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OPTIMIZED RESOURCE BLOCK ALLOCATION AND SCHEDULING FOR REAL-TIME SERVICES IN LTE NETWORKS

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ABSTRACT

In recent times, there has been a huge increase in the demand for real-time multimedia applications from mobile users. In this paper, we propose an Optimized Resource Block Allocation and Scheduling technique for real-time Services in LTE networks. This technique considers both the resource block allocation and the scheduling process. The resource block allocation considers the instantaneous data rate and the average data rate. It will allocate the resources that are required to perform the real-time connection. If the resources are busy then, the user connection is scheduled using the lower level of the scheduler. The scheduler has a timer based on which the user connections are updated. In the scheduling period, the available resources are assigned to the user. The advantage of this approach is that it is possible to assign the reserved blocks to real-time users so that average throughput is improved. By simulation results, we show that the proposed technique improves received bandwidth and fairness while reducing the delay and packet drops.

Key words: *Long Term Evolution (LTE) Networks, Quality of service (Qos), Call Admission Control (CAC), Resource Block (RB) Allocation*

1. INTRODUCTION

1.1 Long Term Evolution (LTE) Networks

In the past few years, there is huge demand for new telecommunication service which involves increasing number of new applications and greater transmission capacity. Maintaining the Quality of service (QoS) is the challenging task in new technology since it increases the user satisfaction. Long Term Evolution (LTE) is the next generation wireless system and the evolution of mobile network technology standardized by 3rd Generation Partnership Project (3GPP) [1][2][3]

LTE adopt the new multiple access systems to the interface area to test its application and content services, such as Multimedia Online Gaming (MMOG), TV Mobile, Web 2.0, video streaming, music downloads and many others. LTE is mainly designed to increase the capacity, coverage and speed of mobile wireless networks.

LTE is a part of 3GPP release 8 and it has been standardized by 3GPP. LTE increases the data rate and improves the spectral efficiency by adopting Orthogonal Frequency Division Multiple Access (OFDMA) and Multiple-Input Multiple-Output (MIMO) technologies. In the existing mobile communication networks, voice traffic is delivered through circuit switched networks, but in LTE, all kinds of traffic, such as voice, streaming, data, etc., are transferred through packet-switched networks based on IP.

The motivation to build the LTE is come from the huge traffic requirements of next generation mobile services such as high-speed internet access, multimedia online gaming, Fixed-Mobile Convergence (FMC), wireless DSL and mobile TV. The 3G evolution aimed at providing wireless broadband to support all these applications at reduced cost and better performance. Besides maintaining seamless mobility, service control and maximizing network capacity with limited spectrum resources [1]-[6].

1.2 Call Admission Control (CAC)

For the next generation system, the integration of multimedia content and applications, such as, video surveillance, gaming, mobile IPTV and VoIP, is necessary to provide QoS assurance for fixed and mobile users. As a result, QoS control mechanisms, including CAC (Call Admission Control), are required to ensure the success of LTE systems. To

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guarantee the QoS, we need some resource availability that is judged by the call admission control algorithm.

1.2.1 Call admission control in LTE networks

The basis for admission control algorithm is eNodeB in LTE. The eNodeB is capable of operating separately on a per cell basis. The main aim of CAC is the congestion avoidance and the CAC scheme limits the number of ongoing connections in the system or denies new connection request so that QoS can be maintained and delivered to different connections at the target level.

In order to admit the user to network two conditions that is given below need to be satisfied in the CAC algorithm:

Resource availability in the selected eNB is the first condition. Available resources are checked by the eNB once the initial condition is checked. Large amount of physical resources between a minimum and maximum threshold are provided by the mobile.

Signal strength is the second condition and the eNB proved maximum signal, the mobile selects this node and shortage in coverage can be caused when signal goes below a certain threshold. The mobile may get blocked in this situation. [6][7][8]

1.2.2. Issues of call Admission control

They are so many issues in designing an efficient Call Admission Control (CAC), in that important issues are,

It is quite irritate for a user when an ongoing call is dropped while handed over than when a fresh call is rejected initially. Thus, it is important for the LTE system to accept the handover calls prior to the fresh calls.

