic spectrum access (DSA) in a cognitive Third Generation Partnership Project (3GPP) long-term evolution (LTE) network based on IEEE802.22 architecture. According to the IEEE802.22 standard. wireless access is offered by a wireless regional area network (WRAN) consisting of a number of service providers (SPs). which share the total available spectrum using a spectrum manager (SM). The SM uses some flexible dynamic spectrum access (DSA) policy to maximize the capacity and quality of service (QoS) for their users [1].

Motivated by the concept of CR network (CRN). many papers have developed various forms of spectrum access strategies to assign the available bandwidth. transmission rate and transmission power. Most of previous work assumes non-strategic non-greedy users following some general resource allocation policy. The recent methods do not have efficient tradeoff between transmission power. bandwidth and transmission rate. This becomes research problem in this domain.

1.4. Contribution

In this dissertation the work are grouped in two parts. During first part the performance of novel strategy for resource allocation to the end-users and the eNBs to minimize their total transmission power subject to capacity and queue stability constraints are investigated.

In second part the novel method presented in first part is improved by adding concept of multilevel queuing and dynamic network adaptation in which different kinds of network data is divided into multiple queues. and hence efficiency of spectrum allocation improves. which in terms improves the QoS performance and transmission power performance.

For this dissertation Hybrid technique HQBC is implemented .The algorithm is simulated using NS2 .the simulation results shows HQBC achieved better performance than existing spectrum allocation methods.

1.5. Objectives

The proposal work considers some algorithm design issues which are very important for practical deployment of the IEEE802.22 architecture in existing LTE infrastructures. Resource allocation in LTE system will be performed in terms of resource blocks (RBs) which fully expresses the relation between modulation and coding scheme (MCS) and the spectrum efficiency in LTE systems [10].

Main objectives of this dissertation are:

- To improve the end to end delay and the packet loss percentage for secondary (unlicensed) network users, without imposing overlarge interference to the primary (licensed) network users.
- To minimize the total transmission power subject to capacity constraints, queue stability constraints, and integer restrictions on the bandwidth.
- To implement the concept of cognitive radio networks (CRN) to assign the available bandwidth, transmission rate and transmission power.

1.6. Organization of Report

The report is organized as follows; the introduction for mobile network evaluation and IEEE802.22 based cognitive LTE networks presented in Chapter 1. The related work to the dynamic spectrum access and resource allocation methods in based cognitive LTE system are given in Chapter 2.Detailed study about cognitive LTE architecture and system model is presented in Chapter 3 which also provides the relation between the network resources. The proposed framework, algorithm and flowchart are introduced in Chapter 4. The NS2 simulation software settings, scenarios and network configuration parameters are presented in Chapter 5. The results obtained by using NS2 and comparative analysis presented in Chapter 6. Finally, chapter 7 provides the conclusions and future directions Concluding remarks based on simulation results are mentioned in chapter in the previous chapter.

CHAPTER-2

LITERATURE SURVEY

2. LITERATURE SURVEY

This chapter investigates the work related to the problem of energy efficient dynamic spectrum access (DSA) in a cognitive Third Generation Partnership Project (3GPP) long-term evolution (LTE) network based on IEEE802.22 architecture. Motivated by this concept of CR network (CRN). many papers have developed various forms of spectrum access strategies to assign the available network resources such as transmission power. bandwidth and transmission rate.

2.1. Review of Existing Methods

- In [12] the authors presented performance of the channel allocation scheme for IEEE802.22 networks in which the base station allocates interference free channels using a spectrum map. In this scheme the spectrum map is created by using the raw spectrum usage data that are shared by a small subset of consumer premise equipment. The usage data are fused at the base station using a modified version of Shepard's interpolation technique. The authors construct a continuous and differentiable spatial distribution of spectrum usage that the base station consults to estimate the spectrum occupancy vector at any arbitrary location in its cell. Such spectrum usage is then utilized to proactively evaluate some key network and radio performance metrics which in turn help allocating the best candidate channel to a given consumer premise equipment ensuring highest achievable performance.
- In [13] the authors consider adaptive modulation and power control for multi-access wireless sensor networks which mainly reduces power consumption to achieve energy efficiency. Cluster head node of each link adaptively adjusts its power control level and modulation type according to the signal to noise ratio (SNR) and target bit error rate (BER). The efficiency of this approach is further illustrated via numerical comparison with the original scheme. Simulation results demonstrate that the proposed scheme. which alleviates to save much transmission power and maintains the target bit error rate. can significantly improve the system performance.

- In [14] the opportunistic spectrum access (OSA) in LTE Advanced (LTE-A) networks has been investigated. It has been shown that implementation of the OSA in LTE-A enhances the overall system performance by intelligently aggregating otherwise unutilized spectrum. However, the set-up parameters of the system (such as sensing periods and amount of signaling) should be carefully chosen to increase the feasibility of the implementation in a real network.
- In [15], authors studied the trade-off between transmission delay and transmission power in wireless networks where a delay-power control (DPC) scheme to balance delay against transmission power in each wireless link has been formulated. It has been shown that DPC converges to a unique equilibrium power with several key properties related to the nature of bandwidth sharing achieved by the links.
- In [16], authors presented distributed resource allocation based on queue balancing in multi-hop CRNs has been investigated. Here the problem of resource allocation is used as a multi-commodity flow problem assuming dynamic link capacity to model dynamically changing spectrum availability in the network. Based on the optimization results, a distributed algorithm is proposed for joint flow control and resource allocation in the nodes of CRN. Simulation results show the performance improvement by the proposed scheme.
- In [17] Joint power control and spectrum access in CRNs has been investigated. The power allocation and DSA aim to improve the throughput and guarantee the fairness for secondary (unlicensed) network users, without imposing overlarge interference to the primary (licensed) network users. Numerical results reflect that, compared with previous studies, this scheme presents advantages in comprehensive performance (e.g., spectrum efficiency, fairness and throughput). Beyond a theoretical framework, the authors solve the optimization problem with the Differential Evolution (DE) algorithm which is more feasible to be implemented in practice.

2.2. Summary

From the literature review provided here, much work has already been done in implementation of the cognitive radio capabilities in LTE networks. However, there are a few drawbacks which follow from very simplified and idealized representation of the resource allocation problem. The main goal of this project is to consider some algorithm design issues which are very important for practical deployment of the IEEE802.22 architecture in existing LTE infrastructures to achieve better performance of transmission power, end to end loss and packet delay.

Most of the related work treat spectrum as "continuous" assuming that the subcarrier spacing is small and the number of subcarriers is large. But in this dissertation the spectrum is considered as "discrete spectrum" as in real LTE system in which the network resources allocated in terms of resource blocks (RBs). One resource block consists of 12 subcarriers, and the number of resource blocks is not very large (for the system operating on 1.4 MHz bandwidth the number of RBs are 6) [18].

All existing algorithms use classical Shannon expression to find relation between the transmission rate, bandwidth and transmission power. However, in the LTE the system spectrum efficiency depends on modulation and coding scheme (MCS) assigned to the channel between the user and the evolved NodeB (eNB). MCS depends on the channel quality measured in terms of signal-to-noise ratio (SNR). The higher MCS index is assigned to the channels with high SNR, and vice versa [19]. Therefore, the Shannon expression in its original form cannot be deployed to calculate the transmission rates of the users in LTE system. To deal with this issue, in this dissertation the transmission rate for a given bandwidth and SNR is calculated using modified Shannon expression which fully expresses the relation between MCS and the spectrum efficiency in a real LTE system[20].

Finally, in most of the existing algorithms the bandwidth and transmission power is assigned to maximize the transmission rates subject to capacity and transmission power constraints without considering the buffer occupancy in the channels.

CHAPTER-3

IEEE 802.22 BASED COGNITIVE LTE NETWORK

3. IEEE802.22 BASED COGNITIVE LTE NETWORK

3.1. Introduction

The standardization of IEEE 802.22 is a milestone for cognitive radio networking (CRN) technology. As the first world-wide wireless standard based on cognitive radio technology, IEEE 802.22 provides network access for users in a cell by reusing vacant TV channels [10]. However, the capacity of IEEE 802.22 networks is limited significantly by cellular topology and single operating channel. This can in principle be overcome by enabling device-to-device (D2D) communication and multiple operating channels.

3.2. Specifications of WRANs

The configurations of the physical (PHY) and medium access control (MAC) layers and the cognitive capability of Wireless Regional Area Networks WRANs are based on the architecture shown in figure 3.1 [12]. A station management entity (SME) is designed to manage the PHY, MAC and higher layers, in which the MAC layer management entity (MLME) and PHY layer management entity (PLME) can be found. There are three main functions in the PHY layer - data communication, spectrum sensing function (SSF) and geo-location. The cognitive radio capability is supported by the SSF and geo-location. Details of the PHY and MAC configurations, the cognitive radio capability and limitations of WRANs are explained in the following sections.

3.2.1. PHY/MAC Configurations

The OFDMA system is designed in Wireless Regional Area Networks WRANs to have a large coverage (from 30 km and up to 100 km). OFDMA system, upstream and downstream communication are supported in each frame via time-division duplex (TDD) or frequency-division duplex (FDD) [13]. IEEE 802.22 networks use TV channels with bandwidth of 6, 7 or 8MHz according to the regulations of different countries and regions. Totally 1680 subcarriers are grouped in 60 subchannels in a TV channel. A pilot OFDMA symbol for channel estimation and synchronization is required every seven symbols both in the time and the frequency domains of frames. Four different cyclic prefixes are defined as 1/4, 1/8, 1/16 and 1/32 of a symbol duration corresponding to different channel delays. Currently, four types of modulation and coding schemes (MCSs) are supported, which are binary phase-shift keying (BPSK), quaternary phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM) and 64-QAM. Four coding rates (1/2, 2/3, 3/4 and 5/6) associate with the MSCs. Different MCSs and coding rates are selected dynamically according to the channel and interference information.

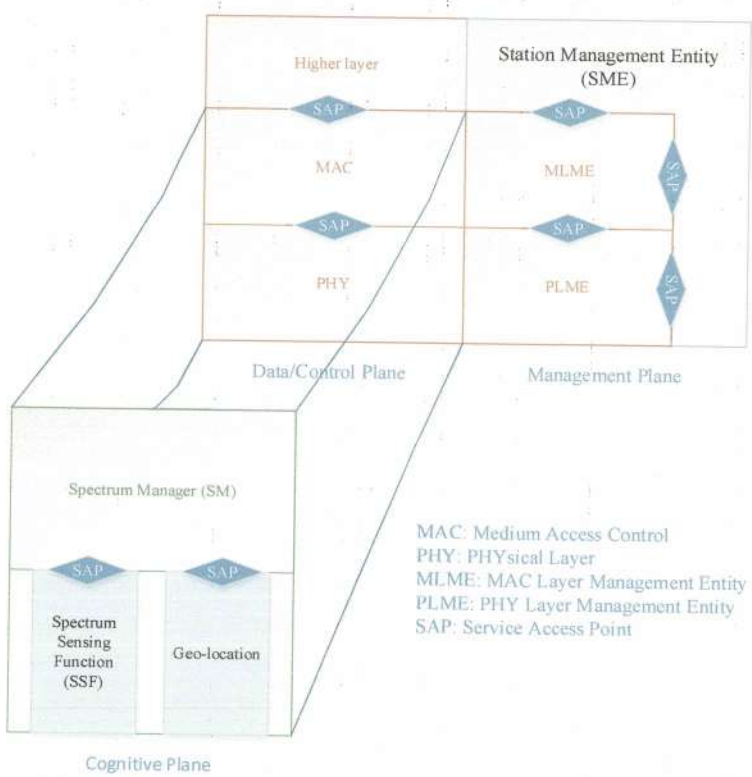


Figure 3.1: The Architecture of IEEE 802.22[13]

For the MAC layer, a point-to-multipoint (P2M) mode is adopted in IEEE 802.22. This cellular topology consists of a single BS and many customer premises equipment (CPEs). The BS manages the network and resource allocation, and all CPEs communicate with the BS in a cell. In the downstream direction, the BS broadcasts both control and data information to all its CPEs. In the upstream direction, CPEs request for channel and upload data to the BS. IEEE 802.22 adopts a superframe/frame structure for efficient data communication and channel management. A superframe consists of a superframe control header (SCH) and 16 frames. When a CPE intends to join an IEEE 802.22 cell, the SCH in the cell is scanned, which contains all necessary information. Once a CPE joins this cell, the geo-location of this CPE is reported to the BS. The self-coexistence of WRAN cells is achieved by the coexistence beacon protocol (CBP). A separate subframe for CBP is attached at the end of some frames. The CBP subframe may contain the sensing results of CPEs and channel usage of the neighboring cells. Due to the cellular topology, the antennas of the BSs should be sectored or omni-directional to communicate with all CPEs in a cell both in the upstream and downstream directions. However, because the CPEs in a cell only need to communicate with the BS and IEEE 802.22 is designed for fixed networks, directional antennas are used in CPEs. Multi-input-multi-output (MIMO) is not supported originally because of the physical size of the antennas operating in TV channels [10], but it is being considered in IEEE 802.22b [11].

3.2.2. Cognitive Radio Capability

Since IEEE 802.22 networks use vacant TV channels based on cognitive radio technology, protection of PUs is managed by the SM as shown in figure 3.1. The SM is in charge of the cognitive functionality, in which the incumbent database and spectrum sensing functions are used.

The incumbent database contains channel availability information of all TV channels in certain areas. It is maintained by spectrum management regulators. All devices are required to be equipped with locating systems, e.g., global positioning system (GPS). CPEs need to report their locations to the BS and then the BS queries the incumbent database for channel availability information in the local area.

Spectrum sensing is also enabled in WRANs to detect channel information in a real time manner because of the possible latency of the incumbent database. Quiet periods (QPs) are scheduled in each cell, during which all devices stop communication and sense both in-band (being used) and out-band channels (not being used currently). The sensing results are reported to the BS and the BS aggregates all channel availability information and makes spectrum allocation decisions.

Additionally, a TV channel can be used as an operating channel in a cell only if both the low and high frequency adjacent channels are also available. The purpose is to eliminate adjacent channel interference to PUs. Channel bonding is also supported in WRANs to increase the network capacity, in which up to three adjacent channels can be used as one channel but with more subchannels.

3.2.3. Limitations

IEEE 802.22 networks are developed to provide broadband services for CPEs in rural areas. However, a data rate of only 1.5Mbps in the downstream and 384 kbps in the upstream for edge CPEs can be guaranteed (at least 12 active CPEs). The low network capacity is one of the main challenges in WRANs and this is because of following reasons:

- All packets in a cell (including intra-cell packets) need to go through the BS. Direct CPE to CPE communication is not supported. Thus, the network capacity is limited by the processing ability of the BS. Besides, extra delay is added to intra-cell packets compared to direct CPE to CPE communication.
- In the OFDMA system designed for WRANs, each slot can be allocated to only one CPE. Multiple links cannot use the same sub-channels simultaneously.
- Even though channel bonding is supported, non-adjacent channels cannot be used simultaneously resulting in a very busy 6MHz channel when there are many other vacant channels.
- QPs are frequently scheduled for spectrum sensing, which also limits the network capacity. For example, some channels need to be sensed at least once in every 2 s.
- MIMO is not supported and more advanced MCSs than 64-QAM is not considered [10].

To increase the network capacity, the IEEE 802.22 working group has started a new task group IEEE 802.22b (Amendment Project for Enhanced Broadband Services and Monitoring Applications) in March, 2012 [12]. New technologies might be introduced in IEEE 802.22b to provide higher data rates, e.g., MIMO, direct CPE to

CPE communication. However, it is still under discussions and no draft is finalized yet. D2DWRANs can be considered as a solution for IEEE 802.22b networks.

3.3. System Model

LTE is a mobile communication standard and a major enhancement of the Long Term Evolution (LTE) standard. It was formally submitted as a candidate 4G system to ITU-T in late 2009 as meeting the requirements of the IMT-Advanced standard, and was standardized by the 3rd Generation Partnership Project (3GPP) in March 2011 as 3GPP Release 10.

