# A Review and Evaluation of Queue Based Control Power Efficient Spectrum Allocation Method for LTE Networks

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***Abstract—****The cognitive radio based wireless regional area networks (WRAN) is nothing but IEEE-802.22 standard. IEEE 802.22 standard enables opportunistic access to in-use or free 900 MHz TV sub bands by secondary networks. There are many other standards presented; however there is no efficient methods for cognitive networks like LTE for channel access and bandwidth utilization. The existing methods for spectrum access in LTE networks, however most of methods are not flexible, power consuming. Also in literature, we studied that existing methods of spectrum allocation in LTE networks does not efficiently achieve the tradeoff between network QoS (Quality of Service) and power efficiency. The goal of this paper is to present the review on such different spectrum efficiency techniques for LTE networks and then evaluate the recent Queue Based Control (QBC) for power efficient spectrum allocation with its limitations and benefits. QBC approach helps in solving the research problem related to the energy efficiency as well as QoS efficiency to some extent. There are two variants of QBC method such as QBC1 and QBC2 with different objectives and configurations. We are evaluating both this approach on LTE network which is composed of Spectrum Manager (SM), evolved Nodes B (eNBs) and number of user's. The experimental work is conducted using network simulator (NS2) for delay and energy consumption parameters.*

***Keywords—Cognitive Radio, LTE, IEEE-802.22, QBC, Energy consumption, Delay, Loss.***

## I. INTRODUCTION

The different applications like government, public and private security systems, military, commercial places etc. are based on wireless networks in which the spectrum allocation is done statically for the various radio services. This type of static spectrum allocations may have few benefits with respect to management and oversight; however based on various practical studies it is observed that spectrum allocation is space as well as time variant.

Therefore the traditional techniques that are based on static spectrum allocation are resulted into inefficient utilization of spectrum. Such method performs as under-utilization in some bands and over-utilization in some bands. The change in old techniques also leads to problems for such static spectrum allocation methods. The bands like VHD and UHF are reserved for the TV broadcast in US, therefore in such cases allocation of 6 MHz band for each channel of TV was dependent on traditional analog NTSC framework regardless of the fact that enhanced video quality broadcasting by using less than 50 % spectrums for each TV channel just [1] [2]. Given the cable TV with prevalent penetration, such large available spectrum which is allocated for each channel is remains unallocated and unused for many locations. The various research studies on spectrum allocation leads to reforms of access policy and spectrum usage [3]. Dynamic spectrum access (DSA) for cognitive radio network is preferred candidate for spectrum allocation at present [4].

IEEE 802.22 proposition is considered as appropriate solution for the present spectrum allocation problems. The standard IEEE 802.22 is nothing but the standard of WRANs (wireless regional area networks) for cognitive radio networks which enables the use of licensed and unused sub 900 MHz television bands by the users those are unlicensed on basis of non-interfering [5]. In order to protect the licensed services such as primary incumbents, it is required that devices of IEEE 802.22 standard should perform the sensing of spectrum periodically as well as promptly evacuate based on licensed users returns commonly referred as spectrum etiquettes.

For LTE-Advanced communication networks, IEEE 802.22 standard is adopted for performance improvement. In IEEE 802.22 standard, the main characteristic for LTE networks is that protection approach for primary users is widely studied and designed. However the important research problem of using IEEE 802.22 standard is achieving the QoS among the networks as self-coexistence (e.g. spectrum etiquettes among secondary-secondary users) is not solved. For wireless communication systems in which unlicensed resources sharing the spectrum with licensed incumbent's presence, hence the problem of self-coexistence between the multiple cognitive radio operators in overlapping area is very notable. The unused TV channels in the region with the digital or analog TV transmissions as well as wireless microphone systems are already useful for demand. In such cases, self-coexistence problem becomes more challenging as the cognitive radio networks cannot having knowledge about selection of bands will be done by other secondary CR users. As compared to other standards of IEEE 802 standards in which issues of self-coexistence is taken under consideration only after finalization of essential specification, for IEEE 80.22 standard, it needs to conduct the proactive methodology as well as mandate in order to include the methods of self-coexistence and protocols for improving the MAC (medium access control) as improvement to earlier standards presented [8]-[10].