Diverse QoS requirements for delay-sensitive and delay-tolerant applications, and the heterogeneous traffic patterns of calls originating from different applications makes the design of efficient admission control algorithms more challenging.

The CAC algorithms are classified into two categories, namely, static and dynamic. Static CAC algorithms reserve resource for handoff calls. Dynamic CAC algorithms perform admission control through the estimation of radio channel state and available resources. Since dynamic CAC algorithms assume that all requested calls have the same QoS requirement, they cannot directly adapt to LTE system that provides various kinds of services. [6][7][8]

1.3 Multi Class in LTE

Multi class in LTE involves all kinds of traffic, such as voice, streaming, data, etc. Trends in mobile data traffic show that multimedia applications such as online gaming, web television and video calling account for the majority of global data traffic. The traffic is divided into two categories: real time traffic and non real time traffic.

Real time traffic is typically modeled by a fixed delay deadline for each packet The non real time traffic is modeled by a concave increasing utility function. The concave increasing utility function is an average rate experienced by flow. More common scheduling rule where potentially multiple users can be scheduled simultaneously has been considered. Most of the above work assumes that the queues have infinite backlogs, i.e., packets are always available in the buffers of all the queues; extensions to finite queues are provided. The proportional fair algorithm where all the resources are allocated to the flow with the maximum ratio of instantaneous spectral efficiency (which depends on the channel gain) to the average rate has been analyzed. [7][8][9]

1.4 Resource Block (RB) Allocation

In LTE Networks, the resource block allocation plays an important role. The two-dimensional time-frequency resource allocation gives more chances to obtain multi-user diversity gain and frequency diversity gain. The lower level scheduler is mainly concentrated on resource block allocation based on users channel state information such as traffic queue information and QoS requirements. It should provide support for different QoS profiles with consideration of fairness among users experiencing different channel conditions.

1.5 Problem Identification

The approach proposed in [11] is a novel Radio Admission Control (RAC) scheme for multiclass services in LTE systems. It aims at optimizing system capacity while guaranteeing QoS constraints of each service class. An objective function of maximizing the number of admitted users is proposed to evaluate the system capacity. To optimize the system capacity, they adopt a service degradation scheme in case of resource limitations in our RAC scheme. System performance is evaluated by using a K-dimensional Markov Chain Model.

The drawbacks observed in this approach are as follows:

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1. A call is blocked if there is no sufficient bandwidth so that the probability of total system also increases.
2. They are not considering the call when handover occurs.

The approach proposed in [14] is a an optimized scheduling approach that exploits multiuser diversity by considering each user's instantaneous downlink conditions and QoS information when distributing resources. The proposed scheme aims to satisfy the application quality of service requirements and improve overall system throughput by exploiting multiuser diversity.

Bandwidth is not allocated dynamically for the connection during a specified period that is the major drawback of this method. When the resources are full, they are not scheduling the user for the next resource allocation.

2. LITERATURE REVIEW

Haipeng LEI et al., [6] have proposed a resource allocation algorithm and a connection access control scheme (CAC) for LTE systems. The proposed allocation algorithm introduces a transmission guard interval that gives high priority to real-time (RT) service packets approaching the delay deadline. The proposed CAC can adaptively adjust the threshold according to the network condition. Simulation results show that the proposed CAC scheme can not only balance the ongoing connections of different classes of traffics but also be easy to reserve resource and support handover users potentially.

Bilal Sadiq et al., [9] have proposed a practical LTE downlink scheduler and characterized its performance for three traffic scenarios, namely, full-buffer, streaming video (loose delay constraint), and mixed streaming and live video (tight delay constraint). Through analysis and numerical results for different traffic models, they illustrate the various design choices (e.g., the specifics of the tradeoff mentioned earlier in this section) that need to be made while selecting a scheduling policy. They demonstrate that queue and channel-aware schedulers lead to significant performance improvements for LTE. Such schedulers not only increase the system capacity in terms of the number of QoS flows that can be supported but also reduce resource utilization.