The LTE format was first proposed by NTT DoCoMo of Japan and has been adopted as the international standard.[2] LTE standardization has matured to a state where changes in the specification are limited to corrections and bug fixes. The first commercial services were launched in Sweden and Norway in December 2009[3] followed by the United States and Japan in 2010. More LTE networks were deployed globally during 2010 as a natural evolution of several 2G and 3G systems, including Global system for mobile communications (GSM) and Universal Mobile Telecommunications System (UMTS) (3GPP as well as 3GPP2).

The work by 3GPP to define a 4G candidate radio interface technology started in Release 9 with the study phase for LTE-Advanced. Being described as a 3.9G (beyond 3G but pre-4G), the first release of LTE did not meet the requirements for 4G (also called IMT Advanced as defined by the International Telecommunication Union) such as peak data rates up to 1 Gb/s. The ITU has invited the submission of candidate Radio Interface Technologies (RITs) following their requirements in a circular letter, 3GPP Technical Report (TR) "Requirements for Further Advancements for E-UTRA (LTE-Advanced)."[4] These are based on ITU's requirements for 4G and on operators' own requirements for advanced LTE. Major technical considerations include the following:

- Continual improvement to the LTE radio technology and architecture
- Scenarios and performance requirements for working with legacy radio technologies

- Backward compatibility of LTE-Advanced with LTE: An LTE terminal should be able to work in an LTE-Advanced network and vice versa. Any exceptions will be considered by 3GPP.
- Consideration of recent World Radio communication Conference (WRC-07) decisions regarding frequency bands to ensure that LTE-Advanced accommodates the geographically available spectrum for channels above 20 MHz. Also, specifications must recognize those parts of the world in which wideband channels are not available.

The model for LTE based IEEE802.22 cognitive radio network (CRN) illustrated in figure (3.2).It comprises evolved NodeBs (eNBs) numbered eNB1,. . . ,eNBn sharing the total available spectrum using the spectrum manager(SM). To enable fast data transmission, the communication between the eNBs and SM is realized using high-speed internet protocol (IP) based links.

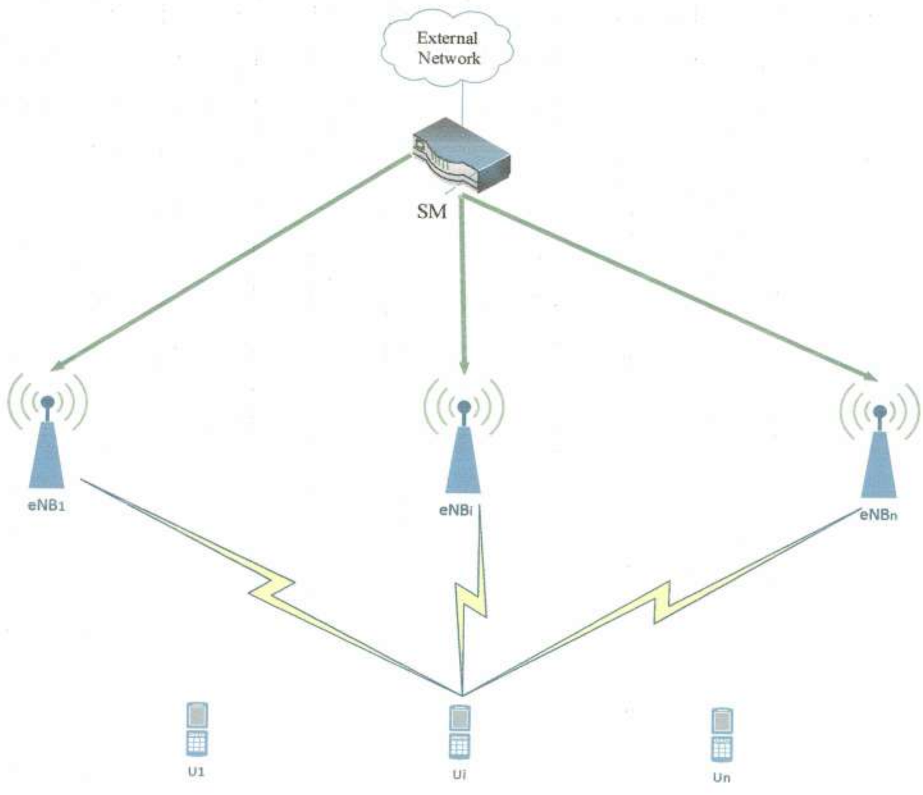


Figure 3.2: A Typical CRN Model Based on LTE Standard Network

The CRN provides wireless access to m wireless users numbered U1, ... Um. A particular user is allowed to connect to any eNB within the network. The practical transmitters might employ directional antennas to achieve frequency reuse, and expand the available bandwidth resources. However, when the cross-gains between different transmitter–receiver pairs are stronger than direct gains only orthogonal spectrum allocation will guarantee allocation efficiency [9].

Similar to the standard LTE system, the network operates on a slotted time basis: the time axis in the model is partitioned into discrete, mutually disjoint intervals {tTs, (t + 1)Ts} (called time slots in LTE system), t = 0,1,2.. . .. of length Ts with t denoting the integer valued index of an interval. Resources are allocated to the users for uplink and downlink data transmission in terms of resource blocks (RBs).

Table (3.1) shows the number of available resource blocks RBs for different channel bandwidths in LTE-A system.

Table (3.1) the number of RBs for different bandwidths [11].

Channel bandwidth (MHz)	1.4	3	5	10	15	20
Number of RBs	6	15	25	50	75	100

The number of available RBs for different channel bandwidths in LTE-A system is listed in Table (3.1).As shown in table (3.1) the number of resource blocks RBs increased as the channel bandwidth increase.

Assumptions:

- The total available spectrum is fixed, and there are B Available RBs (B > 0)
- The channel between eNB_i and U_j is characterized by some noise and interference coefficient $0 < h_{ij} \leq 1$ which is known to eNB_i and U_j (note that in LTE the values of h_{ij} in the uplink and downlink directions can be obtained from the channel state information (CSI) through the use of the reference signals (RSs) transmitted in uplink and downlink directions [9,14].
- At any time slot t the size of the buffers and the arrival rate (in bits) of the eNB_i and U_j can be observed.

Notations:

- b_{ij}^{DL}(t) and b_{ij}^{UL}(t) denote the amount of spectrum (in RBs) obtained by U_j from eNB_i at time (t) in downlink and uplink directions, respectively;
- P_{ij}^{DL}(t) and P_{ij}^{UL}(t) denote the power necessary to transmit the data over the channel between eNB_i and U_j at time t in downlink and uplink directions, respectively;
- $P_{eNBi}(t)$ and $P_{Uj}(t)$ denote the transmission power of the eNB_i and U_j, respectively;
- $R_{eNBi}(t)$ and $R_{Uj}(t)$ denote the transmission rate (in bits) of the eNB_i and U_j, respectively;
- $A_{eNBi}(t)$ and $A_{Uj}(t)$ denote the arrival rate (in bits) to the buffer of the eNB_i and U_j, respectively;
- $Q_{eNBi}(t)$ and $Q_{Uj}(t)$ denote the size of the buffer (in bits) of the eNB_i and U_j, respectively.

The objective of CRN is to distribute the available spectrum and the transmission power of the users and the eNBs given by the unknown n and m dimensional transmission power and bandwidth allocation vectors defined as:

$$P_j^{UL} = \left[P_{1j}^{UL}, \dots, P_{nj}^{UL}\right]^T \quad , \quad b_j^{UL} = \left[b_{1j}^{UL}, \dots, b_{nj}^{UL}\right]^T \qquad (1a)$$

$$P_i^{DL} = \left[P_{1j}^{DL}, \dots, P_{nj}^{DL}\right]^T \quad , \quad b_i^{DL} = \left[b_{1j}^{DL}, \dots, b_{nj}^{DL}\right]^T \qquad (1b)$$

For the uplink and downlink directions, respectively.

By minimizing the total transmission power

$$\min \sum_{i\in I} \sum_{j\in J} \left(P_{ij}^{UL}(t) + P_{ij}^{DL}(t)\right) \qquad (2)$$

where $I=\{1, \dots, n\}$, $J=\{1, \dots, m\}$

The sets of all admissible values that the power allocation vectors P_j^{UL} and P_i^{DL} can take are given by:

$$P_j^{UL} = \left\{ P_j^{UL} \middle| \sum_{i \in I} P_{ij}^{UL}(t) \le P_{Uj}\, , P_{ij}^{UL}(t) \ge 0\, , \forall i \in I \right\} \qquad (3a)$$

For the uplink direction

$$P_i^{DL} = \left\{ P_i^{DL} \middle| \sum_{j \in I} P_{ij}^{DL}(t) \le P_{eNBi}\, , P_{ij}^{DL}(t) \ge 0\, , \forall i \in I \right\} \qquad (3b)$$

For the downlink direction

To achieve required orthogonality of bandwidth allocation and eliminate the need for additional protection against the interference. the frequency reuse has been included in the model. Hence. the number of RBs allocated for data transmission at any time slot t should not exceed B RBs in uplink and downlink directions,

$$b_j^{UL} \in B_j^{UL} = \left\{ b_j^{UL} \middle| \sum_{i \in I} \sum_{j \in J} b_{ij}^{UL}(t) \le B, b_{ij}^{UL} \in Z^+\, , \forall i \in I \right\} \qquad (4a)$$

For the uplink direction. and

$$b_i^{DL} \in B_i^{DL} = \left\{ b_i^{DL} \middle| \sum_{i \in I} \sum_{j \in J} b_{ij}^{DL}(t) \le B, b_{ij}^{DL} \in Z^+\, , \forall i \in I \right\} \qquad (4b)$$

For the downlink direction.

In (4) Z^+ represents all non-negative integers.Note. that if frequency reuse is allowed. To prevent congestion in the buffers of the communicating nodes (eNBs and the users) some queue stability constraints has been added. To form these constraints. the main concept of congestion control theory has been used. which states that a congested node is usually characterized by rapid growth of buffers [15. 16]. Thus. to prevent congestion in the network. it is enough to keep buffer size non-increasing for each UE/eNB. i.e. at any time slot (t)

$$Q_{eNBi}(t+1) \le Q_{eNBi}(t) + \mathcal{E}_{eNBi} \quad , \quad \forall i \in I \qquad (5a)$$

$$Q_{Uj}(t+1) \le Q_{Uj}(t) + \mathcal{E}_{Uj} \quad , \quad \forall j \in J \qquad (5b)$$

Where $\mathcal{E}_{eNBi}$ and $\mathcal{E}_{Uj}$ are some small numbers chosen by the network designer. There is, however, one drawback of the congestion control strategy given by (5).

In particular, this method works well when the initial buffer size is small, but is not efficient when buffer size is already large. Therefore, to prevent that backward some maximal buffer size threshold has been proposed to set (denote these thresholds by Q_{eNBi}^{max} and Q_{Uj}^{max} for eNB_i and U_j, respectively), and keep the buffers in the nodes below this threshold. To make such refinement to (5), it is enough to set the thresholds in the equation (5)

$$\mathcal{E}_{eNBi} = \frac{Q_{eNBi}^{max}/_2 - Q_{eNBi}(t)}{Q_{eNBi}^{max}} \quad , \quad \forall i = I \qquad (5c)$$

$$\mathcal{E}_{Uj} = \frac{Q_{Uj}^{max}/_2 - Q_{Uj}(t)}{Q_{Uj}^{max}} \quad , \quad \forall j = J \qquad (5d)$$

This will guarantee that buffer size will be less than maximal threshold all of the time. The strategy to choose the values of the maximal buffer size thresholds is arbitrary. For instance, Q_{eNBi}^{max} and Q_{Uj}^{max} can be set to be equal to mean arrival rate (in bits) in eNB_i and U_j, respectively (to guarantee that node buffers will be fully cleared most of the time).

In (5), the values $Q_{eNBi}(t)$ and $Q_{Uj}(t)$ are known, whereas the values $Q_{eNBi}(t+1)$ and $Q_{Uj}(t+1)$ can be calculated using well-known Lindley's equation given by [17]

$$Q_{eNBi}(t+1) = \left[Q_{eNBi}(t) + A_{eNBi}(t) - R_{eNBi}(t)\right]^{+} \quad , \quad \forall i \in I \qquad (6a)$$

$$Q_{Uj}(t+1) = \left[Q_{Uj}(t) + A_{Uj}(t) - R_{Uj}(t)\right]^{+} \quad , \quad \forall j \in J \qquad (6b)$$

$$R_{eNBi}(t) \geq A_{eNBi}(t) - \mathcal{E}_{eNBi} \quad , \quad \forall i \in I \qquad (7a)$$

$$R_{eNBi}(t) \leq Q_{eNBi}(t) + A_{eNBi}(t) \quad , \quad \forall i \in I \qquad (7b)$$

$$R_{Uj}(t) \geq A_{Uj}(t) - \mathcal{E}_{Uj} \quad , \quad \forall j \in J \qquad (7c)$$

$$R_{Uj}(t) \leq Q_{Uj}(t) + A_{Uj}(t) \qquad , \quad \forall j \in J \qquad (7d)$$

In (7), the rates $R_{eNBi}(t)$ and $R_{Uj}(t)$ are the functions of bandwidth and power allocation vectors p_j^{UL}, P_i^{DL} and b_j^{UL}, b_i^{DL}, for $i \in I$, $j \in J$. Relation between the power, bandwidth and rate will be established in the next subsection. Through rate the allocation vectors affect the network performance.

Now the resource allocation problem ready to formulate as follows :

$$\text{Minimize: } \sum_{i\in I}\sum_{j\in J} P_{ij}^{UL} \qquad (8a)$$

$$\text{Subject to: } \quad b_j^{UL} \in B_j^{UL} \qquad , \quad \forall j \in J \qquad (8b)$$

$$R_{Uj}\left(P_j^{UL}, b_j^{UL}\right) \geq A_{Uj} - \mathcal{E}_{Uj} \qquad , \quad \forall j = J \qquad (8c)$$

$$R_{Uj}\left(P_j^{UL}, b_j^{UL}\right) \leq Q_{Uj} + A_{Uj} \qquad , \quad \forall j = J \qquad (8d)$$

$$\mathcal{E}_{Uj} = \frac{Q_{Uj}^{max}/_{2} - Q_{Uj}(t)}{Q_{Uj}^{max}} \qquad , \quad \forall j = J \qquad (8e)$$

For the uplink direction , and

$$\text{Minimize: } \sum_{i\in I}\sum_{j\in J} P_{ij}^{DL} \qquad (9a)$$

$$\text{Subject to: } \quad b_i^{DL} \in B_i^{DL} \qquad , \quad \forall i \in I \qquad (9b)$$

$$R_{eNBi}(P_i^{DL}, b_i^{DL}) \geq A_{eNBi} - \mathcal{E}_{eNBi} \qquad , \quad \forall i \in I \qquad (9c)$$

$$R_{eNBi}(P_i^{DL}, b_i^{DL}) \leq Q_{eNBi} + A_{eNBi} \qquad , \quad \forall i \in I \qquad (9d)$$

$$\mathcal{E}_{eNBi} = \frac{Q_{eNBi}^{max}/_{2} - Q_{eNBi}}{Q_{eNBi}^{max}} \qquad , \quad \forall i = I \qquad (9e)$$

For the downlink direction.

In above problems, the optimization variables are represented by the unknown power and bandwidth allocation vectors p_i^{UL}, p_i^{DL} and b_j^{UL}, b_i^{DL}, for $i \in I$, $j \in J$. The following parameters are known (observable) for all $i \in I$, $j \in J$ (see description of the network model provided above):

- bit arrival rates to the buffers of U_j and the eNB_i, given by A_{Uj} and A_{eNBi}, respectively;
- The size of the buffers of U_j and the eNB_i, given by Q_{Uj} and Q_{eNBj}, respectively;
- Maximal buffer thresholds of U_j and the eNB_i, given by Q_{Uj}^{max} and Q_{eNBi}^{max}, respectively.

In problem (8) consider the uplink transmission from the users to the eNBs. Here the power and bandwidth are allocated to each uplink channel between m users placed in n different eNBs given the known bit arrival rate A_{Uj}, buffer size Q_{Uj}, and maximal buffer threshold Q_{Uj}^{max} of each user U_j in J.