For wireless networks like cognitive radio networks, the most studied problem is spectrum allocation. The goal is to use QoS efficient spectrum allocation approach for advance communication networks like LTE where demands of services are frequent and of high speed. There are number of techniques studied and presented so far for efficient spectrum allocation, however along with spectrum allocation, there is another challenge for cognitive radio networks is power. Therefore, further number of researchers worked on energy efficient spectrum allocation to aim at minimizing the energy consumption performance while achieving the highest QoS performance. Most of these methods failed to achieve the efficient tradeoff between QoS efficiency and power efficiency.

During this research article, we are first introducing the related methods of spectrum efficiency and power efficiency for cognitive radio networks and survey over the IEEE 802.22 standard on which advance LTE networks are based. In addition to this, as a base of our main research, we have investigated the Que Based Control (QBC) technique for achieving the tradeoff between energy efficiency and QoS efficiency performances through the efficient spectrum allocation. We presented algorithm design and flowchart for this technique with its two variants. As per our study the goal of QBC method is energy efficient spectrum allocation for LTE advance communication networks. The practical work and performance evaluation for this method is conducted using NS2 tool against existing PCMA method. In section II the related methods have been reported, section III presenting the detailed analysis of IEEE 802.22 standard. Section III presenting study over OBC method with its algorithm details. Section IV presenting the simulation results and comparative study with limitations.

## II. RELATED WORKS

Since the last decade, dynamic spectrum sensing as well as efficient allocation has become an interesting research challenge for group of researchers in advanced communication systems. There are number of methods already presented and still many researches are in progress with a goal of introducing the overall efficient spectrum allocation for networks like LTE. In this section we listed some of the recent methods.

In [2]-[5], authors of all these papers introduced the approaches for monitoring the primary spectrum allocation process using energy detection.

In [6], author introduced the signal detection using spectral correlation for the sensing of spectrum in IEEE 802.22 standard based WRAN systems.

In [7], author proposed the spectrum sensing method based on signature to investigate the presence of ATSC DTV signals.

In [8], author presented the study over the ATSC DTV signals sensing based on sequential pilot is conducted in order to sense the primary utilization in cognitive radio network based on IEEE 802.22 Standard.

In [9], author of this paper proposed novel technique for channel sensing known as DFH (dynamic frequency hopping). In this method, In DFH, neighboring cells of WRAN from the cooperating communities which coordinate the operations of DFH. In this case data transmission is executed parallel with respect to the spectrum sensing operation without any interruption. The goal of this approach is further to reduce the number of interrupts due to quiet sensing.

In [10], authors of this research article introduced the new metric called as GoS (Grade of Service). In addition to this, study over the tradeoff between the false alarm and miss detection is presented for the performance of spectrum sensing.

The methods which we discussed in above section are focused on primary spectrum usage sensing, however the main research problem for cognitive networks is self-coexistence between multiple cognitive radio networks. This research problem is not considered in [2]-[10] methods.

In [11]-[15], authors of these papers introduced the survey over allocation of resources in the cellular networks as well as WLAN based on technique of graph coloring. But these works did not work on dynamic allocation of spectrum bands because of primary user's presence and hence it cannot be applied direction to the IEEE 802.22 based networks for spectrum sharing.

In [16], author presents the study on investigation over the problem of channel assignment in multi radio wireless mesh systems based on graph coloring approach such a way that present flow rates set can be schedulable.

In [17], author introduced the novel approach for dynamic channel allocation solution based on graph coloring problem formulation in which availability of channels dynamically is observed by secondary users.

In [18], author introduced the study over the problems of spectrum scheduling and spectrum allocation problems in cognitive radio networks with goal of achieving the efficient sharing of spectrum. But the problem with this approach is that all channels equally treated.

In [19], author presented another spectrum sharing method which is real time, distributed called as ODSC (on demand spectrum contention) method which employs the interactive messaging of MAC between the 802.22 cells. But the through the excessive MAC messaging, control signaling is extensively increased.

## III. REVIEW OF IEEE 802.22

As the LET-Advance communication networks are based on standard IEEE 802.22, in this section we are presenting the details on 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. IEEE 802.22 Background

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. Terminologies of IEEE 802.22

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 Mpbs in the

downlink direction.

### 3.3. Characteristics of IEEE 802.22

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

*Table 1: Basic IEEE 802.22 Standard Specification Parameters*

| 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: 1.5Mbps<br>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. OFDMA will be 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 will be 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 will consist of two structures: Frame and Superframe. A superframe will be 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. ALGORITHM AND DESIGN

During this section we are presenting the algorithm and flowchart of QBC method for energy efficient spectrum sensing for LTE networks. Figure 1 is showing the main architecture of QBC method which is introduced recently in [1]. From figure below, end users gets allocated with network resources and the evolved NodeBs (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).