Mostafa Zaman Chowdhury et al., [10] have proposed an efficient Call Admission Control (CAC) that relies on adaptive multi-level bandwidth-allocation scheme for non-real-time calls. They are using the queuing analysis for the new call blocking probability and handover call dropping probability. While the proposed scheme blocks more new calls instead of dropping handover calls, the scheme also reduces the number of handovers and the average call duration as compared to the non-prioritized bandwidth-adaptive scheme.

Manli Qian et al., [11] have proposed novel radio admission control (RAC) scheme is proposed for handling multiclass services in Long Term Evolution (LTE) systems. An objective function of maximizing the number of admitted users is proposed to evaluate the system capacity. To solve the optimization problem, we present a combined complete sharing (CS) and virtual partitioning (VP) resource allocation model and develop a service degradation scheme in case of resource limitations in the proposed RAC scheme. Call blocking probability, system resource utilization and system capacity are used as performance metrics and are evaluated by using a K-dimensional Markov Chain model.

Mauricio Iturralde et al., [12] have proposed a two level resource allocation scheme is proposed to enhance the Quality of Service (QoS) for multimedia services in LTE downlink system. It corresponds to a solution that combines cooperative game theory, a virtual token mechanism, and the EXP-RULE algorithm. By using cooperative game theory such as bankruptcy game and Shapley value, the proposed mechanism works by forming coalitions between flow classes to distribute bandwidth fairly. EXP-RULE algorithm has been modified to use a virtual token mechanism to improve its performance. By taking into account constraints such as Shapley value fairness and the virtual token robustness, the proposed mechanism can increase remarkably the performance for real time flows such as video and VoIP in downlink system.

A. Antonopoulos et al., [13] have proposed a connection admission control (CAC) mechanism for IEEE 802.16 broadband wireless access standard. Our scheme is based on the bandwidth reservation concept and has been developed considering the problem of "busy hour" in communications traffic variation during a typical day. The proposed solution, which is compatible to the IEEE 802.16 Standard, provides higher priority to VoIP calls compared to other types of traffic in the network. Although the admission control algorithm has been designed considering a WiMAX

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infrastructure, the flexibility of the scheme allows the adaption in other similar technologies as Long Term Evolution (LTE).

Joel Makara et al., [14] have proposed an optimized scheduling approach that exploits multiuser diversity by considering each user's instantaneous downlink conditions and QoS information when distributing resources. They propose an approach towards the management of resources in the LTE downlink that fully exploits multiuser diversity.

3. PROPOSED SOLUTION

3.1 Overview

To overcome the problems mentioned in section 1.5, we proposed an Optimized Resource Block Allocation and Scheduling approach for real-time services.

In the proposed method, the approach will allocate the resource to the real-time users using the Resource Block (RB) allocation [6]. In the RB allocation, it will allocate the resources that are required to perform the real-time connection. A time constant is used to update the average rate that is allocated to the users and Q(t) factor is used to support different class of QoS.

If the resources are busy then the approach will schedule the user connection using the lower level of the scheduler [15]. The scheduler has a timer based on this the user connections are updated. In the scheduling period, the available resources are assigned to the user.

The main advantage of this method is that we can assign the reserved RBs to real-time users so that average spectrum efficiency and average cell throughput will be improved and we are using the schedulers to assign the resource to the users more effectively.

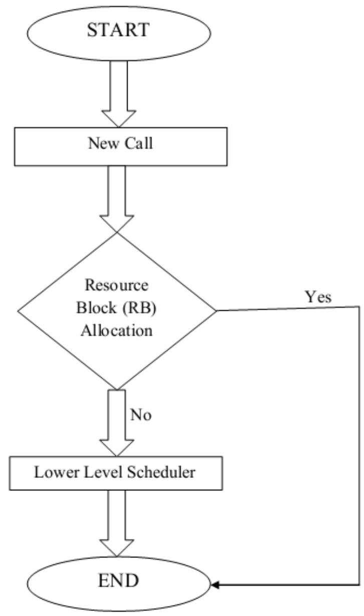

Figure.1. Flow chart of the proposed approach

The proposed approach basically consists of two main parts, namely, resource block allocation and the lower level scheduler, where the instantaneous data rate and the average data rate will be considered. When a new call is initiated in the LTE systems, the resource block allocation will be implemented where a block of resource will be allocated. If the resource block is busy then the lower level scheduler will be implanted and schedule the call in the LTE systems.