In problem (9) the downlink transmission from the eNBs to the users is considered. The power and bandwidth are allocated to each downlink channel between n eNBs and m users given the known bit arrival rate A_{eNBi}, buffer size Q_{eNBi}, and maximal buffer threshold Q_{eNBi} max of each eNB_i in I.

In (8) and (9) the rates of the users and the eNBs, R_{Uj} and R_{eNBi}, are represented by the functions of power and bandwidth allocation vectors p_j^{UL}, p_i^{DL} and b_j^{UL},b_i^{DL}.

3.4 Relation between the Network Resources

To find the relation between the network resources (transmission rate, bandwidth and transmission power of the eNBs and the users). Recall that in an LTE system the transmission rates of the eNB_i and U_j can be found using the modified Shannon expression [10]:

$$R_{Uj}\left(P_j^{UL}, b_j^{UL}\right) = \omega\Psi \textstyle\sum_{i\in I} \boldsymbol{b}_{ij}^{UL} \log\left(1+g(SNR_{ij}^{UL}).SNR_{ij}^{UL}\right)$$

$$=\omega\Psi \textstyle\sum_{i\in I} \boldsymbol{b}_{ij}^{UL} \log\left(1+g(p_{ij}^{UL}).h_{ij}p_{ij}^{UL}\right) \qquad , \qquad \forall j \in J \qquad (10a)$$

$$R_{eNBi}(P_i^{DL}, b_i^{DL}) = \omega\Psi \textstyle\sum_{j\in J} \boldsymbol{b}_{ij}^{DL} \log\left(1+g(SNR_{ij}^{DL}).SNR_{ij}^{DL}\right)$$

$$= \omega\Psi \textstyle\sum_{i\in I} \boldsymbol{b}_{ij}^{DL} \log\left(1+g(p_{ij}^{DL}).h_{ij}p_{ij}^{DL}\right) \qquad , \qquad \forall i \in I \qquad (10b)$$

Where ω is the bandwidth of one RB (ω= 180 kHz):SNR_{ij}^{UL} and SNR_{ij}^{DL} are the signal-to-noise ratio SNR of the wireless channel between eNB_i and U_j in uplink and downlink directions, respectively: $\boldsymbol{\Psi}$ is the system bandwidth efficiency of the wireless channel between eNB_i and U_j: the function g(.) determines the SNR efficiency of the wireless channel between eNB_i and U_j [10]. Note. that in LTE system the SNR information is constantly updated (at each time slot t) via the use of the CQI information through the use of the reference signals (RSs) transmitted in uplink and downlink directions [9.14]. This information is then used by the eNBs to select relevant modulation and coding scheme (MCS) (the LTE mechanism for adjusting MCS will describe).

In LTE system the bandwidth efficiency and the SNR efficiency are strictly less than 1 due to the numerous reasons [10]. The system bandwidth efficiency $\boldsymbol{\Psi}$ is reduced because of the several overheads on link level and system level. Therefore, it is fully determined by the design and internal settings of the LTE system. and do not depend on the physical characteristics of the wireless channels between the users and the eNB [10]. The system SNR efficiency is mainly limited by the maximum efficiency of the supported MCS [10]. In LTE, MCS is chosen using the adaptive modulation and coding (AMC) to maximize the data rate by adjusting transmission parameters to the current channel conditions. AMC is one of the realizations of dynamic link adaptation. In AMC algorithm the appropriate MCS for packet transmissions is assigned periodically by the eNB based on instantaneous channel conditions reported by the users. The period of allocation is usually one slot time T_s.

The higher MCS values are allocated to the channels with good channel quality to achieve higher transmission rate and throughput. The lower MCS values are assigned to the channels with poor channel quality to decrease the transmission rate and, consequently, to ensure the transmission quality [14,18].

$$MCS = \begin{cases} MCS_1 & SNR < \gamma_1 \\ MCS_2 & \gamma_1 \leq SNR < \gamma_2 \\ . & . \\ . & . \\ MCS_{15} & \gamma_{14} \leq SNR < \gamma_{15} \end{cases} \tag{11}$$

In (11) the values $\gamma_1 < \gamma_2 < \ldots < \gamma_{15}$ are the SNR thresholds for choosing corresponding MCS index. In Table (3.2)

Table (3.2) MCS indices, associated modulation and code rate, SNR efficiencies and threshold in LTE standard [14].

MCS Indices MCS_k	Modulation Technique	Code Rate	SNR Efficiency (ζ_k)	SNR Thresholds (dB),γ_k
1	QPSK	78	0.1523	-3.1
2	QPSK	120	0.2344	-1.2
3	QPSK	193	0.3770	1.5
4	QPSK	308	0.6016	4
5	QPSK	449	0.8770	6
6	QPSK	602	1.1758	8.9
7	16QAM	378	1.4766	12.7
8	16QAM	490	1.1914	14.9
9	16QAM	616	2.4063	17.5
10	64QAM	466	2.7305	20.5
11	64QAM	567	3.3223	22.5
12	64QAM	666	3.9023	23.2
13	64QAM	772	4.5234	24.9
14	64QAM	873	5.1152	27
15	64QAM	948	5.5547	29.1

The LTE standard allows 15 MCS indices as detailed in Table (3.2) [14]. Based on the instantaneous radio channel conditions and power allocations the SNR of the wireless channels vary. Depending on the SNR the corresponding MCS index is chosen as [14].

Figure (3.3) shows the SNR efficiency g(SNR) for different values of SNR. In which illustrates the increase of SNR leads to increase in the efficiency of SNR[14].

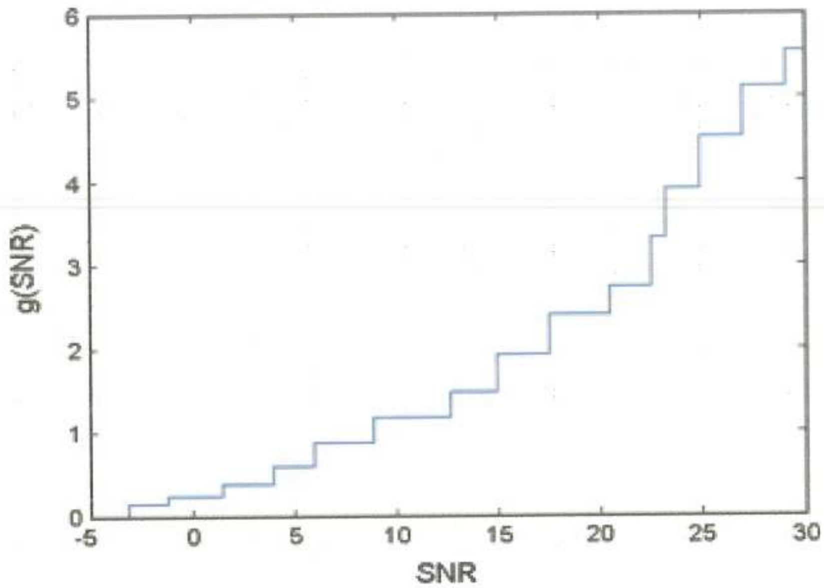


Figure: 3.3 The SNR Efficiency g(SNR) for Different SNR Values[14]

$$g(SNR) = \begin{cases} \zeta_1 & SNR < \gamma_1 \\ \zeta_2 & \gamma_1 \leq SNR < \gamma_2 \\ . & . \\ . & . \\ \zeta_{15} & \gamma_{14} \leq SNR < \gamma_{15} \end{cases} \tag{12}$$

Using the expression for g (.) given by (12), and (10) representing the transmission rate as a function of allocated bandwidth and power, the final optimization problem takes the form

Minimize: $\sum_{i\in I}\sum_{j\in J} P_{ij}^{UL}$ (13a)

Subject to: $b_j^{UL} \in B_j^{UL}$, $\forall j \in J$ (13b)

$\sum_{i\in I} \boldsymbol{b_{ij}^{UL}} \log(1+g(p_{ij}^{UL}).\, h_{ij}p_{ij}^{UL}) \geq \frac{A_{Uj}-\mathcal{E}_{Uj}}{\psi}$, $\forall j \in J$ (13c)

$\sum_{i\in I} \boldsymbol{b_{ij}^{UL}} \log(1+g(p_{ij}^{UL}).\, h_{ij}p_{ij}^{UL}) \leq \frac{Q_{Uj}+A_{Uj}}{\psi}$, $\forall j \in J$ (13d)

$\mathcal{E}_{Uj} = \frac{Q_{Uj}^{max}/_{2} - Q_{Uj}}{Q_{Uj}^{max}}$, $\forall j \in J$ (13e)

For the uplink direction , and

Minimize: $\sum_{i\in I}\sum_{j\in J} P_{ij}^{DL}$ (14a)

Subject to: $b_i^{DL} \in B_i^{DL}$. $\forall i \in I$ (14b)

$\sum_{i\in I} \boldsymbol{b}_{ij}^{DL} \log\left(1-\beta \cdot g(p_{ij}^{DL}).\, h_{ij} p_{ij}^{DL}\right) \geq \frac{A_{eBNi}-\mathcal{E}_{eBNi}}{\psi}$. $\forall i \in I$ (14c)

$\sum_{j\in J} \boldsymbol{b}_{ij}^{DL} \log\left(1+\beta \cdot g(p_{ij}^{DL}).\, h_{ij} p_{ij}^{DL}\right) \leq \frac{Q_{eNBi}+A_{eNBi}}{\psi}$. $\forall i \in I$ (14d)

$\mathcal{E}_{eNBi} = \frac{Q_{eNBi}^{max}/_2 - Q_{eNBi}}{Q_{eNBi}^{max}}$, $\forall i = I$ (14e)

For the downlink direction.

Because of the integer restrictions on allocated bandwidth, the problems (14) and (15) are the mixed integer programming (MIP) problems, and therefore NP-hard. However, many efficient methods for solving such problems exist.

CHAPTER-4

SYSTEM DESCRIPTION

4. SYSTEM DESCRIPTION

4.1. Methodology

As per discussed in previous chapters, in this dissertation the main motive was to present hybrid technique for spectrum allocation with goal of achieving the efficient tradeoff between transmission rate, bandwidth, and transmission power in IEEE 802.22 based LTE networks. Before proceeding next, below the methodology that shows the complete practical working flow of the dissertation.

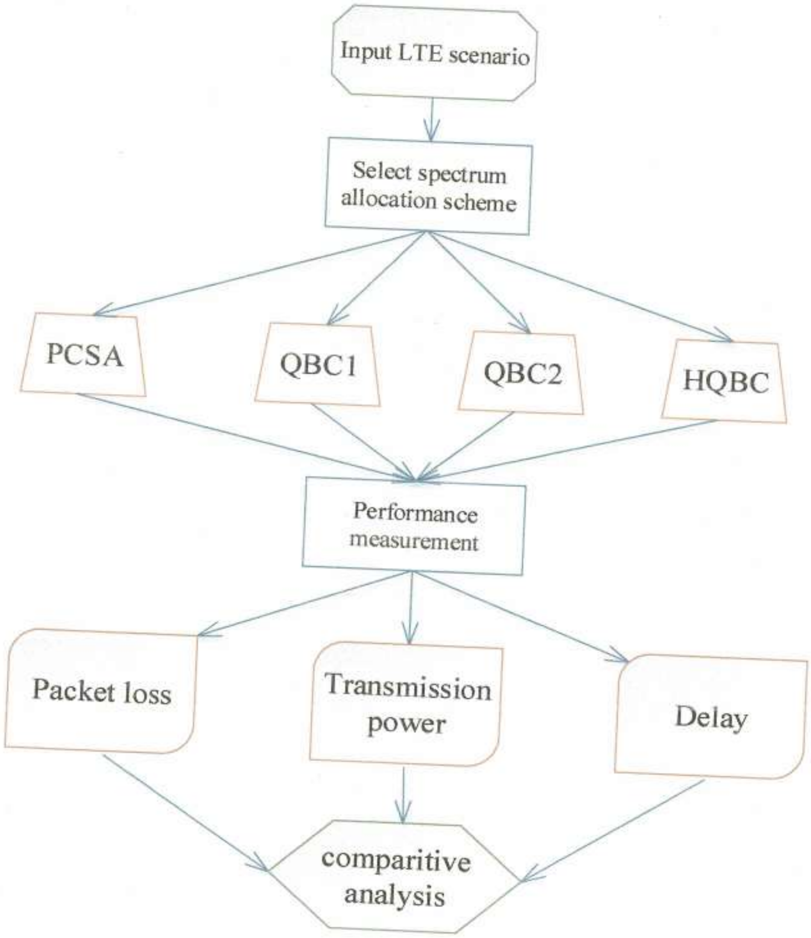


Figure 4.1: Proposed System Methodology

4.2. Core Concepts

In this section first present the existing QBC1 and QBC2 algorithm and then will list out limitations of QBC1 and QBC2, those are overcome by proposed HQBC method by using multilevel queue concepts.

4.3 Existing Methodology

This section presents the architecture and algorithm of proposed power efficient dynamic spectrum allocation method. Below figure 4.2 showing the basic architecture of proposed algorithm as per given in [1]. From figure below, end users gets allocated with network resources and the evolved Node Bs (eNBs) by the spectrum manager (SM) using some optimal resource allocation strategy. Basically this method proposed to allocate the bandwidth and transmission power to the uplink and downlink of LTE system with goal of total transmission power is minimized subject to capacity constraints, queue stability constraints, and some integer restrictions on the bandwidth. To find the buffer occupancy in the system, use modified Shannon expression which depends on signal-to-noise ratio (SNR) and modulation and coding scheme (MCS).

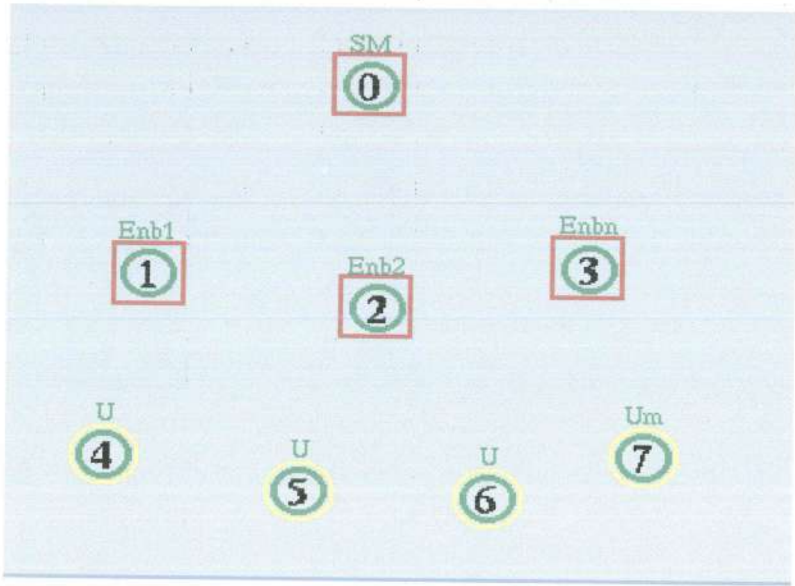


Figure 4.2: A typical CRN Model Based on LTE Standard Network NAM Results

Based on system architecture. below the algorithm for LTE-based network architecture. The objective of the algorithm is to assign the spectrum and transmission power to the uplink and downlink channel between the users and the eNBs to minimize the total transmission power. The corresponding algorithm can be described as follows.

At time t:

– Each users/eNB collects the values QUj(t)/QeNBi(t). AUj(t)/AeNBi(t) and sends them to SM:

– SM finds the optimal (or near-optimal) resource allocation vectors $b_j^{UL}, P_j^{UL}, P_i^{DL}, b_i^{DL}$ and sends this information to corresponding eNBs;

– The eNBs assign the resources to the uplink and downlink channels of the users.

The maximal threshold buffer size is assumed to be equal to the average arrival rate of the respective eNB/user. and is calculated using constantly updated values from()()

Algorithm Name: Branch & Bound B&B Algorithm for QBC-1 and QBC-2

Input Set

RPk = relaxed sub-problem at node **k**

(bk, pk)= solution of RPk

yk= value of the objective function at **(bk, pk)** which corresponds to the lower bound of node k

(bMIP, pMIP) = best obtained MIP solution of the primary **MIP** problem;

yMIP= best obtained value at **(bMIP, pMIP)** which corresponds to the upper bound of the primary MIP problem.