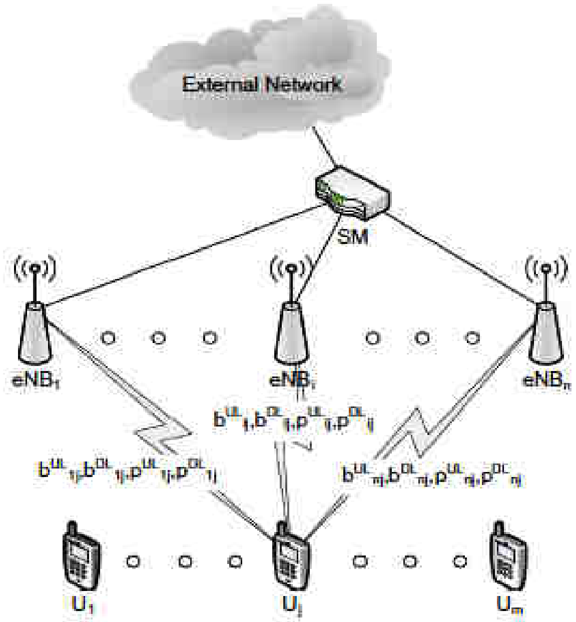


*Fig.1: LTE Standard Network based on IEEE 802.22 and Cognitive ratio network.*

Based on above architecture below is 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 $p_i^{UL}, b_i^{UL}$ and $p_i^{DL}, b_i^{DL}$ 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

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

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

Below figure 2 showing the flowchart of proposed algorithm:

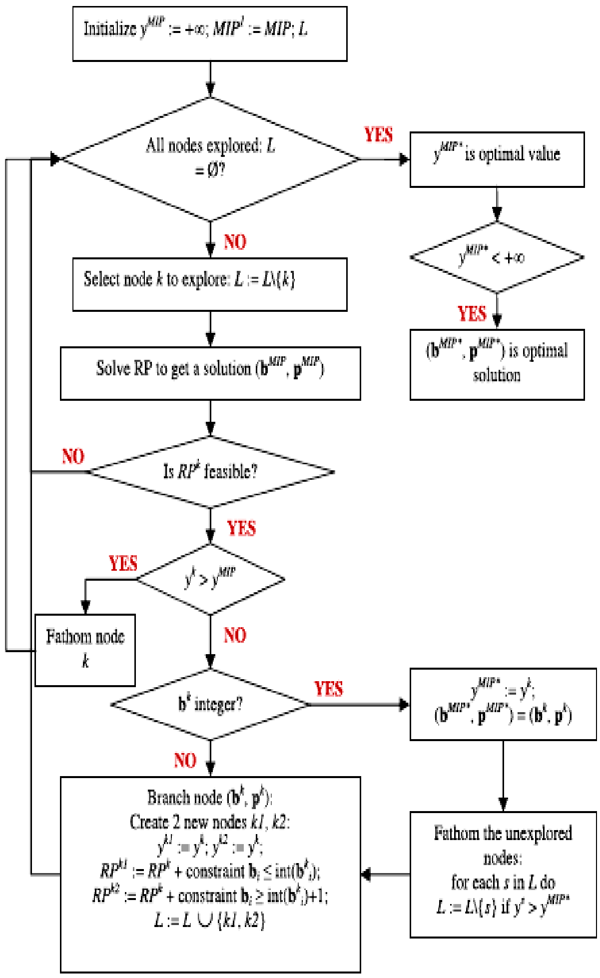


*Fig.2: Algorithm flowchart for QBC Method Details can be seeing below on the table 2 as showed the performance parameters used in this practical analysis.*

## V. PRACTICAL 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 (Power Control and Spectrum Access) for the scheme considered as existing method; QBC (Queue Based Control) for the scheme investigated in this paper.

**Mac protocol:** 802.22

**Scenarios-1:** 50/100/150/200/250/300 Number of users

**Routing Protocols:** AODV

**Spectrum Allocation**: PCSA/QBC1/QBC2

**5.3 Performance Metrics:**

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

*Table 2: Network Configuration for Scenario*

| | |
|---|---|
| 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 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 Results Analysis**

Using above network configuration parameters we have measured below results for PCSA, QBC1 and QBC2. Figure 3 showing the performance of transmission power consumed in all three methods with varying number of users. QBC2 method achieves better energy efficiency as compared to QBC1 and existing PCSA method.