3.2 Resource Block (RB) Allocation Algorithm

Resource block allocation is based on users channel state information, traffic queue information and QoS requirements by the LTE systems. It also supports different QoS profiles by considering fairness among users with different channel conditions.

We consider instantaneous data rate for user on the particular sub channel and on the particular slot.

$$\mathrm{dr}_i(n) = \sum_{sc=1}^{N} \mathrm{dr}_{i,sc}(n) \bullet \beta_{i,sc}(n) \quad (1)$$

where, $dr_i(n)$ is the total available instantaneous data rate of user i at the n^{th} slot, $dr_{i,sc}$ is the achievable instantaneous data rate for user i on sub-channel (sc) at the n^{th} slot, $\beta_{i,sc}(n)$ is an allocation index variable where,

$$\beta_{i,sc}(n) = \begin{cases} 1 & \text{when the subchanel } s_c \text{ at the } n^{th} \text{ slot is allocated to user i} \\ 0 & \text{otherwise} \end{cases}$$

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After updating the average rate of user i at the end of each slot, the equation for the total available instantaneous data rate and average data rate of user becomes

$$DR_i(n+1) = (1-\frac{1}{T_c})DR_i(n) + \frac{1}{T_c}dr_i(n) \quad (2)$$

where, $DR_i(n)$ is the average data rate of user i at the n^{th} slot, after updating the average rate of user i at the end of each slot. Here if the user i is not served by any sub-channel in the n^{th} slot, then $r_i(n)$ will become equal to zero. T_c is the time constant.

In real time traffic, the different classes of QoS have to be supported. For this, a QoS satisfaction indicator function Q(t) is introduced.

$$Q(t) = \max\{1, \exp[\delta(W(t)+\Delta T+T)]\} \quad (3)$$

where, δ is the delay weight factor, W is the delay of HOL (head of line), ΔT is the transmission guard interval and T is the maximum allowed packet delay. δ is set to be zero for delay insensitive traffic.

The packet delay W of HOL (head of line) is given by

$$W \in \begin{cases} 0, T-\Delta T & \text{when the delay requirements are satisfied} \\ T-\Delta T, T & \text{when the delay reached the maximum allowed delay} \end{cases}$$

From (1), (2) and (3), we get (4) to apply Proportional Fair (PF) algorithm for each user i on each sub-channel j at the n^{th} slot

$$i(n) = \arg\max_{1\le i\le I}\left(\frac{dr_{i,sc}(n)REQ_i(n)}{DR_i(n)}\right)Q_i(t), \quad 1 \le s_c \le N \quad (4)$$

where, $dr_{i,sc}$ is the achievable instantaneous data rate for user i on sub-channel j at the n^{th} slot. $REQ_i(n)$ is the requested service rate of user i.

If the QoS satisfaction indicator function Q(t) in equation (3) fails to satisfies and support the real time traffic in the LTE systems, then the lower level scheduler which is described in the section 3.3.1 gets implemented in order to schedule the initiated call in the LTE systems.

3.3 Scheduler in LTE systems

3.3.1 Lower level scheduler

The lower level scheduler allocates the RBs to real time flows for each of the ten TTIs forming a frame. The PF algorithm [6] [15] has been used in the lower level scheduler in order to achieve a high level of fairness among multimedia flows. The main advantage of this PF algorithm is that it allocates approximately the same number of resources to all users. It also tries to allocate resources in any given scheduling interval to a user whose channel condition is good. It achieves high throughput and maintains proportional fairness among all users**.** The link adaptation module estimates the maximum instantaneous data rate for each user in particular for every Transmission Time Interval (TTI) in each sub-channel. The estimated value is computed using feedbacks on channel quality sent by the user in the previous TTI. The RBs have been assigned to the downlink connections by the PF algorithm belonging to users with the best ratio R. This ratio is computed by the instantaneous available data rate over the average data rate with the reference to the i^{th} user in the s_c^{th} sub-channel.