The node k has no branches in the following cases:

RPk=has no feasible solutions

bk = is integer;

bk= non-integer and worse than the best obtained integer solution **(bMIP, pMIP)(yk>yMIP** for minimization problem).

Main Algorithm Steps:

Step 1:

Initialize yMIP to last (infinity)

set MIP' equal to MIP

Initialize L

Step 2:

If (all node is present == theta)

{

go to step 3

} else

{

go to step 4

}

Step 3:

yMIP* is optimal value

if (check yMIP* < infinity/infinity+)

{

Optimal_Solution =[bMIP* , pMIP*]

}

Step 4:

Select node k and set L = L / {'k'}

Step 5:

Solve RP to get bMIP and pMIP

Step 6:

If (RPk ==true)

{

go to step 7

} else

{

go to step 2

}

Step 7:

if (yk > yMIP)

{

go to step 8

} else

{

go to step 9

}

Step 8:

Confirm k is fathom node, go to step 2

Step 9:

if (isint (bk))

{

go to step 10

} else

{

go to step 12

}

Step 10:

set yMIP* = yk

set (bMIP,pMIP) = (bK,pK)

Step 11:

for each s node in L set :

if (yk > yMIP*)

{

set L = L of S set

}

Step 12:

Select branch node bk and pk

create two new nodes k1,k2

set yk1=yk and yk2=yk

RPk1=RPk+constraint bi , where biis <= integer bk of Numbers i

RPk2=RPk+constraint bi , where biis => integer (bk of Numbers i)+1 set L to union of L with k1 and k2 set

go to step 2

End

4.4 Limitations of Existing Methodology

There are two variants of previously presented power efficient method for spectrum sensing such as QBC1 and QBC2. from the practical analysis some conclusion and limitations can be noted as listed below:

- QBC1 is having better performance in terms of loss and de1lay as compared to QBC2.
- QBC2 is having better performance in terms of transmission power as compared to QBC1.
- Therefore there is no tradeoff between loss, delay and transmission power performance in either QBC1 or QBC2.
- QBC1 is efficient in delay and loss whereas worst in transmission power.
- QBC2 is efficient in transmission power whereas worst in delay and loss.

4.5 Proposed Algorithm

To overcome the limitations of QBC1 and QBC2, this dissertation presents hybrid technique which is based on QBC1 and QBC2. In short, proposed technique is combined extension of both QBC1 and QBC2. The proposed spectrum sensing scheme is called as HQCB.

This method is includes the concepts of multilevel priority queues, in which different kinds of network data is divided into multiple queues. and hence efficiency of spectrum allocation improves. which in terms improves the QoS performance and transmission power performance.

Algorithm: Dynamic Bandwidth Allocation Algorithm

- Initially set high and low thresholds as T2 and T1
- At each node
  1. Receive Packet.
  2. Classify packet according to priority.
  3. Check intermediate buffer occupancy for number of packets initially occupied.
  4. Calculate transmission of number of packets to intermediate buffer according to threshold value.
  5. Push packets into intermediate buffer.
  6. Repeat steps 3-5 for all priority buffers.

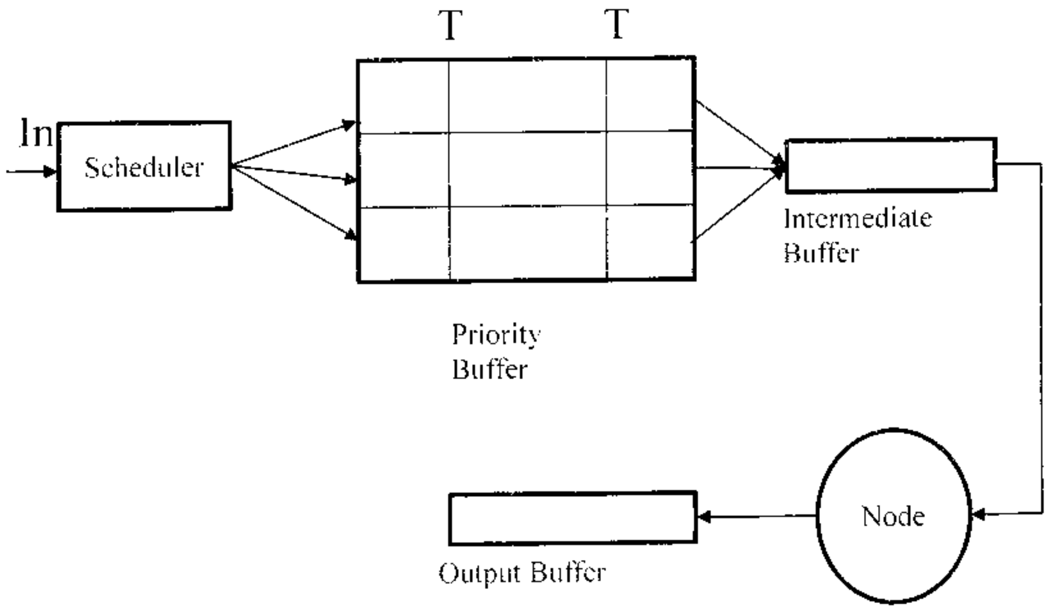


Figure 4.3: The Architecture for A single User the Network.

CHAPTER-5

EXPERIMENTATIONS

5. EXPERIMENTATIONS

5.1 Network Simulator (NS-2)

NS2 is stand of the Network Simulator Version 2 which is targeted specially for the networks simulations. NS2 is nothing but the discrete event simulator for the researches in the area of networking. NS2 provides the simulation and research supports for the wired networks, wireless networks by using TCP, and UDP, IP, and CBR patterns of the communications. NS2 is made of two parts basically such as NS means network simulator and other one is NAM means network animator.

NS is used to simulate all the protocols like commonly used IP protocols over the wireless as well as wired networks. On the other hand, the network animator tool is used to visualize the simulation of the networks in the form of actual communication patterns. NAM supports the wired network simulation fully as compared to wireless simulation which is possible only partially with the NAM. NS2 is the recent version 2 of the network simulator which was developed and published by the one the university in the Berkeley city called as University of California. But after that, VINT project as well. Initially network simulator was developed only for the wired networks; recently Carnegie Mellon University in 1999, extended the working and simulation of the NS2 for the wireless ad hoc networks means MANET as well. There also some other features of the ns-2 which increases our interests of using the ns2 simulator for the simulation of our network applications such as:

- NS2 provides the network simulation environment for both wired, wireless means MANET networks.
- Provides the modules for the wireless channel such as 802.11, 802.16 etc.
- Provides the number of routing protocols for choice in which the routing is done along multiple paths.
- Simulations of the cellular networks possible as the mobile hosts are simulated as well.

Using the technologies like CPP and OTCL, NS2 is developed as the completely object oriented network simulator. The class hierarchy which is presented in the C++

and OTcl interpreted is very much supported by the network simulator in which there is one to one mapping in between the class in the interpreted hierarchy and compile hierarchy.

For the NS2 two kinds of programming languages used which discussed above such as C++ and OTcl because of the reason is that OTcl language is suitable for the programs and configurations which are demanding for the fast and frequent network changes and on the other hand C++ is used for the speed efficiency in the simulation of the networks. Thus such tool is very flexible for the useNs-2 as it also allows user to existing protocols for their application simulations as well as to develop their network protocol in order to extend the functionality of the tool. Network simulator also helps for the performance measurement from the trace analysis functionality which is very important for the research purposes in order to measure the efficiency of particular application or particular routing protocol. NS2 is open source and free software tool which is widely available for downloads from the Internet. It was initially developed for the UNIX systems but later by using the environment of the Cygwin under the Windows XP the ns2 simulator can run.

5. 2 GloMoSim: A network simulator

This is also one kind of scalable network simulator which provides the simulation environment for the networks like wireless networks as well as wired networks. However right now this simulator available with the protocols which are used for the only for the MANET. Thus is doesn't supports the simulation for the wired networks. Using the layered structured architecture like OSI architecture for the network. This simulator is divided into the modules of library for the each wireless routing protocol for the network simulation. Using these library modules users can simulate the wireless communication protocols from the protocol stack. Such libraries are developed using the C and PARSEC used as the parallel language for the simulation.

The extension in this simulation tools can be done by developing the library for the new protocol and add it to the existing libraries. Like NS2, u can also download this simulation tool from the any of the academic institution websites which provides them for free. It's not available for the complete download for free, but for academic purposes you will get it for free.

5.3 OPNET Modeler

This is most widely used commercially and full featured simulation tool for all kinds of network simulation. For the network simulation and network modeling, OPNET network simulator is available as commercially and also one version for the academic researches which is for free only for the university candidates to use. OPNET is designed and developed by using the modeler concepts in which for different protocols different OPNET released modeler are available to use and add it to the OPNET. These tools are used for the study and simulation of the all kinds of networks, protocols simulations, devices and different applications.

Here the networks are simulated both ways like animated as well as graphically, different kinds of graphs for the network simulation with the matrices measurement such throughput, delay, jitter etc. OPNET modeler is developed using the C language.

5.4 Comparison

While considering our application that required to simulate the using the any of the above simulation tools. But while choosing simulation tools for the network simulation, accuracy of the simulator is considered. But still then, no one conclude that which tool is more accurate from the above listed tools.

Although many researchers did the simulations using different network simulators in order to find out their accuracy, it was concluded that the results were not showing any proper clarifications about the accuracy of simulation tool which has most. The simulator will be chosen depending on the simulator availability, flexibility and kinds of services that simulator will gives to us.

As per the knowledge gained from the study of this three network simulators, following table shows their comparisons in terms of their availability, programming language support etc.

Table 5.1: Comparison of the three simulators

	Free	Open Source	Programming Lang.
NS-2	Yes	Yes	C++, TCL
GloMoSim	Limited	Yes	Parse
Opnet	No	No	C

NS 2 is selected because of the following advantages of using it:

1. Open Source and free software for the simulations.
2. Easily available for the download and installation.
3. Programming is done in C++.
4. More features implemented for the simulation.

5.5 Software Requirements

For the simulation of this work the setup requirements are:

1) Cygwin: for the windows XP
2) Ns-allinone-2.32:

1) Computer Requirements
a. 5 GB free space of HDD
b. 3 GB of RAM
2) Installation Assumptions
a. Windows is installed in C drive.
3) Installing Cygwin as following ways:
a. download the latest version Cygwin setup.
b. execute the Cygwin setup

5.6 Performance Metrics

1) Packet delivery ratio: It is the calculation of the ratio of packet received by the destinations which are sent by the various sources of the CBR.

2) Normalized routing load: This metrics is used to calculate the number of routing packets which are transmitting with the original data packet over the network. This metrics indicates the efficiency of routing protocol in the MANET.

3) End to end packet delay: This metrics calculates the time between the packet origination time at the source and the packet reaching time at the destination. Here if any data packet is lost or dropped during the transmission, then it will not consider for the same. Sometimes delay occurs because of discovery of route, queuing, intermediate link failure, packet retransmissions etc are considered while calculating the delay. Such kind of metrics has to measure against the different number of nodes, different traffic patterns and data connections.

4) Throughput: This metrics calculates the total number of packets delivered per second. means the total number of messages which are delivered per second.

5) Energy Consumption: The metric is measured as the percent of energy consumed by a node with respect to its initial energy. The initial energy and the final energy left in the node, at the end of the simulation run are measured. The percent energy consumed by a node is calculated as the energy consumed to the initial energy. And finally the percent energy consumed by all the nodes in a scenario is calculated as the average of their individual energy consumption of the nodes.

*Percent_Energy_Consumed=(InitialEnergy−FinalEnergy)/InitialEnergy*100*

Average_Energy_Consumed = Sum_of_Percent_Energy_Consumed_by_All_Nodes / Number_of_Nodes

5.7 Simulation Scenarios

There are three main modules considered in this dissertation those are listed below:

Module 1 [40 %]

Routing Protocol: AODV

Spectrum Sensing Scheme: PCSA

Number of users: 50, 100, 150, 200, 250, 300

Outputs:

- Delay Vs. Number of Users
- Loss Vs. Number of Users
- Transmission Power Vs. Number of Users

Module 2 [30 %]

Routing Protocol: AODV

Spectrum Sensing Scheme: QBC1 and QBC2

Number of users: 50, 100, 150, 200, 250, 300

Outputs:

- Delay Vs. Number of Users
- Loss Vs. Number of Users
- Transmission Power Vs. Number of Users

Module 3 [30 %]

Routing Protocol: AODV

Spectrum Sensing Scheme: HQCB

Number of users: 50, 100, 150, 200, 250, 300

Outputs:

- Delay Vs. Number of Users

- Loss Vs. Number of Users

- Transmission Power Vs. Number of Users

Table 5.2 shows the simulation parameters used in this practical analysis for the proposed work.

Table 5.2 Network Configuration for Simulation

Number of Nodes	50/100/150/200/250/300
Traffic Patterns	CBR (Constant Bit Rate)
Network Size (X x Y)	1000 x 1000
Max Speed	5 m/s
Simulation Time	100s
Transmission Packet Rate Time	10 ms
Pause Time	1.0s
Routing Protocol	AODV
MAC Protocol	802.22
Spectrum Sensing	PCSA/QBC1/QBC2
Number of Flows	5
PDCCH symbols per subframe	3
UL loading facto	1
DL loading factor	1
Inactive bearer timeout	20s
Periodic timer	5 sub fames
Retransmission timer	2560 subframes
Reserved size	2 RBs
Starting RBP for Format messages	10
Allocation periodicity	5 sub frames
Operation mode	FDD

Cyclic prefix type	Normal (7 Symbols per Slot)
EPC bearer definitions	348 kbit/s (Non-GBR)
Subcarrier spacing	15 kHz
Transmitter/receiver antenna gain	10 dBi (pedestrian), 2 dBi (indoor)
Receiver antenna gain	10 dBi (pedestrian), 2 dBi (indoor)
Receiver noise figure	5 Db
Number of preambles	64
Number of RA resources per Frame	4

Table 5.2 shows the network simulation parameters that selected according to IEEE802.22 standards and 3GPP LTE system.

CHAPTER-6

RESULTS & DISCUSSIONS

6. RESULTS AND DISCUSSIONS

In this dissertation three different spectrum sensing methods are simulated for IEEE 802.22 based LTE networks such as PCSA, QBC and proposed HQBC. The aim of this dissertation is to propose HQBC with goal of improving performance against QBC method.

This section summarizes the results achieved through different LTE network scenarios and compare performances against investigated existing methods. Figure 6.1 shows network animator NAM representation in NS2 for 50 users.

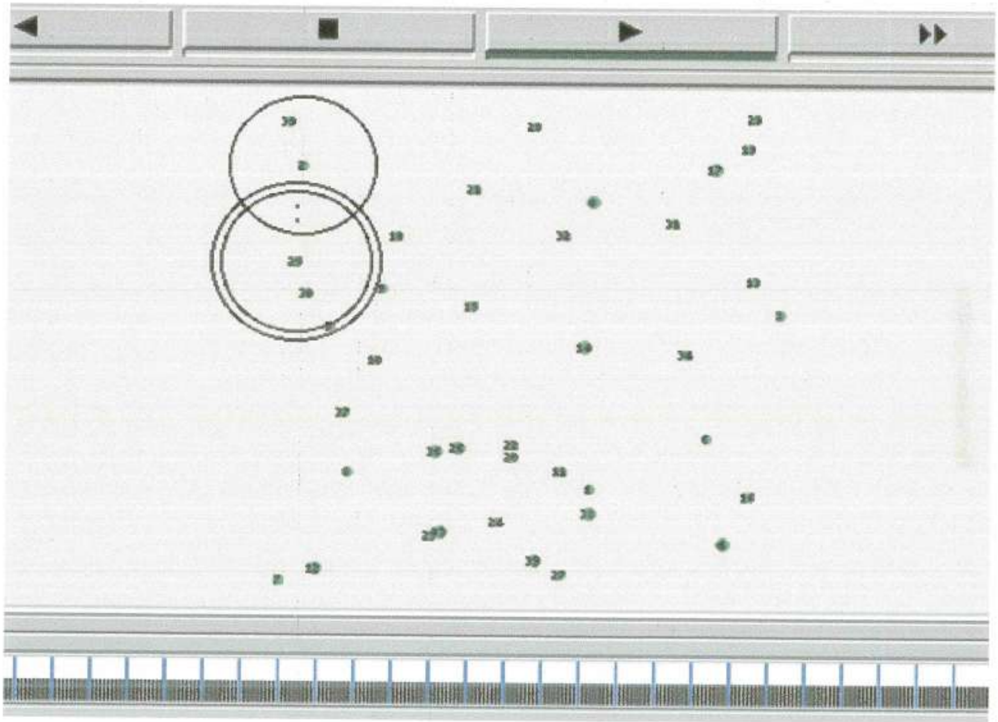


Figure 6.1: HQBC 50 Nodes Simulation

The performance of aforementioned is methods compared in terms of transmission power, packet loss and delay. These graphs are plotted using the AWK script to measure each performance metrics. Simulation results for different transmission power are shown in figure 6.2.

