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Dynamic and Efficient Power Efficient Bandwidth Allocation Method for LTE Networks

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Abstract**—**Recently major research is proceeding 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. In LTE architecture, allocation of network resources is done with end-users as well as evolved NodeBs (eNBs) by the spectrum manager (SM) using some optimal resource allocation strategy. For power efficiency, recent method presented in which transmission power and bandwidth assigned to downlink and uplink of LTE network with goal of minimizing total transmission power subject to constraints of capacity, queue stability and some other integer over bandwidth. In this method two variants of technique called Queue Based Control (QBC) are presented. These two variants are QBC version 1 and QBC version 2. Performance of QBC version 1 and QBC version 2 showing that QBC version 1 is having better Delay and Los performance as compared to QBC version 2, and QBC version 2 is having better power consumption performance as compared to QBC version 1. It means both this techniques are based on concepts of carrier aggregation of LTE networks. Both approaches showing that, they failed to address the tradeoff between power efficient and QoS efficiency. Therefore, for this research work, we are contributing new Improved QBC method to achieve the tradeoff between power efficiency and QoS efficiency. The proposed method is based on methodology of multilevel queues and dynamic network adaptation.

Index Terms—*DSA, WRAN, LTE, IEEE 802.22, LTE, Cognitive Radio, Multilevel Queue*

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I. INTRODUCTION

For cognitive radio networks, it is important to address the problem of inefficient and limited resource allocation with power efficiency. For the same, in 2004 a special IEEE working group was set up to implement the new 802.22 cognitive radio (CR) standard. It has been proposed that the wireless access be provided by a (WRAN) collaborating a number of SPs with their base stations [1] [2]. Within the network, the SPs are sharing the total given bandwidth among to the each other according to some predefined flexible spectrum usage policy using a spectrum manager (SM). The standard describes the overall network topology, and on physical (PHY) and medium access control (MAC) layers. Hence, the correct algorithm for spectrum allocation is not specified.

In addition, to assume of the best chance given by the CR architecture, it is very important to develop an applicable DSA policy as it helps to maximize the whole spectrum efficiency & improve the quality of service (QoS) for the individual network operators. Efficient spectrum allocation system is to implement a tough process given the known difficulty of modelling and measuring the wireless medium. Although some significant progress has been made in diverse cognitive techniques during the last few years, many challenges still remain outstanding. For example, most research has been focused on techniques for identifying & minimizing the interference (by the control of the transmit power, carrier sense, or scheduling) for the users of CR network (CRN) [3]. In general, however, the system performance depends on many external factors, including user behavior, traffic load, channel quality, etc. Some theoretical models of the user behavior and traffic load in CRNs have been proposed recently, 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). Hence, this is some general theoretical model that network deployment scenarios [4] can be applied as it is very difficult to obtain. IEEE 802.22 wireless network with spectrum allocation efficiency in; IEEE 802.22 architecture based on the third generation partnership project (3GPP) long-term cognitive evolution (LTE) network in which energy-efficient dynamic spectrum access (DSA) is related to another performance metrics.

As the IEEE802.22 standard, the wireless access is offered by the wireless regional area network (WRAN) consisting of the number of the service providers are (SPs), which share the total available spectrum using a spectrum manager (SM) [5]. The SM uses some of the dynamic spectrum access (DSA) policy to maximize the capacity and quality of service (QoS) for their users. Motivated by this concept of CR network (CRN), many papers have developed various forms of spectrum access system is to give the availability network resources (bandwidth, transmission rate and transmission power). Most of the papers assume non-strategic non-greedy operators following some general resource allocation policy. The recent methods do not have efficient of the tradeoff in the transmission power, bandwidth and transmission rate. This has become a research problem in the domain. In the research of this work,we are presenting a novel improved technique for spectrumallocation in IEEE 802.22 depends on the LTE networks. This new method is likein IQBC, as it is based on existing QBC method. Main idea behind IQBC is the use of many queues to operate the multiple kinds of data efficiently & dynamically.

The reminder of the paper comprises of sections such as, section II presenting the study on related works in which we discussed the recent methods presented for energy efficient spectrum allocation. Section III presenting the information on current research challenges, proposed system architecture, algorithm design and flowchart. Section IV, presents detailed information simulation platform, network configurations, performance metrics and comparative results. Section V, presents the conclusion and suggestions for future work.