The essence of this algorithm is to allocate approximately the same number of resources to all users (averaged over a period) and to allocate resource in any given scheduling interval to a user whose channel condition is near its peak.

$$R_{i,sc} = \frac{dr_{i,sc}(n)}{DR_i(n)} \quad (5)$$

where, $R_{i,sc}$ is the ratio between the assigned RBs and the PF algorithm, $dr_{i,sc}(n)$ is the achievable instantaneous data rate for user i on sub-channel (sc) at the n^{th} slot, $DR_i(n)$ is the average data rate of user i at the n^{th} slot.

The value of $DR_i(n)$ is updated on every TTI using a weighted moving average formula by considering the transmitted frames within the LTE system.

$$DR_i(f) = 0.8DR_i(f-1) + 0.2DR_i(f-1) \quad (6)$$

where, $DR_i(f)$ is the data rate of the f frame of the i^{th} user, $DR_i(f-1)$ represents the data rate achieved by the i^{th} users during the previous sub frame.

4. SIMULATION RESULTS

In this section, we simulate the proposed Optimized Resource Block Allocation and Scheduling for Real-time Services (ORAS) scheme using Network simulator (NS-2) [16] which is a general-purpose simulation tool that provides discrete event simulation of user defined networks. We have used the LTE/SAE implementation model for NS2.

The simulation parameters are given in table 1.

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Table 1: Simulation Parameters

No of eNB	2
No. of UEs	18
Traffic Types	Exponential and VoIP
Traffic Rate	10 to50 kb
VoIP Codec	GSM.AMR
No. of VoIP frames per packet	2

In the simulation settings, we have one server to provide HTTP, FTP and signaling services, two eNB to provide flow control information and eight UEs. The simulation topology is given in the following figure 2.

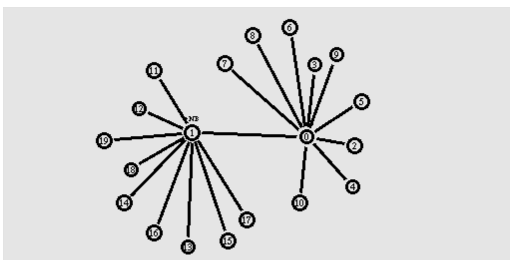

Figure. 2. Simulation Topology

We compare the ORAS with the novel radio admission control (RAC) scheme [11].

Case-1 Video Traffic

A. Based on Rate

In this experiment, we vary the data sending rate from 10 to 50Mb to measure the received throughput, fairness, packet drop and delay.