6.1. Transmission Power

Transmission power is nothing but the amount of energy consumed during the data transmission over IEEE 802.22 LTE network. Figure 6.2 shows the performance of different spectrum sensing methods with varying number of end users in cognitive LTE network.

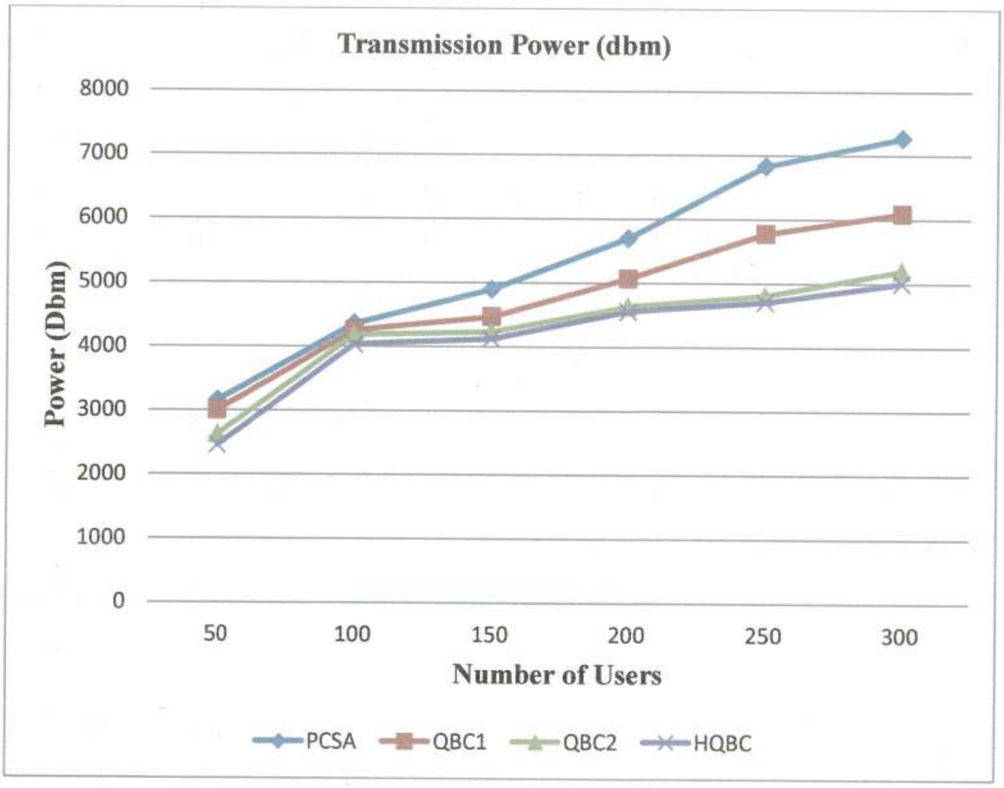


Figure 6.2: Transmission Power Performance

Figure 6.2 shows the transmission power performance for PCSA, QBC1, QBC2 and HQBC. Performance of HQBC is better than all other existing methods, HQBC outperformance compared with QBC2 which is most recent energy efficient technique. For each kind of network, HQBC provides energy efficient spectrum allocation for data transmission and communication.

6.2. Packet Loss

When the number of network users increases the packet loss performance for each existing method starts degrading. The hybrid resource allocation technique (HQBC) archives the smallest packet loss value shown in figure 6.3.

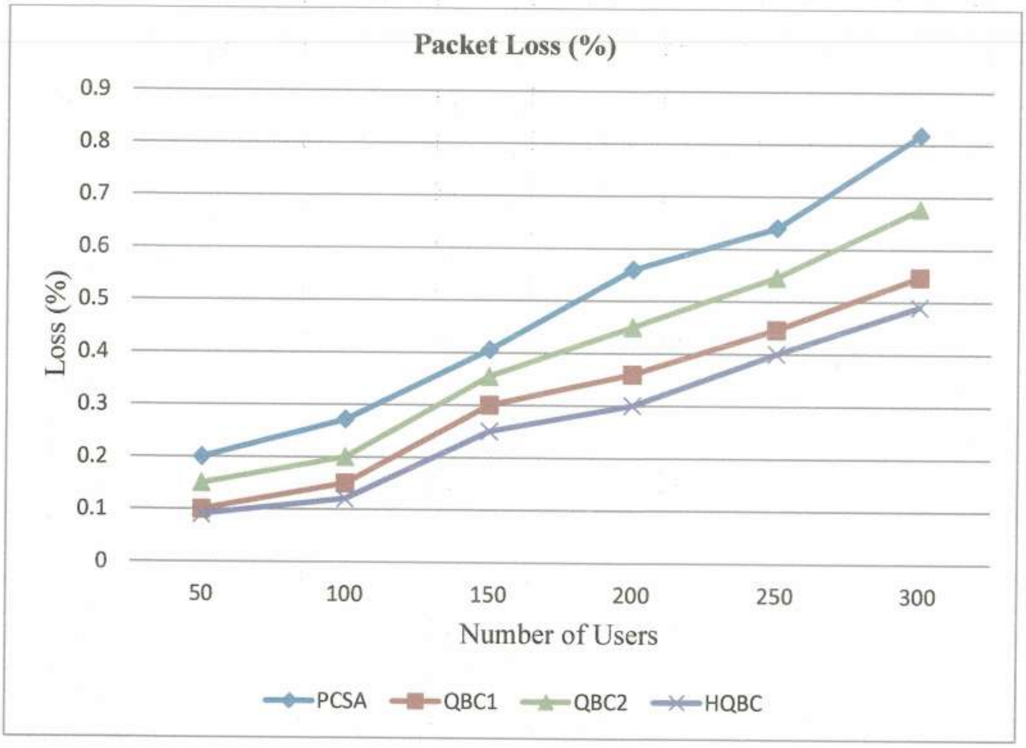


Figure 6.3: Packet Loss Performance

Figure 6.3 shows the performance of packet loss with varying number of users for different spectrum allocation methods in cognitive LTE network. It is clear that QBC1 outperforms compared with existing PCSA and QBC2. The contradiction between QBC1 and QBC2 is that, QBC2 gives better energy efficiency while QBC1 giving better packet loss and delay performance but HQBC provides better performance for transmission power, delay and packet loss.

6.3. Delay

Figure 6.4 shows delay performance with varying number of users for different spectrum allocation methods in cognitive LTE network. HQBC outperformance compared with existing PCSA method QBC1 and QBC2methods.

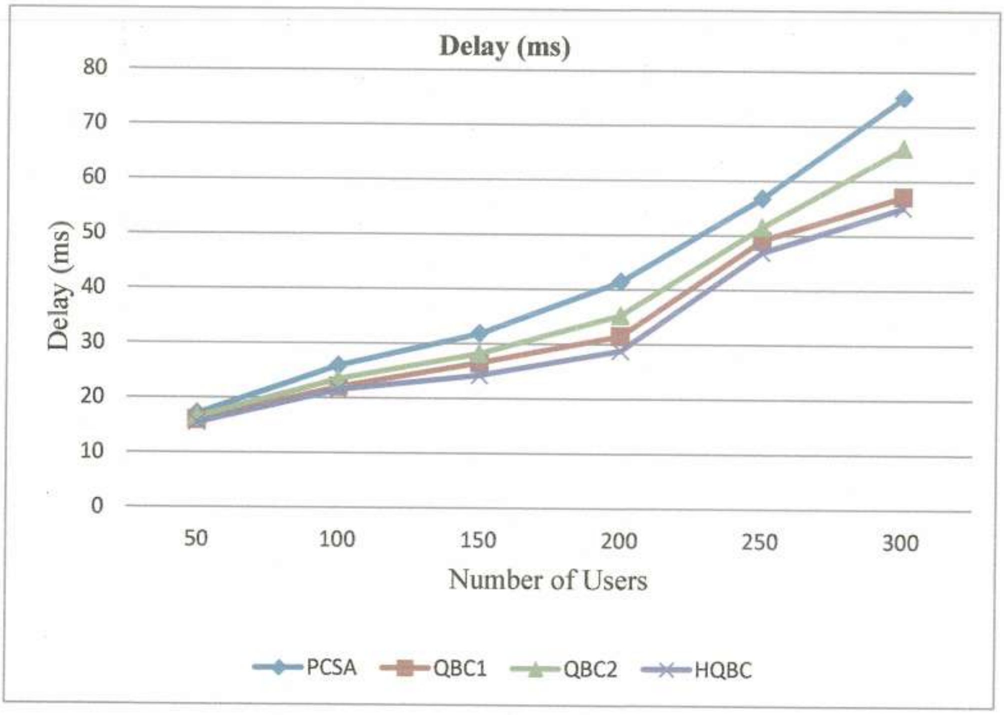


Figure 6.4: Delay Performance

From figure 6.4 it is clear that performance of HQBC is improved as compared to all other existing spectrum sensing algorithms. This is one, which cannot be achieved by any of previous methods. Along with loss, delay is another important parameter for spectrum sensing technique.

When the network is loaded with large number of users, PCSA, QBC1andQBC2 takes no action against the queuing delay of the users and the eNBs. Unlike the existing resource allocation methods, HQBC is designed to prevent the growth in the buffers, which is achieved by additional constraints in the size of the queues of the users.

CHAPTER-7

CONCLUSION AND FUTURE SCOPE

CONCLUSION AND FUTURE SCOPE

7.1 Conclusion

In this dissertation the performance of recently presented efficient spectrum sensing allocation method for LTE cognitive radio networks based on 802.22 frameworks has been investigated. Then limitations of existing methods are discussed. New hybrid technique is proposed to overcome limitations of existing methods. The basic architecture of IEEE 802.22 standard is presented. after that presented algorithm and architecture of proposed bandwidth allocation method is discussed.

The investigated algorithm is named as QBC. To overcome the limitations of QBC. the hybrid technique (HQBC) has been proposed and implemented based on concepts of multiple priority queues for both real time and non-real time data transmission. The aim of this method is to achieve the efficient performance of transmission power, delay. and packet loss. The proposed work is totally based on cognitive radio networks with use of IEEE 802.22 LTE networks. Simulation of existing methods and proposed method is done using NS2. HQBC outperformance compared with existing methods such as PCSA,QBC1,QBC2 for transmission power ,delay and packet loss .

7.2 Future Scope

The work in this dissertation which presents basic architecture of IEEE 802.22 standard for LTE network can be extended for other wireless networks such as WiMAX and wireless sensor network (WSN) to enhance the spectrum efficiency by allocating the network resources in efficient manner.

For future work. this technique can be developed in real time environment and check its tested results.

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PUBLICATIONS

[1] Hussein Tuama hazim, S.A.Shirsat "Energy-Efficient Bandwidth Allocation for Cognitive LTE Networks" *Conference for Post Graduate Students of Electronics/Electronics and Telecom Engineering under Savitribai Phule Pune University, e-PG Project Exhibition* 2015, 29-30 May 2015.

[2] Hussein Tuama hazim, S.A.Shirsat "Power Efficient Bandwidth Allocation for Cognitive LTE Networks" *International journal of advanced research in computer science and software engineering (IJARCSSE).* ISSN: 2277 6451, Volume 5 Issue 4 pp. 1068-1076, April 2015

[3] Hussein Tuama hazim, S.A.Shirsat "Hybrid Efficient Bandwidth Allocation Technique for Cognitive LTE Networks" *International journal of engineering science and research technology (IJESRT).* ISSN: 2277-9655, Volume 4 Issue 6. pp. 164-171, June 2015

Certificate of Participation

e-PGPEX

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e-PG Project Exhibition

29-30 May, 2015

Savitribai Phule Pune University
(Formerly University of Pune)

Energy-Efficient Bandwidth Allocation for Cognitive LTE Networks

Hussein Tuama, Prof.S.A.Shirsat
Department of Electronics & Telecommunication Engineering
Sinhgad College of Engineering, Savitribai Phule Pune University, Pune, INDIA.
hussein.tuama@gmail.com, sashirsat.scoe@sinhgad.edu

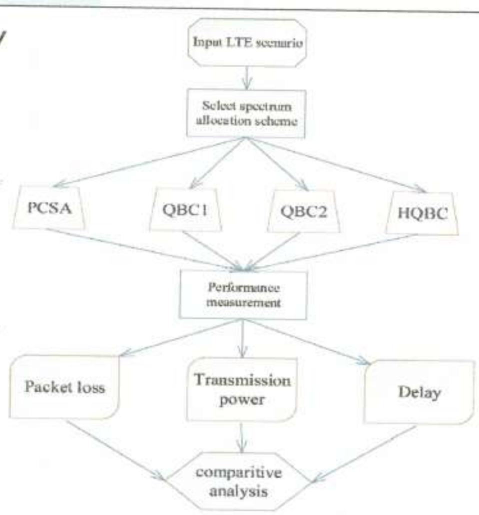
Introduction

- ❖ IEEE 802.22 standard is based on cognitive radio network (CRN).
- ❖ The existing methods used for spectrum access in cognitive third generation partnership project (3GPP) long term evaluation (LTE) network based on IEEE 802.22 standard are not efficient
- ❖ In this work a power efficient dynamic spectrum access (DSA) method for cognitive LTE is investigated.
- ❖ The new technique based on recently presented two bandwidth allocation methods Queue Based Control QBC-1 and QBC-2which named HQBC.
- ❖ The NS2 simulation results show that HQBC achieved better performance of transmission power, packet loss and end to end delay than existing methods.

Aim and Objectives

- ❖ To allocate the network resources in efficient manner.
- ❖ To enhance the spectrum utilization efficiency.
- ❖ High quality mobile services.
- ❖ The data rate, transmit power; channel allocation are improved with proposed allocation algorithm for CR LTE network.
- ❖ T[illegible] aim of this method is to achieve the efficient tradeoff analysis between performance of transmission p[illegible]wer, delay, and packet loss.

Methodology



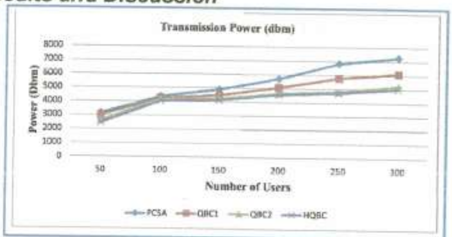
Simulation/ Experimental Setup

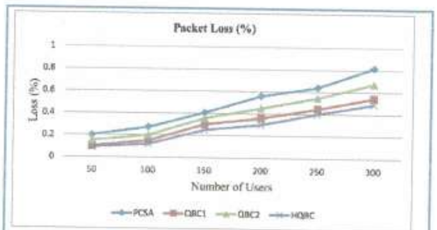
Simulation Platform: For the simulation of this work the following setups requirement for the same

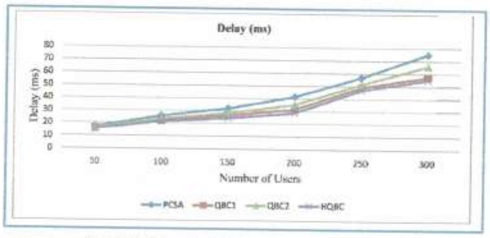
1) Cygwin: for the windows XP
2) Ns-allinone-2.31

Mac protocol: 802.22
Scenarios: 50/100/150/200/250/300 Number of users
Spectrum Allocation: PCSA/QBC1/QBC2/HQBC

Results and Discussion







Performance of QBC1 and QBC2 showing that QBC1 is having better Delay and Los performance as compared to QBC2, and QBC2 having better power consumption performance as compared to QBC1. Therefore hybrid technique presented which is known as HQBC (Hybrid QBC), which is main goal of improving performance in terms of loss, delay, and power consumption as compared to QBC1 and QBC2. This achieved by using concept of multilevel queues and dynamic network adaptation.