II. RELATED WORKS

There are number of techniques that have been presented so far in literature for investigating and solving the research problem of power efficient spectrum allocation in cognitive radio networks. The 3GPP (Third Generation Partnership Project) called LTE (long-term evolution) network based on the architecture of IEEE802.22 standard. From this standards and networks, number of research articles presented the design and development of different types of methods for spectrum allocation in order to allocate the network resource available (network resources are transmission rate, bandwidth, transmission power etc.). Many research articles considering the non-greedy and non-strategic cognitive users by using the basic policies of resource allocation. This section presents study over some recent methods for energy efficient resource allocation.

- In [6], Joint power control and spectrum access in CRNs has been investigated. In this paper,main Purpose is power allocation and DSA throughput and improving secondary (without license) for fairness of network users (licenses) network users without thrust overlarge intervention guarantee. Numerical results reflect that, compared with previous studies, the benefits of comprehensive performance plan (for example, spectrum efficiency, fairness and throughput) presents. Below the theoretical framework of the researchers is to cover the optimization problem with the Differential Evolution (DE) algorithm it is very feasible for implementation in practice.

- In [7] the authors consider adaptive modulation and power control is for the multi access WSN which mainly reduces power consumption to achieve energy efficiency. As the cluster head node of each link acceptable in power control the level and modulation type noise ratio (SNR) and the target bit error rate adjusts according to the indicate (number). 9. This approach further with the original scheme is illustrated through the numeric comparison. Simulation outputs showing that the advanced plan which alleviates to complete more transmission power &maintenance the target bit error rate, can significantly improve the system performance.

- In [8], author presented performance metric is depending on the channel allocation of scheme for IEEE802.22 networks in which the base station assigned [the] without interference channels is using a spectrum map. In this scheme the spectrum map consumer based tools are shared by a small subset of that raw data is created by using the spectrum. Data base station Shepard interpolation techniques, using a modified version of the PM are fused together. The author is a continuous and differentiable vector in spatial distribution spectrum occupancy on any arbitrary location to estimate the cell base station build
advice spectrum use. Such spectrum operations is after done to the proactively evaluate some key network and radio performance metrics which in turn help assigning the ultimate candidate of the channel to a given consumer premise equipment ensuring highest achievable performance.

- In [9], authors presented distributed resource allocation depends on queue balancing into the multi-hops CRNs which has been analyzed. Here the problem of resource (power, channel and data rate) assigned is functioned like as a multi commodity flow issues found dynamic link capacity to model dynamically changing spectrum existence into the networks. Depend on the optimization calculations, a distributed algorithm is proposed for joint flow control & the resource allocation system into the nodes of CRN. Simulation results show the performance improvement by the proposed scheme.

- In [10], authors studied the trade-off between transmission delay and transmission power in wireless networks which is a delay-power control (DPC) scheme is to cover the delay against transmission power in each wireless link has been formulated. It showing the DPC converges is to a unique equilibrium power with several key properties related to the working of the bandwidth assigning achieved by the links.

- In [11], the opportunistic spectrum access (OSA) in LTE proposed (LTE-A) networks it has been searched. It has been formulated that implementation of the OSA in LTE-A enhances the wholemethod performance by the intelligently aggregating otherwise unutilized spectrum. However, the set-up parameters of the method (like as sensing periods & amount of signaling) should be carefully chosen to increase the feasibility of the implementation in a real network.

- In [12], authors presented study on achieving the trade-off between energy efficiency, backhaul capacity, and network capacity. For this author formulate the resource allocation problem for energy efficient connection into themulticellular OFDMA methods with limited backhaul capacity as an optimization problem. The practical results of this method claimed it converges within a small number of iterations and unveiled a trade-off under in energy efficiency, also the network capacity & backhaul capacity.

- In[13], authors presented the comprehensive literature survey on available D2D related methods varying from the methodology based papers to practical analysis of the research must be a standard activity. Researcher discussed the open research challenges to address for future studies over the spectrum allocated in LTE networks.