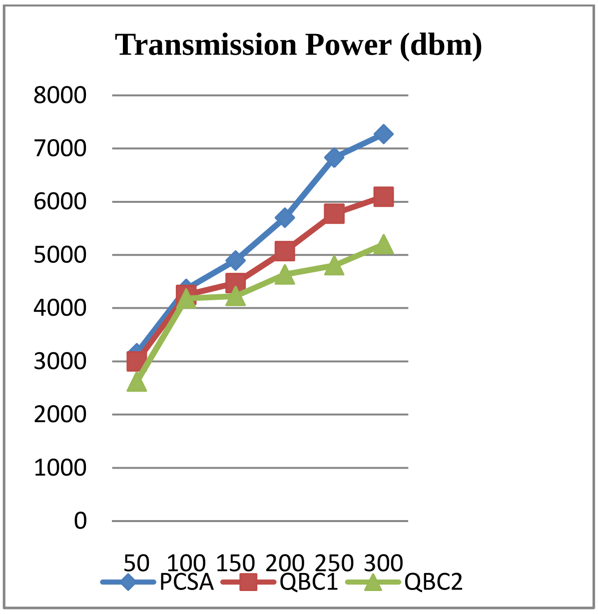


*Fig.3: Transmission Power Performance*

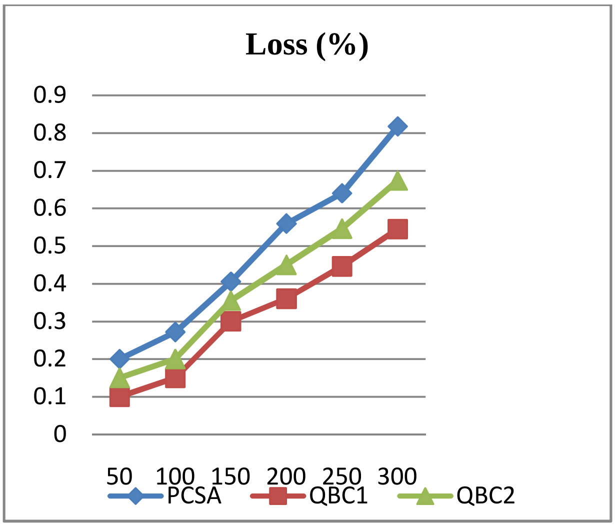


*Fig.4: Loss Performance*

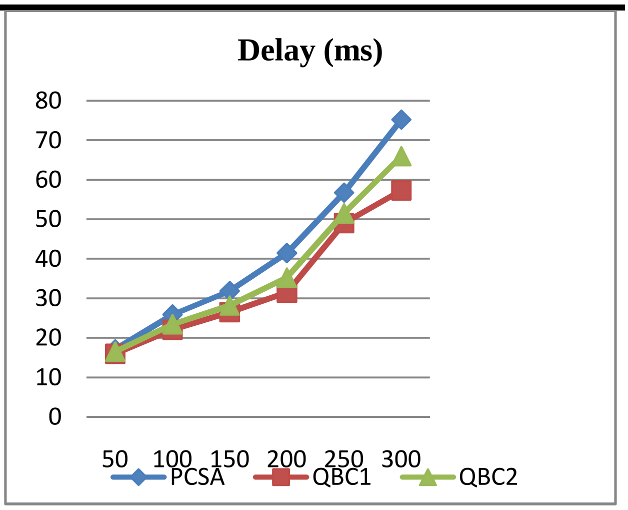


*Fig.5: Delay Performance*

From the figure 4 and 5, it is clear that QBC1 outperforming existing PCSA method and QBC2. The contradiction between QBC1 and QBC2 is that, QBC2 giving better energy efficiency while QBC1 giving better loss and delay efficiency.

## VI. CONCLUSION AND FUTURE WORK

The objective of this paper is to investigate the performance of recently presented efficient spectrum sensing allocation method for LTE cognitive radio networks based on 802.22 frameworks. We have presented basic architecture of IEEE 802.22 standard, after that presented algorithm and architecture of proposed bandwidth allocation method. Practical simulation of investigated method is done using NS2. Performance results outperforming existing method for loss, delay and transmission power. From this study we conclude that recent method QBC failed to achieve the complete tradeoff between energy efficiency and spectrum efficiency for LTE networks. For further work, we can improve performance of QBC1 method for transmission power utilization.

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