Summary

- ❖ The Objective of this project is to investigate the performance of recently presented efficient spectrum sensing allocation method for LTE cognitive radio networks based on 802.22 frameworks, then discussing the limitations of investigated methods, and then proposed new hybrid technique to overcome said limitations.
- ❖ To overcome the limitations of QBC, new technique HQBC have been presented .HQBC based on concepts of multiple priority queues for both real time and non-real time data transmission.
- ❖ Practical simulation of existing methods and investigated method is done using NS2. Performance results outperforming existing methods for loss, delay and transmission power.

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Power Efficient Bandwidth Allocation for Cognitive LTE Networks

Hussein Tuama Hazim, S. A. Shirsat
Department of Electronics & Telecommunication Engineering
Sinhgad College of Engineering, Pune,
Maharashtra, India

Abstract*—*IEEE 802.22 standard is based on cognitive radio network (CRN).It allows opportunistic use of TV white space as spectrum holes by secondary user. The existing methods used for spectrum access in cognitivethird generation partnership project (3GPP) long term evaluation (LTE)network based on IEEE 802.22 standard are not power efficient. In this paper power efficient dynamic spectrum access (DSA) method in cognitive third generation partnership project (3GPP) long term evaluation (LTE) network based on IEEE 802.22 is proposed. This method enhances the transmission power efficiency along with spectral efficiency. The work is simulated by using NS2. The performance of the proposed method is evaluated in terms of transmission power, packet loss and end to end delay by compared with the performance of existing method called power control and spectrum access (PCSA) approach.

Index Terms*— *IEEE802.22, 3GPP LTE, Spectrum Access, Energy efficiency, QBC1, QBC2

I. INTRODUCTION

Wireless spectrum is basically allocated statically for different radio services in applications like military, government, commercial, private and public safety systems. Though such long-termstatic allocations have certain advantages in terms of oversight and management, it has beendemonstrated through experimental studies that spectrum utilization is time and space variant.

Existing static spectrum allocation methods suffer from spectrum underutilization problem [1]. Due to technology advancement digital television has replaced analog television broadcasting. The current digital television requires 50% less bandwidth as compared to old analog television broadcasting , this saves 50% bandwidth in very high frequency (VHF) and ultra high frequency (UHF) bands reserved for television broadcast.

Such studies over spectrum allocation resulted to spectrum usage and access policy reforms [3] and *dynamic spectrumaccess* (DSA) based on *cognitive radio* (CR) [4] is seen as a viable option that can help thecurrent reforms.

One of the efforts that are seen as a solution to the current spectrum scarcity problem isthe proposition of the *IEEE 802.22* standard. IEEE 802.22 is a cognitive radio-based wirelessregional area networks (WRANs) standard that would allow the unused, licensed sub–900 MHzTV bands to be used by unlicensed users on a non-interfering basis [5]. To protect the licensedservices (primary incumbents), IEEE 802.22 devices are required to perform periodic spectrumsensing and evacuate promptly upon the return of the licensed users.

Even though the primary user protection mechanisms (primary-secondary spectrum etiquettes)have been predominantly studied and designed in IEEE 802.22 standard [6], the critical issue ofensuring quality of service (QoS) among IEEE 802.22 networks themselves, in other words,maintaining *self-coexistence* (secondary-secondary spectrum etiquettes) have not been addressed.In a system where unlicensed devices share the spectrum under the presence of licensed users,the issue of self-coexistence among multiple CR operators in an overlapping region isvery significant. In areas with analog/digital TV transmissions and wireless microphone services,unused channels are already commodities of demand. The challenge of self-coexistence becomeseven tougher as the networks do not have information about which bands other secondary CRnetworks will choose. Different from other IEEE 802 standards where self-coexistence issuesare only considered after the specification essentially is finalized, it is required for IEEE 802.22to take the proactive approach and mandate to include self-coexistence protocols and algorithmsfor enhancing the medium access control (MAC) as a revision to the initial standard [8]-[10].

In this paper we are investigating the performance of recently presented power efficient and scalable dynamic spectrum allocation method for LTE networks. This method is basically focusing on power efficient resource allocation. The size of the node buffers is controlled by this method in the system using the queue stabilityconstraints [12] in order to prevent potential network congestion(which may result in longer delays and large losses).The practical evaluation of this protocol is compared against existing PCSA method using different network scenarios. In below sections, section II take review of different spectrum allocation methods in cognitive networks.In section III, IEEE 802.22 is discussed along with its different layers and components. Concepts of proposed spectrum sensing methods are discussed along with its algorithm. In section V, practical results and analysis have been introduced. Finally, section VI shows the conclusion and future work.

II. RELATED WORKS

Over the years, dynamic spectrum sensing and allocation is becoming interesting research area for research panels with considering different decision making aspects, problems, and challenges in LTE networks.

In [11]-[14], energy detection has been largely used to monitor primary spectrum usage activity. Spectral correlation based signal detection for primary spectrumsensing in IEEE 802.22 WRAN systems is presented in [15].

In [16], signature-based spectrum sensingalgorithms are presented in order to investigate the presence of Advanced Television SystemsCommittee (ATSC) DTV signals.

In [17], sequential pilot sensing of AdvancedTelevision Systems Committee (ATSC) DTV signals is carried out to sense the primaryusage in IEEE 802.22 cognitive radio networks.

In [18], new channel sensing method isproposed called as dynamic frequency hopping (DFH). In DFH, neighboring WRAN cells formcooperating communities that coordinate their DFH operations where WRAN data transmissionis performed in parallel with spectrum sensing without interruptions. The aim here is to minimizeinterrupts due to quiet sensing.

In [19], a novel metric called Grade-of-Service (GoS) is defined and the trade-off between miss-detection and false alarm is studied for optimizing spectrumsensing performance.

Above all methods presented in [11]-[19] are targeting on sensing of primary spectrum usage, but research problem of self-coexistence among multiple CR networks are not considered.

A broad survey on resource allocation in cellular networks and WLAN thoughgraph coloring mechanisms can be found in [20], [21], [22], [23], [24] and in the referencestherein. However, most of these works do not consider the dynamic availability of spectrumbands due to the presence of primary users and thus cannot be directly applied to IEEE 802.22network spectrum sharing.

In [25], an author investigates the channel assignment problem ina multi-radio wireless mesh networks using graph-coloring such that a given set of flow rates areschedulable.

In [26], an author presented the dynamic channel allocation problem is formulated as graph coloringproblem where dynamic channel availability is observed by the secondary users.

In [27], spectrumallocation and scheduling problems are studied jointly in cognitive radio wireless networks withthe objectives of achieving fair spectrum sharing. However, all channel divisions are treatedequally here.

In [28], a distributed, real-time spectrum sharing protocol called On-DemandSpectrum Contention (ODSC) is proposed that employs interactive MAC messaging among thecoexisting 802.22 cells. However, control signaling is greatly increased through extensive MACmessaging. Game theoretic approaches are recently being investigated in [29], [30] for distributedcoexistence.

III. INTRODUCTION TO IEEE 802.22

The IEEE 802.22 standard defines a system for a Wireless Regional Area Network, WRAN that uses unused or white spaces within the television bands between 54 and 862 MHz, especially within rural areas where usage may be lower. To achieve its aims, the 802.22 standard utilizes cognitive radio technology to ensure that no undue interference is caused to television services using the television bands. In this way 802.22 is the first standard to fully incorporate the concept of cognitive radio. The IEEE 802.22 WRAN standard is aimed at supporting license-exempt devices on a non-interfering basis in spectrum that is allocated to the TV Broadcast Service. With operating data rates comparable to those offered by many DSL / ADSL services it can provide broadband connectivity using spectrum that is nominally allocated to other services without causing any undue interference. In this way IEEE 802.22 makes effective use of the available spectrum without the need for new allocations.

3.1. Background of IEEE 802.22

The IEEE 802.22 standard for a Wireless Regional Area Network or WRAN system has been borne out of a number of requirements, and also as a result of a development in many areas of technology. In recent years there has been a significant proliferation in the number of wireless applications that have been deployed, and along with the more traditional services this has placed a significant amount of pressure on sharing the available spectrum. Coupled to this there is always a delay in re-allocating any spectrum that may come available.

In addition to this the occupancy levels of much of the spectrum that has already been allocated is relatively low. For example in the USA, not all the TV channels are used as it is necessary to allow guard bands between active high power transmitters to prevent mutual interference. Also not all stations are active all of the time. Therefore by organizing other services around these constraints it is possible to gain greater spectrum utilization without causing interference to other users. Despite the fact that the impetus for 802.22 is coming from the USA, the aim for the standard is that it can be used within any regulatory régime. One particular technology that is key to the deployment of new services that may bring better spectrum utilization is that of cognitive radios technology. By using this radios can sense their environment and adapt accordingly. The use of cognitive radio technology is therefore key to the new IEEE 802.22 WRAN standard.

3.2. IEEE 802.22 Concepts

There are a number of elements that were set down for the basis of the 802.22 standard. These include items such as the system topology, system capacity and the projected coverage for the system. By setting these basic system parameters in place, the other areas fall into place.

- *System topology:* The system is intended to be a point to multipoint system, i.e. it has a base station with a number of users or Customer Premises Equipments, CPEs located within a cell. The base station obviously links back to the main network and transmits the data on the downlink to the various users and receiver's data from the CPEs in the uplink. It also controls the medium access and addition to these traditional roles for a base station; it also manages the "cognitive radio" aspects of the system. It uses the CPEs to perform a distributed measurement of the signal levels of possible television (or other) signals on the various channels at their individual locations. These measurements are collected and collated and the base station decides whether any actions are to be taken. In this way the IEEE 802.22 standard is one of the first cognitive radio networks that has been defined.

- ***Coverage area:*** The coverage area for the IEEE 802.22 standard is much greater than many other IEEE 802 standards - 802.11, for example is limited to less than 50 meters in practice. However for 802.22, the specified range for a CPE is 33 km and in some instances base station coverage may extend to 100 km. To achieve the 33 km range, the power level of the CPE is 4 Watts EIRP (effective radiated power relative to an isotropic source).
- ***System capacity:*** The system has been defined to enable users to achieve a level of performance similar to that of DSL services available. This equates to a downlink or download speed of around 1.5 Mbps at the cell periphery and an uplink or upstream speed of 384 kbps. These figures assume 12 simultaneous users. To attain this overall system capacity must be 18 Mpps in the downlink direction.

3.3. IEEE 802.22 Specifications

The basic specification parameters of the IEEE 802.22 standard can be seen in the table below:

Table 3.1: Specifications of IEEE 802.22 standard [3]

PARAMETER	SPECIFICATION
Typical cell radius(km)	30-100 KM
Methodology	Spectrum sensing to identify free channels
Channel bandwidth (MHz)	6,7,8
Modulation	OFDM
Channel capacity	18 Mbps
User capacity	Downlink:1.5 Mbps Uplink :384 kbps

3.4. IEEE 802.22 PHY Layer

The PHY layer must be able to adapt to different conditions and also needs to be flexible for jumping from channel to channel without errors in transmission or losing clients (CPEs). This flexibility is also required for being able to dynamically adjust the bandwidth, modulation and coding schemes. It use OFDMas the modulation scheme for transmission in up and downlinks. With OFDMA it will be possible to achieve this fast adaptation needed for the BS's and CPEs. By using just one TV channel the approximate maximum bit rate is 19 Mbit/s at a 30 km distance. The speed and distance achieved is not enough to fulfill the requirements of the standard. The feature *Channel Bonding* deals with this problem. Channel Bonding consists in using more than one channel for Tx / Rx. This allows the system to have higher bandwidth which will be reflected in a better system performance.

3.5. IEEE 802.22 MAC layer

This layer is based on cognitive radio technology. It also needs to be able to adapt dynamically to changes in the environment by sensing the spectrum. The MAC layer consists of two structures: Frame and Superframe. A superframe formed by many frames. The superframe will have a superframe control header (SCH) and a preamble. These will be sent by the BS in every channel that it's possible to transmit and not cause interference. When a CPE is turned on, it will sense the spectrum, find out which channels are available and will receive all the needed information to attach to the BS. Two different types of spectrum measurement will be done by the CPE: *in-band* and *out-of-band*. The in-band measurement consists in sensing the actual channel that is being used by the BS and CPE. The out-of-band measurement will consist in sensing the rest of the channels. The MAC layer will perform two different types of sensing in either in-band or out-of-band measurements: *fast sensing* and *fine sensing*. Fast sensing will consist in sensing at speeds of fewer than 1ms per channel. This sensing is performed by the CPE and the BS and the BS's will gather all the information and will decide if there is something new to be done. The fine sensing takes more time and it is used based on the outcome of the previous fast sensing mechanism.

IV. METHODOLOGY INVESTIGATED

In this section we are presenting the architecture and algorithm of proposed power efficient dynamic spectrum allocation method. Below figure 4.1 showing the basic architecture of proposed algorithm as per given in [1].

From figure below, end users gets allocated with network resources and the evolved NodeBs (eNBs) by the spectrummanager (SM) using some optimalresource allocation strategy. Basically this method proposed to allocate the bandwidth and transmissionpower to the uplink and downlink of LTE system with goal of total transmission power isminimized subject to capacity constraints, queue stability constraints, and some integerrestrictions on the bandwidth. To find the buffer occupancy in the system, use modifiedShannon expression which depends on signal-to-noise ratio (SNR) and modulation and codingscheme (MCS).

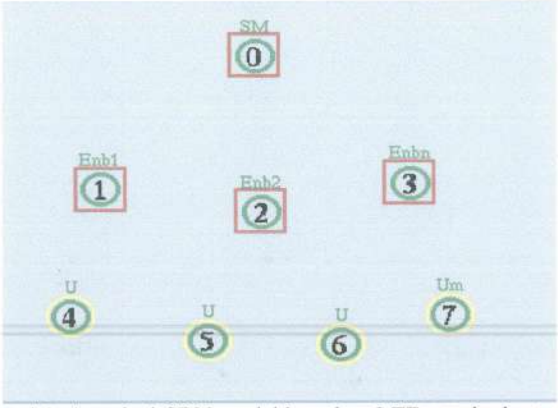

Figure 4.1: A typical CRN model based on LTE standard network.

Based on above architecture below is algorithm for LTE-based networkarchitecture. The objective of the algorithm is to assign thespectrum and transmission power to the uplink and downlinkchannel between the users and the eNBs to minimizethe total transmission power. Thecorresponding algorithm can be described as follows.

Attime t:

– each users/eNB collects the values QUj(t)/QeNBi(t), AUj(t)/AeNBi(t) and sends them to SM;

– SM finds the optimal (or near-optimal) resource allocationvectors $b_j^{UL}, P_j^{UL}, P_i^{DL}, b_i^{DL}$ and sends this informationto corresponding eNBs;

– the eNBs assign the resources to the uplink and downlinkchannels of the users.

The maximal threshold buffer size is assumed to beequal to the average arrival rate of the respective eNB/user,and is calculated using constantly updated values from

$$Q_{eNBi}^{max} = A_{eNBi}(t) = \sum_{t=0}^{t} A_{eNBi}(\tau) \ , \ \forall i \in I \ (1)$$

$$Q_{Uj}^{max} = A_{Uj}(t) = \sum_{t=0}^{t} A_{Uj}(\tau) \ , \ \forall j \in J \qquad (2)$$

BelowAlgorithm Name: Branch &Bound (B & B) Algorithm for QBC-1 and QBC-21 spectrum allocation methods:

Input Set

RPk = relaxed sub-problem at node **k**

(bk, pk)= solution of RPk

yk= value of the objective function at **(bk, pk)** which corresponds to the lower bound of node k

(bMIP, pMIP) = best obtained MIP solution of the primary **MIP** problem;

yMIP= best obtained value at **(bMIP, pMIP)** which corresponds to the upper bound of the primary MIP problem.