III. ALGORITHM DESIGN AND METHODOLOGY

3.1. Introduction

In this paper, dynamic method is proposed based on recently presented two bandwidth allocation schemes QBC (Queue Based Control)-1 and QBC-2. The QBC 1 is having efficient delay and loss performances as compared to QBC-2, whereas QBC-2 is having better power efficiency as compared to QBC-1. The proposed method called IQBC is designed by combining both approaches to achieve efficient loss, delay and power performances by combining both QBC-1 and QBC-2 method using multilevel dynamic queues concept. Figure 1 is showing the simulation flowchart and architecture for this study.

3.2. Current Research Problems

Recently Queue Based Control method is presented which is having two different versions based on different configuration parameters for the energy efficiency and spectrum efficiency like as QBC version 1 and QBC version 2. We have evaluated this two methods in our recent studies and concluded below listed current research problems to address:

A. The method QBC version 1 is giving the efficient performance for data loss and end to end delay against QBC version 2. However version 1 is having inefficient performance for energy consumption as compared version 2. Hence it is concluded that OBC method not success to cover the tradeoff among throughput, data rate, and delay and energy efficiency. This is the major research problem.
B. In short, QBC version 1 is showing efficiency in loss as well as delay performance whereas showing worst for energy consumption performance.
C. QBC version 2 is showing the energy efficiency but worst for delay and loss performances.

3.3. Proposed Algorithm

In this paper, the research problems associated with QBC version 1 and QBC version 2 are discussed and proposed improved technique which is based on QBC version 1 and QBC version 2 to overcome them. The new method is combined version of both QBC version 1 and QBC version 2. The proposed spectrum sensing scheme is called as IQBC. This step involves the method of multi-level priority queues, in which different kinds of network data is divided into the different queues, and hence efficiency of the spectrum allocation improves, which in terms improves the QoS (Quality of Service) performance and transmission power performance. Figure 2 is showing the proposed multilevel and dynamic scheduling algorithm is to the cover the tradeoff among the QoS & power efficiency for QBC method. This designed algorithm is combined with existing QBC technique.