The node k has no branches in the following cases:

RPk=has no feasible solutions

bk = is integer;

bk= non-integer and worse than the best obtained integer solution **(bMIP, pMIP)(yk>yMIP** for minimization problem).

Main Algorithm Steps:

Step 1:

Initialize yMIP to last (infinity)
set MIP' equal to MIP
Initialize L

Step 2:

```
If (all node is present == theta)
 {
 go to step 3
} else
{
go to step 4
}
```

Step 3:

```
yMIP* is optimal value
 if (check yMIP* < infinity/infinity+)
{
Optimal_Solution =[ bMIP* ,  pMIP*]
}
```


Step 4:
Select node k and set L = L / {K}
Step 5:
Solve RP to get bMIP and pMIP
Step 6:
If (RPk == true)
{
go to step 7
} else
{
go to step 7
}
Step 7:
if (yk > yMIP)
{
go to step 8
} else
{
go to step 9
}
Step 8:
Confirm k is fathom node, go to step 2
Step 9:
if (isint (bk))
{
go to step 10
} else
{
go to step 12
}
Step 10:
set yMIP* = yk
set (bMIP,pMIP) = (bK,pK)
Step 11:
for each s node in L set :
if (yk > yMIP*)
{
set L = L of S set
}
Step 12:
Select branch node bk and pk
create two new nodes k1,k2
set yk1=yk and yk2=yk
RPk1=RPk+constraint bi , where biis <= integer bk of Numbers ;
RPk2=RPk+constraint bi , where biis => integer (bk of Numbers)+1
set L to union of L with k1 and k2 set
go to step 2
End

V. SIMULATION RESULTS AND ANALYSIS

5.1 Simulation Platform: For the simulation of this work we have to need the following setups requirement for the same
1) Cygwin: for the windows XP
2) Ns-allinone-2.31.

5.2 Network Scenarios: For CRNs, different network scenarios with varying mobile end users required to be prepared.PCSA (PowerControl and Spectrum Access) for the scheme considered as existing method: QBC (Queue Based Control) for the scheme investigated in this paper.

MACProtocol: IEEE802.22 Standards
Scenarios-1:50/100/150/200/250/300 Number of users
Routing Protocols: AODV
Spectrum Allocation Methods: PCSA/QBC1/QBC2

5.3 Performance Metrics:

- Transmission Power (dbm) vs. number of user
- Loss (%) vs. number of users
- Delay (ms) vs. number of users

Table 5.1 shows the simulation parameters used in this practical analysis for the proposed work.

Table 5.1 Network Configuration for Simulation

Number of Nodes(users)	50/100/150/200/250/300
Traffic Patterns	CBR (Constant Bit Rate)
Network Size (X x Y)	1000 x 1000
Max Speed	5 m/s
Simulation Time	100s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV
MAC Protocol	802.11
Spectrum Sensing	PCSA/QBC1/QBC2
Number of Flows	5
PDCCH symbols per subframe	3
UL loading facto	1
DL loading factor	1
Inactive bearer timeout	20s
Periodic timer	5 sub fames
Retransmission timer	2560 subframes
Reserved size	2 RBs
Starting RBP for Format 1 messages	0
Allocation periodicity	5 sub frames
Operation mode	FDD
Cyclic prefix type	Normal (7 Symbols per Slot)
EPC bearer definitions	348 kbit/s (Non-GBR)
Subcarrier spacing	15 kHz
Transmitter/receiver antenna gain	10 dBi (pedestrian), 2 dBi (indoor)
Receiver antenna gain	10 dBi (pedestrian), 2 dBi (indoor)
Receiver noise figure	5 dB
Number of preambles	64
Number of RA resources per frame	4

5.4 Simulation Results

Figure 5.1 shows transmission power performance for information network configuration. It gives comparative performance for PCSA, QBC1 and QBC2. It shows transmission power consumption as a function of number of users. The required transmission power increases as the number of users increase.QBC2 method achieves better energy efficiency as compared to QBC1 and existing PCSA method.

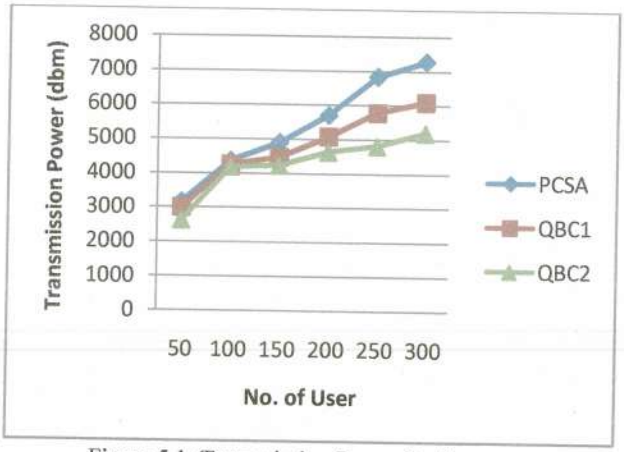

Figure 5.1: Transmission Power Performance

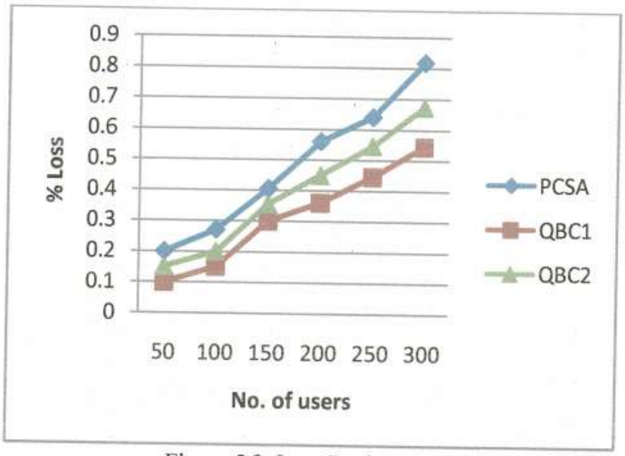

Figure 5.2: Loss Performance

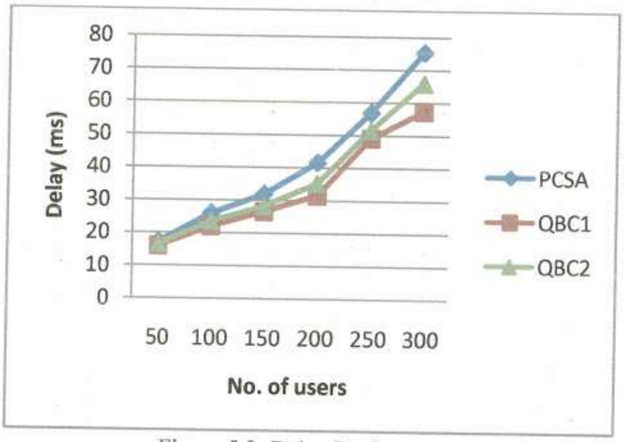

Figure 5.3: Delay Performance

Figure 5.2 depicts percentage packet loss as a function of no of users. Packet loss increases as the number of users increase.

From the figure 5.2 and 5.3, it is clear that QBC1 outperforms existing PCSA method and QBC2. The contradiction between QBC1 and QBC2 is that, QBC2 gives better energy efficiency while QBC1 giving better packet loss and delay performance.

VI. CONCLUSION AND FUTURE WORK

In this paper basic architecture of IEEE 802.22 standard for LTE network is presented. The Proposed work has investigated power efficient bandwidth allocation method for LTE cognitive radio networks based on 802.22 frameworks.

Presented work is simulated using NS2.Results shows that QBC1 gives better performance for packet loss and delay as compared with PCSA and QBC2 methods whereas QBC2 performance better for transmission power. Improving the transmission power utilizationefficiency for QBC1 is the future work.

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HYBRID EFFICIENT BANDWIDTH ALLOCATION TECHNIQUE FOR COGNITIVE LTE NETWORKS

Mr. Hussein Tuama Hazim*, Mrs. S.A.Shirsat
*Department of Electronics & Telecommunication Engineering, Sinhgad College of Engineering, Pune, India
Department of Electronics & Telecommunication Engineering, Sinhgad College of Engineering, Pune, India

ABSTRACT

Now days, use of IEEE 802.22 based LTE network is growing worldwide due to its high speech capability. IEEE 802.22 is nothing but cognitive radio networks which are suffering from problems like efficient bandwidth and spectrum allocation, delay and loss ratio etc. In addition to this there is another research problem in this domain called power efficiency. Many methods already presented in literature, however most of methods failed to achieve the tradeoff between, transmission power, transmission rate, and bandwidth. In this paper we are extending two kinds of techniques presented such as QBC1 and QBC2 which are variants of main QBC (Queue Based Control) algorithm presented. QBC1 and QBC2 mean for different conditions of LTE network. Performance of QBC1 and QBC2 showing that QBC1 is having better Delay and Los performance as compared to QBC2, and QBC2 is having better power consumption performance as compared to QBC1. Therefore we are presenting hybrid technique which is known as HQBC (Hybrid QBC), which is main goal of improving performance in terms of los, delay, and power consumption as compared to QBC1 and QBC2. This can be achieved by using concept of multilevel queues and dynamic network adaptation.

KEYWORDS: IEEE 802.22, LTE, Cognitive Radio, QBC, HQBC, Multilevel Queue.

INTRODUCTION

To address problem of limited bandwidth or inefficient bandwidth allocation methods, in 2004 a special IEEE working group was set up to develop a new 802.22 cognitive radio (CR) standard. It has been proposed that the wireless access be provided by a Wireless Regional Area Network (WRAN) comprising a number of SPs with their base stations. Within the network, the SPs share the total available bandwidth among each other according to some predefined flexible spectrum usage policy using a spectrum manager (SM) [1]. The standard describes the overall network topology, and on physical (PHY) and medium access control (MAC) layers. However, the exact algorithm for spectrum allocation is not specified [2]. In addition, to realize the great opportunity offered by the CR architecture, it is very important to develop an applicable DSA policy which will help to increase the overall spectrum efficiency and improve the quality of service (QoS) for the individual network users. Efficient spectrum allocation method development is tough process given the known difficulty of modelling and measuring the wireless medium [4]. Although some significant progress has been made in diverse cognitive techniques during the last few years, many challenges still remain [3]. For example, most research has been focused on techniques for identifying and reducing the interference (by controlling transmit power, carrier sense, or scheduling) for the users of CR network (CRN), see e.g., [5], [6], [7]. In general, however, the system performance depends on many external factors, including user behaviour, traffic load, channel quality, etc [3]. Some theoretical models of the user behaviour and traffic load in CRNs have been proposed in [8], [9], [10], [11], but the assumptions in these models are often quite restrictive under realistic operating conditions. This is mainly due to the fact that a system may operate in diverse environments (e.g., in different types of city, rural, campus, and indoor deployments) [3]. Hence, it is very difficult to obtain some general theoretical model which can be applied for different network deployment scenarios.

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Along with spectrum allocation efficiency in IEEE 802.22 wireless networks; there is another performance metrics which is related to energy efficient dynamic spectrum access (DSA) in a cognitive Third Generation Partnership Project (3GPP) long-term evolution (LTE) network based on IEEE802.22 architecture. According to the IEEE802.22 standard, wireless access is offered by a wireless regional area network (WRAN) consisting of a number of service providers (SPs). which share the total available spectrum using a spectrum manager (SM). The SM uses some flexible dynamic spectrum access (DSA) policy to maximize the capacity and quality of service (QoS) for their users [12]. Motivated by this concept of CR network (CRN), many papers have developed various forms of spectrum access strategies to assign the available network resources (bandwidth, transmission rate and transmission power). Most papers assume non-strategic non-greedy users following some general resource allocation policy. The recent methods do not have efficient tradeoff between transmission power, bandwidth and transmission rate. This becomes research problem in this domain.

In this paper we are presenting new hybrid method for spectrum allocation in IEEE 802.22 based LTE networks. This new method is called as HQBC, as it is based on existing QBC method. Main idea behind HQBC is use of multiple queues to handle different kinds of data efficiently and dynamically. In next section II we are presenting the literature survey over the various methods those are introduced for the energy efficient spectrum allocation. In section III, the proposed approach and its system block diagram is depicted. In section IV we are presenting simulation results and discussion. Finally conclusion and future work is predicted in section V.

REVIEW OF LITERATURE

In literature different methods introduced to investigate the problem of energy efficient dynamic spectrum access (DSA) in a cognitive Third Generation Partnership Project (3GPP) long-term evolution (LTE) network based on IEEE802.22 architecture. Motivated by this concept of CR network (CRN), many papers have developed various forms of spectrum access strategies to assign the available network resources (bandwidth, transmission rate and transmission power). Most papers assume non-strategic non-greedy users following some general resource allocation policy.

- In [13], author presented performance metric based channel allocation scheme for IEEE802.22 networks in which the base station allocates interference free channels using a spectrum map. In this scheme the spectrum map is created by using the raw spectrum usage data that are shared by a small subset of consumer premise equipments. The usage data are fused at the base station using a modified version of Shepard's interpolation technique. The authors construct a continuous and differentiable spatial distribution of spectrum usage that the base station consults to estimate the spectrum occupancy vector at any arbitrary location in its cell. Such spectrum usage is then utilized to proactively evaluate some key network and radio performance metrics which in turn help allocating the best candidate channel to a given consumer premise equipment ensuring highest achievable performance.
- In [14] the authors consider adaptive modulation and power control for multi-access wireless sensor networks which mainly reduces power consumption to achieve energy efficiency. Cluster head node of each link adaptively adjusts its power control level and modulation type according to the signal to noise ratio (SNR) and target bit error rate (BER). The efficiency of this approach is further illustrated via numerical comparison with the original scheme. Simulation results demonstrate that the proposed scheme, which alleviates to save much transmission power and maintains the target bit error rate, can significantly improve the system performance.
- In [15], the opportunistic spectrum access (OSA) in LTE Advanced (LTE-A) networks has been investigated. It has been shown that implementation of the OSA in LTE-A enhances the overall system performance by intelligently aggregating otherwise unutilized spectrum. However, the set-up parameters of the system (such as sensing periods and amount of signaling) should be carefully chosen to increase the feasibility of the implementation in a real network.
- In [16], authors studied the trade-off between transmission delay and transmission power in wireless networks where a delay-power control (DPC) scheme to balance delay against transmission power in each wireless link has been formulated. It has been shown that DPC converges to a unique equilibrium power with several key properties related to the nature of bandwidth sharing achieved by the links.
- In [17], authors presented distributed resource allocation based on queue balancing in multi-hop CRNs has been investigated. Here the problem of resource (power, channel and data rate) allocation is formulated as a multi-commodity flow problem assuming dynamic link capacity to model dynamically changing spectrum

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availability in the network. Based on the optimization results, a distributed algorithm is proposed for joint flow control and resource allocation in the nodes of CRN. Simulation results show the performance improvement by the proposed scheme.

- In [18], Joint power control and spectrum access in CRNs has been investigated. In this paper, the power allocation and DSA aim to improve the throughput and guarantee the fairness for secondary (unlicensed) network users, without imposing overlarge interference to the primary (licensed) network users. Numerical results reflect that, compared with previous studies, this scheme presents advantages in comprehensive performance (e.g., spectrum efficiency, fairness and throughput). Beyond a theoretical framework, the authors solve the optimization problem with the Differential Evolution (DE) algorithm which is more feasible to be implemented in practice.

PROPOSED METHODOLOGY

With defined aim of this paper which is to present hybrid technique for spectrum allocation with goal of achieving the efficient tradeoff between transmission rate, bandwidth, and transmission power in IEEE 802.22 based LTE networks. Figure 3.1 is showing proposed system architecture and practical analysis flow. HQBC is proposed method is compared against recently presented QBC1, QBC2 and PCSA spectrum allocation techniques.