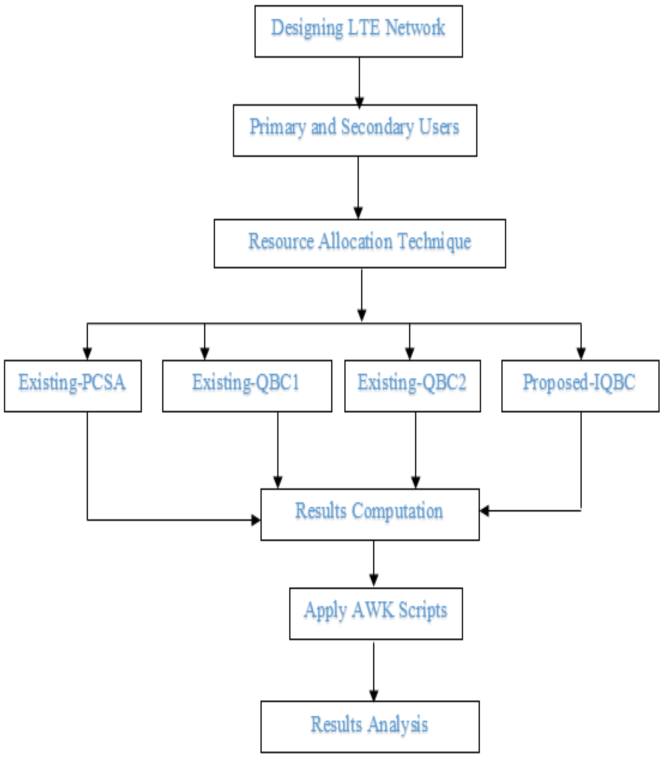

Figure 1: Simulation Flowchart and Architecture

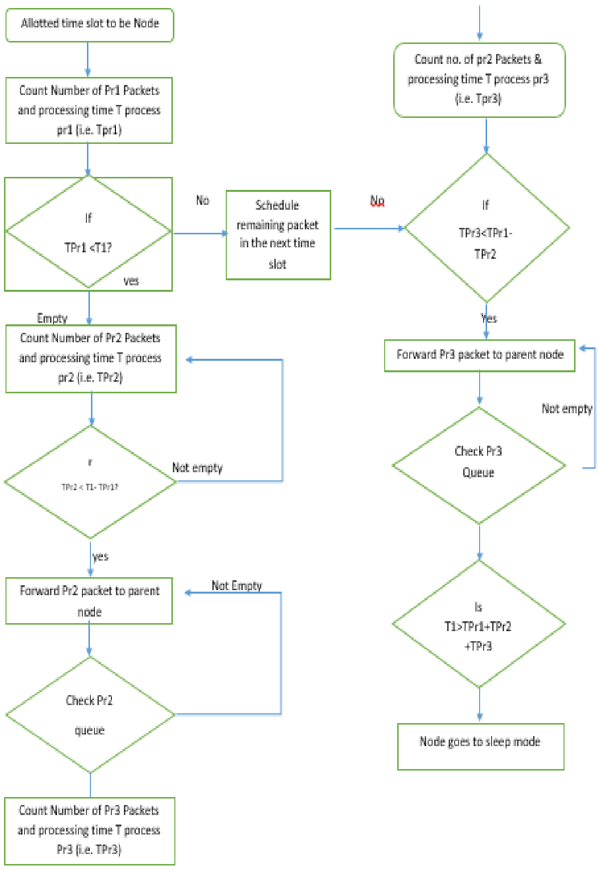

Figure 2: Power and QoS Efficient Algorithm Design

Algorithm 1: Efficient and Dynamic Resource Scheduling Method.

Step 0: Set the threshold for all three queues such pr1, pr2 and pr3 for high, medium and low respectively.

Step 1: Allotted Time Slot to node T1

Step 2: Count Number of Pr1 packets and processing time $T_{process}$ Pr1 (i.e. TPr1)

Step 3: If TPr1 < T1

Else scheduling remaining Packets in the next time slots

Step 4: Forward Pr1 packets to Parent node

Step 5: if check Pr1 queues empty

Else go to step 4

Step 6: Count no. of Pr2 packets and processing time $T_{process}$ Pr2 (i.e. TPr2)

Step 7: Check TPr2 < T1 - TPr1

Else scheduling remaining Packets in the next time slots

Step 7: Forward Pr2 packets to Parent node

Step 8: if check Pr2 queues empty

Else go to step 7

Step 9: Count no. of Pr2 packets and processing time $T_{process}$ Pr3 (i.e. TPr3)

Step 10: Check TPr3 < T1 - TPr1-TPr2

Else scheduling remaining Packets in the next time slots

Step 11: Forward Pr3 packets to Parent node

Step 12: if check Pr3 queues empty

Else go to step 11

Step 13: T1 > TPr1 + TPr2 + TPr3

Step 14: Node goes to sleep mode

Mathematical Equations

Below are number of mathematical formulas those are accessed in above algorithm for computing the delay and waiting time parameters. The end-to-end delay for a real-time task t1 considering that t1 has npr1 number of real-time tasks ahead of it is showing in equation 1 below:

$$\boldsymbol{delayt1 \geq \sum_{i=1}^{npr1} (delaypr_1)i} \qquad \textbf{(1)}$$

The transmission time or delay to place pr2 data from a node into the medium can be therefore computed as data*pr2/st*. Thus, the total end-to-end delay for a *pr*2 task that can be processed in the same timeslot exceeds:

$$\boldsymbol{l_k \times \left(\frac{data_{pr1}}{s_t} + \frac{data_{pr2}}{s_t} + pr1_{proc}(t) + pr2_{proc}(t) + \frac{d}{S_p} + \left(l_{k\times t_{overhead}}\right)\right.} \qquad \textbf{(2)}$$

The transmission time or delay to place pr3 data from a node into the wireless medium is equal to data*pr2/st*. However, during the processing of the pr3 queue tasks, these tasks can be preempted by realtime tasks. They are processed again after the completion of real-time tasks. Thus, the end-to-end delay for processing pr3 tasks will be exceeding:

$$\boldsymbol{a \times t(k) + l_{k\times}\left(\frac{data_{pr3}}{s_t} + pr3_{proc}(t) + \frac{d}{S_p} + \left(l_{k\times t_{overhead}}\right)\right.} \qquad \textbf{(3)}$$

Since pr1 tasks are processed as FCFS, the average wa time for real-time, pr1 tasks at node x is

$$\boldsymbol{AvgWaitingTimePr_1(t) = \frac{\sum_{j1=1}^{n1-1} \sum_{m=1}^{j1} Pr_{1,}m(t)}{n_1}} \qquad \textbf{(4)}$$