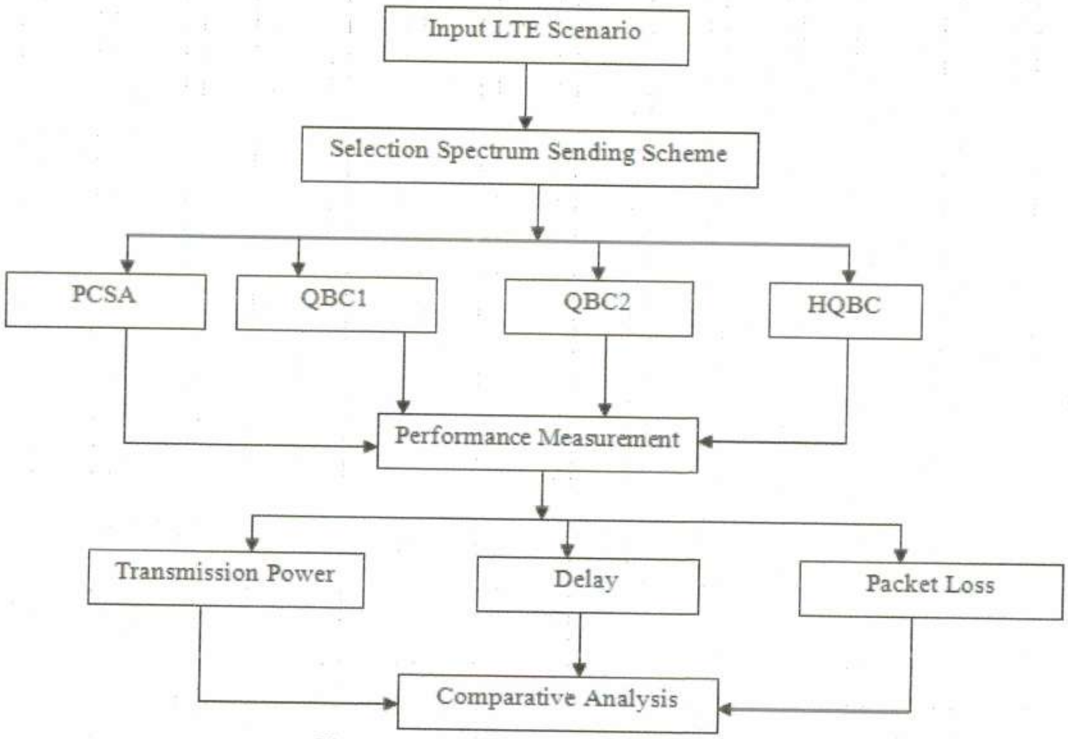

Figure 3.1: Proposed System Architecture

Limitations of Existing Methodology

There are two variants of previously presented power efficient method for spectrum sensing such as QBC1 and QBC2, from the practical analysis we come to below conclusion and limitations:

- QBC1 is having better performance in terms of loss and delay as compared to QBC2.
- QBC2 is having better performance in terms of transmission power as compared to QBC1.
- Therefore there is no tradeoff between loss, delay and transmission power performance in either QBC1 or QBC2.
- QBC1 is efficient in delay and loss whereas worst in transmission power.
- QBC2 is efficient in transmission power whereas worst in delay and loss.
-

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Proposed Algorithm
To overcome above listed limitations of QBC1 and QBC2, in this paper we are presenting hybrid technique which is based on QBC1 and QBC2. In short, proposed technique is combined extension of both QBC1 and QBC2. The proposed spectrum sensing scheme is called as HQCB. This method is includes the concepts of multilevel priority queues, in which different kinds of network data is divided into multiple queues, and hence efficiency of spectrum allocation improves, which in terms improves the QoS performance and transmission power performance. Below is algorithm which is combined with QBC algorithm for further improvement. Figure 3.2 is showing the flowchart of proposed multilevel queue algorithm:

Algorithm: Dynamic Bandwidth Allocation Algorithm
- Initially set high and low thresholds as T2 and T1
- At each node
  1. Receive Packet.
  2. Classify packet according to priority.
  3. Check intermediate buffer occupancy for number of packets initially occupied.
  4. Calculate transmission of number of packets to intermediate buffer according to threshold value.
  5. Push packets into intermediate buffer.
  6. Repeat steps 3-5 for all priority buffers.

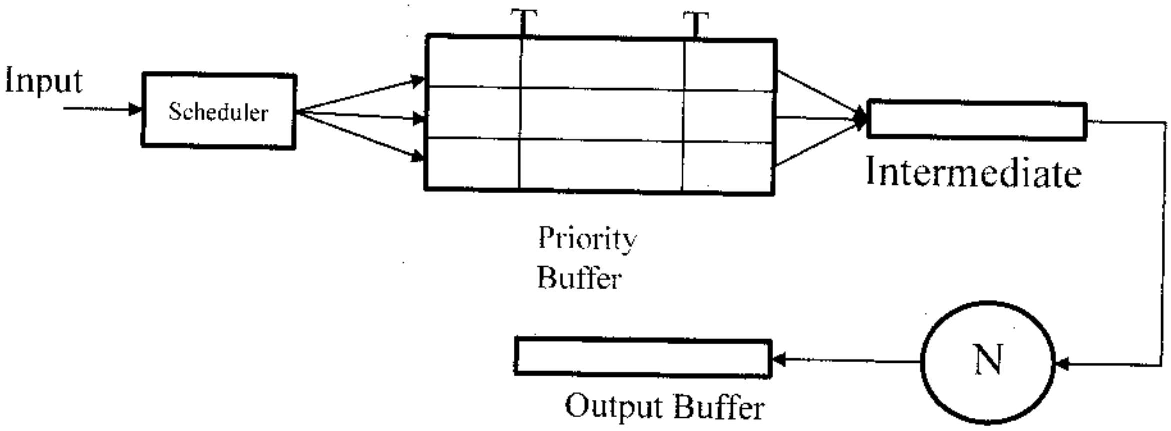

Figure 3.2: The architecture for a single network user.

RESULTS AND DISCUSSION

Network Simulators
"According to dictionary, Simulation can be defined as ―reproduction of essential features of something as an aid to study or training." In simple words, the process where we can construct the one model of mathematic is called as simulation in order to solve the system problem. Such process frequently uses to reproduce the characteristics of the complex work. In order to simulate the network like mobile ad hoc networks called MANET, number simulators are available such as OPNET, Qualnet, and NS2 etc. For our simulation, we are using NS2 as:
- NS2 provides the network simulation environment for both wired, wireless means MANET networks.
- It is open source.
- Provides the modules for the wireless channel such as 802.11, 802.16, 802.21, 802.22 etc.
- Provides the number of routing protocols for choice in which the routing is done along multiple paths.
- Simulations of the cellular networks possible as the mobile hosts are simulated as well.

Network Scenario and Configurations

Number of Nodes	50/100/150/200/250/300
Traffic Patterns	CBR (Constant Bit Rate)

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Network Size (X x Y)	1000 x 1000
Max Speed	5 m/s
Simulation Time	100s
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV
MAC Protocol	802.22
Spectrum Sensing	PCSA/QBC1/QBC2/HQBC
Number of Flows	5
PDCCH symbols per subframe	3
UL / DL loading factor	1
Inactive bearer timeout	20s
Periodic timer	5 sub fames
Retransmission timer	2560 subframes
Reserved size	2 RBs
Allocation periodicity	5 sub frames
Operation mode	FDD
Cyclic prefix type	Normal (7 Symbols per Slot)
EPC bearer definitions	348 kbit/s (Non-GBR)
Subcarrier spacing	15 kHz
Transmitter/receiver antenna gain	10 dBi (pedestrian), 2 dBi (indoor)
Receiver antenna gain	10 dBi (pedestrian), 2 dBi (indoor)
Receiver noise figure	5 dB
Number of preambles	64
Number of RA resources per frame	4

RESULT ANALYSIS

In this research methodology, we simulated the three different spectrum sensing methods for IEEE 802.22 of LTE networks such as PCSA, QBC and proposed HQCB. The aim of this project was to propose HQBC with goal of improving performance against QBC method. In this section we will summarize the results achieved through different LTE network scenarios and compare performances against investigated existing methods. Below is figure 4.1 of showing NAM representation in NS2. From NAM visualization, we cannot measure or predict any performance parameter.

The performance difference between methods is evaluated using the trace file of each scenario and AWK script to measure each performance metrics. Below section presents the graphical comparative analysis of both routing protocols.

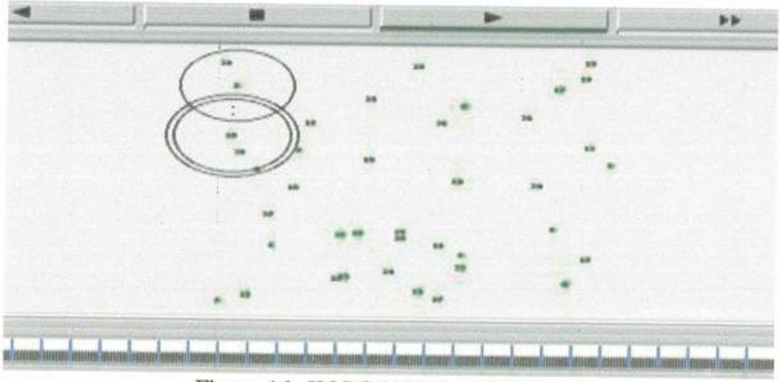
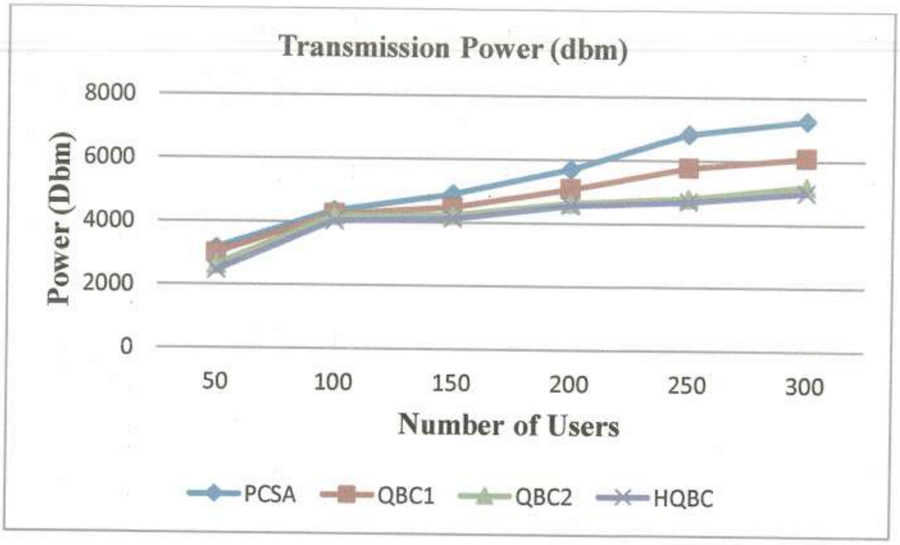


Figure 4.1: HQBC 50 Nodes NAM Result

Transmission Power Analysis

Transmission power is nothing but the amount of energy consumed during the data transmission over IEEE 802.22 LTE network. Below figure 4.2 is showing the current performance of different spectrum sensing methods with varying number of end users in LTE network.



From above result of transmission power for methods like PCSA, QBC1, QBC2 and HQBC, performance of HQBC is better than all other existing methods, HQBC outperforming QBC2 which is most recent energy efficient technique. For each kind of network, HQCB is delivering energy efficient spectrum allocation for data transmission and communication.

Packet Loss Analysis

The aim of proposing HQBC technique is to achieve the fairness and tradeoff between transmission power, packet loss, and delay parameters. By considering this, below two graphs in figure 4.3 and 4.4 are showing performances of Packet loss results and delay results.

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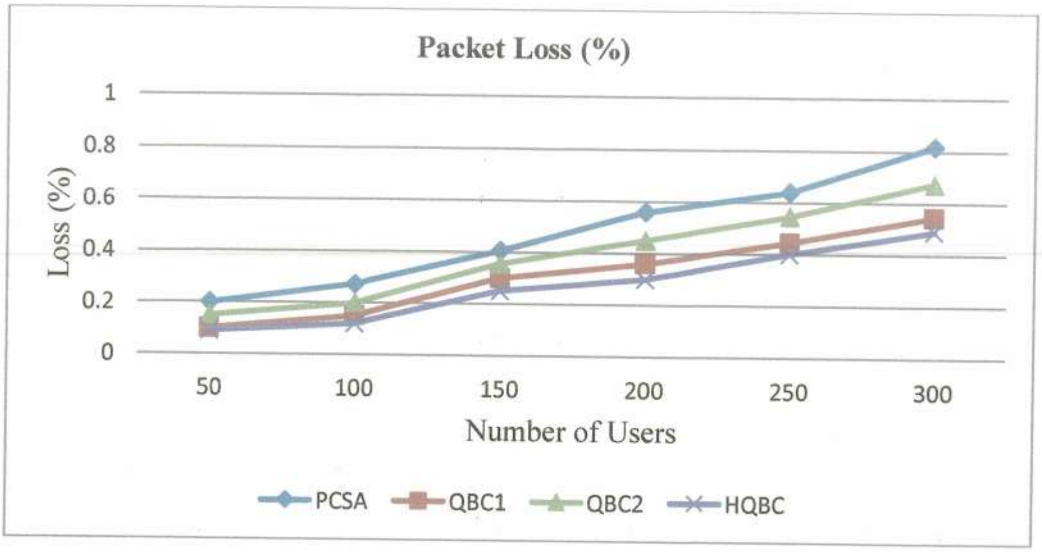

Figure 4.3: Loss performance analysis

From above result, it is clear that performance of HQBC is improved as compared to all other existing spectrum sensing algorithms. This is one, which cannot be achieved by any of previous methods. Along with loss, delay is another important parameter spectrum sensing technique. If we achieving good performance for loss, it means that delay is better too. Below figure 6.4 is showing delay performance, in which HQBC outperforming existing methods. As per the goals of this project, practically we claim the efficiency of proposed method.

Delay Analysis

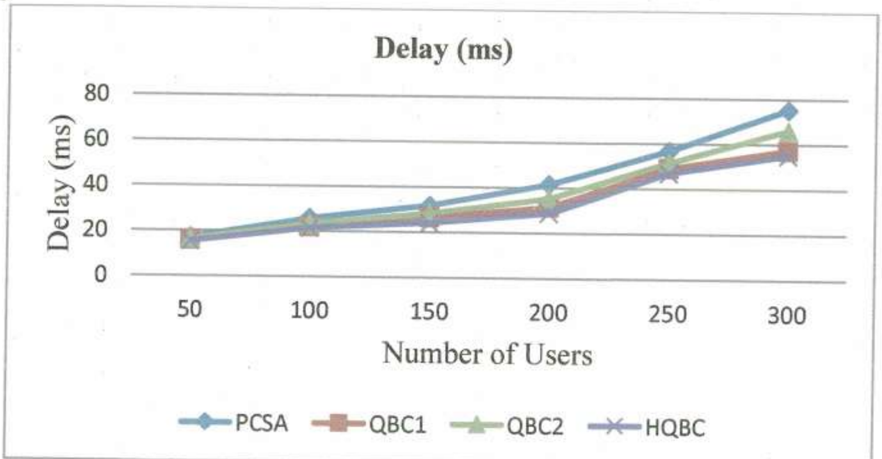

Figure 4.4: Delay performance analysis

CONCLUSION AND FUTURE WORK

The Objective of this project is to investigate the performance of recently presented efficient spectrum sensing allocation method for LTE cognitive radio networks based on 802.22 frameworks, then discussing the limitations of investigated methods, and then proposed new hybrid technique to overcome said limitations. We have presented basic architecture of IEEE 802.22 standard, after that presented algorithm and architecture of proposed bandwidth allocation method. The investigated algorithm is named as QBC. To overcome the limitations of QBC, we have presented HQBC based on concepts of multiple priority queues for both real time and non-real time data transmission. The aim of this method is to achieve the efficient tradeoff analysis between performance of transmission power, delay, and loss. The proposed work is totally based on cognitive radio networks with use of IEEE 802.22 LTE networks. Practical simulation of investigated method and proposed method is done using NS2. Performance results outperforming existing methods for loss, delay and transmission power. For future work. we will suggest to deploy this method in real time environment and check its tested results.

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