The average waiting time for pr2 tasks can be expressed as follows:

$$\boldsymbol{AvgWaitingTimePr_2(t) = \frac{\sum_{j2=1}^{n2-1} \sum_{m=1}^{j2} Pr_{2,}m(t)}{n_2}} \qquad \textbf{(5)}$$

Thus, the average waiting time of pr3 tasks at a node, *Avg*WaitingTimePr3 (t), exceeds:

$$\boldsymbol{\begin{aligned} AvgWaitingTimePr_3(t) & \\ \geq & \frac{\sum_{j31=1}^{n31} \sum_{m=1}^{j31} Pr_{3,}m(t)}{n_{31}} \\ & + \frac{\sum_{j32=n_{31}+1}^{n32} \sum_{m=1}^{j32} Pr_{3,}m(t)}{n_{32}} + \cdots \\ & + \frac{\sum_{j3,\varphi-1=n(3,\varphi-2)}^{n3,\varphi-1} +1 \sum_{m=1}^{j3,\varphi-1} Pr_{3,}m(t)}{n_{3,\varphi}} \\ & + (\psi \times T) + \sum_{m=1}^{\psi} Ym + \left(\alpha \times \sum_{j=1}^{k} t(j)\right) \end{aligned}} \qquad \textbf{(6)}$$

IV. Simulation Results and Analysis

4.1. Introduction

For practical evaluation of proposed and existing methods, well known network simulator tool is used called as NS2. For simulation and evaluation of wireless networks such as MANET, WSN, CRN, LTE etc. there are number of simulation tools available commercially or open source like QualNet, OmNet, OPNET, NS2 etc. For this study NS2 is selected due to below listed benefits.

A. NS2 provides the network simulation environment different kinds of wired and wireless networks.

B. Most important it is for free and any user can do its own model design and its addition to NS2.

C. The various standards like IEEE 802.11, IEEE 802.16, IEEE 802.15.4, IEEE 802.21 and recently IEEE 802.22.

4.2. Network Design Parameters

For the designing of different network scenarios below are important parameters used.

Table 1: List of Network Design Parameters

Cognitive Users	50-300
Communication Pattern	Constant Bit Rate
Network Dimension	1000 x 1000
Cognitive Node Speed	10 m/s
Execution Time	50 Seconds
Transmission Packet Rate Time	10 m/s
Pause Time	1.0s
Routing Protocol	AODV
MAC Protocol	802.22
Spectrum Sensing	PCSA - QBC version 1 - QBC version 2 - IQBC
Total Connections	6

4.3. Graphical Comparative Results

As per discussed earlier there are three different spectrum sensing methods for IEEE 802.22 of LTE networks such as PCSA, QBC and proposed IQCB have been designed and evaluated in NS2. The performance of these methods is measured in terms of data loss rate, energy efficiency and delay. The comparative study by varying number of cognitive users has been done. In NS2 network represent is showing the output of visualization tool called NAM. In NAM, it's only possible to see the number of cognitive users and their movements. There is no support to measure any of performance metrics. The trace file which is another output of NS simulation is used to measure the performances such as data loss, delay and power consumption. This measure is done by using AWK scripts for every performance metrics. The results from AWK scripts are recorded and used to plot the comparative graphs between evaluated spectrum allocation methods. The graphs illustrated below.

A. Comparative Study of Transmission Power

The performance metric transmission power is measured by computing the total energy consumed for each cognitive user at the end of simulation and dividing it by total number of cognitive users. This gives the average energy consumption performance for each network. Figure 3 is showing the comparative analysis between all four methods for energy efficiency performance.

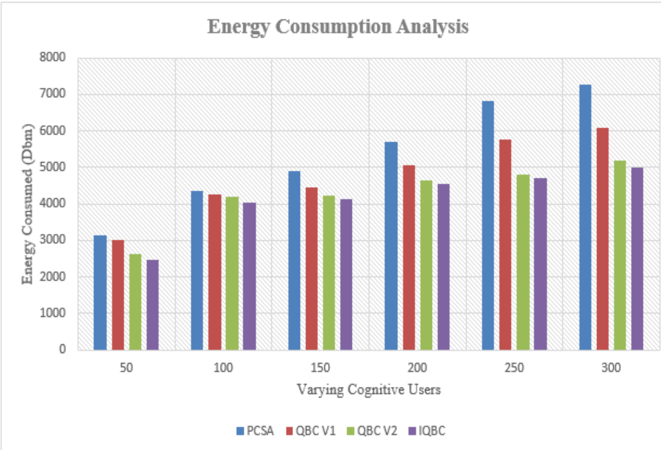

Figure 3: Comparative Study of Transmission Power Consumption

This graph is showing the proposed design method IQBC showing the better energy efficiency as compared to both existing spectrum allocation techniques. The blue lines represents the performance of energy consumption using proposed IQBC method which is less in each network scenarios as compared to existing methods.

B. Comparative Study of Data Loss

Data loss is nothing but the number packets dropped during the communication between source user and destination user. It can be measured by subtracting total number of received packets from total number of generated packets. Figure 4 is showing the comparative analysis for data loss performance metrics under different spectrum allocation methods. Data loss rate for proposed method is significantly reduced as compared to existing methods.

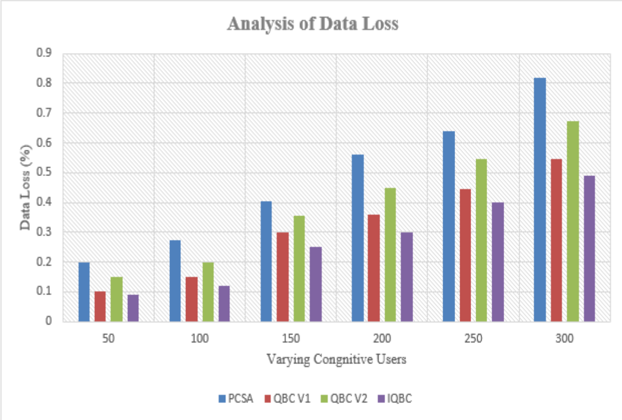

Figure 4: Comparative Analysis of Data Loss Performance

C. Comparative Study of Delay

Delay is measured by using below formula. Delay is nothing but time required to transmit packets from source node to destination node.

$$\textbf{Delay} = \textbf{N} [\textbf{D1} + \textbf{D2} + \textbf{D3} + \textbf{D4}] \tag{7}$$

where,

D1 = transmission delay
D2 = propagation delay
D3 = processing delay
D4 = Queuing delay
N= number of links

By considering this delay performance is minimized for proposed IQBC technique.

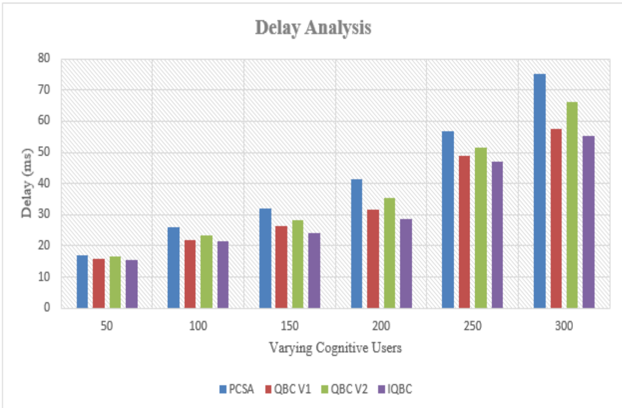

Figure 5: Delay performance analysis

The achieved results claims that proposed method for spectrum allocation in cognitive radio networks achieved efficient tradeoff between power efficiency and QoS efficiency as compared to existing QBC and PCSA method

V. CONCLUSION AND FUTURE WORK

The main aim of this paper is to present the novel approach to overcome the limitations of existing methods for LTE advance networks based on IEEE 802.22 standards. The existing method and current research challenges are discussed in this paper. To address current research problems, we designed the new resource allocation method which is based on multilevel queues terminology. The algorithm and flowchart for this method is presented in this paper. The evaluation and comparative study between existing and newly designed methods is done using NS2. The simulation results depict the proposed IQBC method overcoming the current research problems. This method shows minimization in transmission power, minimization in delay performance, minimization in data loss performance as compared to existing QBC methods. The future work suggestions are evaluation of proposed technique under various network conditions such as network dimensions, mobility speeds, packet transmission rates etc.

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