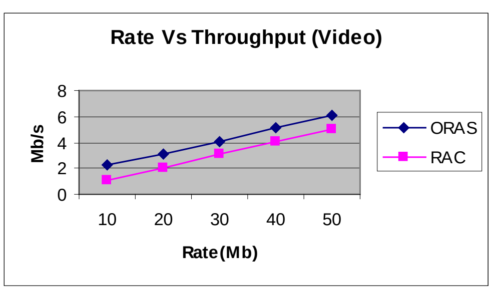

Figure.3. Rate Vs Throughput

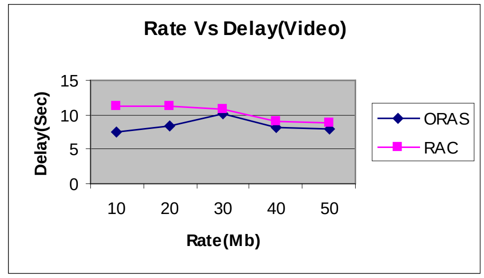

Figure.4. Rate Vs Delay

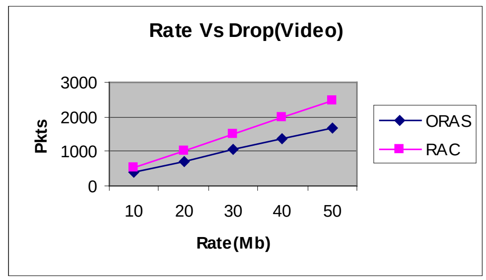

Figure.5. Rate Vs Packet Drop

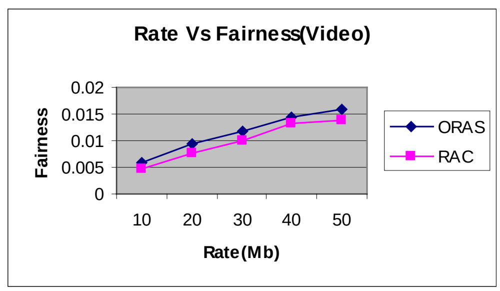

Figure.6. Rate Vs Fairness

From figure 3, we can see that the received bandwidth of our proposed ORAS is 29% higher than the existing RAC method.

From figure 4, we can see that the delay of our proposed ORAS is 17.5% less than the existing RAC method.

From figure 5, we can see that the packet drop of our proposed ORAS is 29% less than the existing RAC method.

From figure 6, we can see that the fairness of our proposed ORAS is 14.3% higher than the existing RAC method.

B. Based on Number of requested Users

In our second experiment we analysis the metrics based on the requested Users. We vary the users as 3, 6,9,12 and 15.

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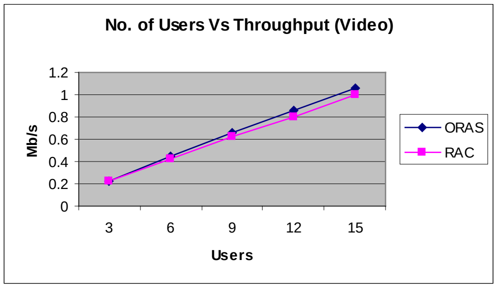

Figure 7: Users Vs Throughput

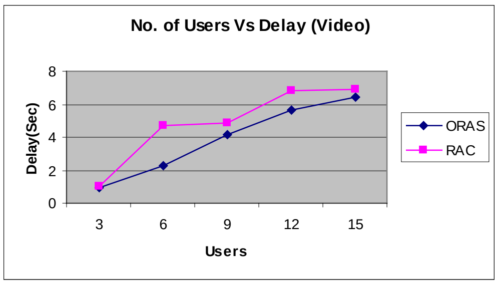

Figure. 8: Users Vs Delay

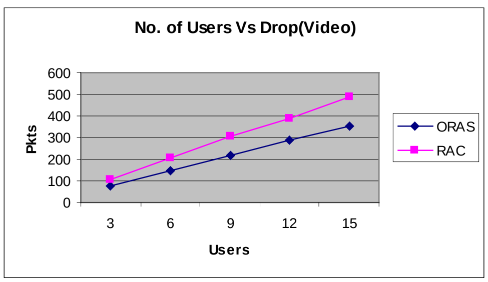

Figure. 9: Users Vs Packet Drop

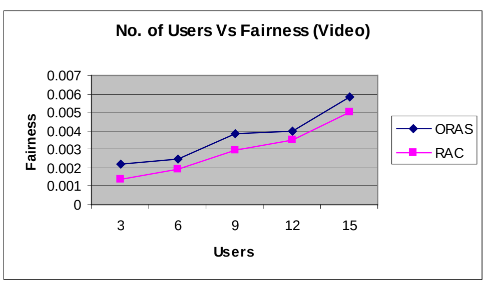

Figure. 10: Users Vs Fairness

From figure 7, we can see that the received bandwidth of our proposed ORAS is 4.7% higher than the existing RAC method.

From figure 8, we can see that the delay of our proposed ORAS is 20% less than the existing RAC method.

From figure 9, we can see that the packet drop of our proposed ORAS is 28% less than the existing RAC method.

From figure 10, we can see that the fairness of our proposed ORAS is 21% higher than the existing RAC method.

Case-2 (VoIP)

B. Based on Rate

In this experiment, we vary the data sending rate from 10 to 50Mb to measure the call throughput, fairness, call drop ratio and delay.

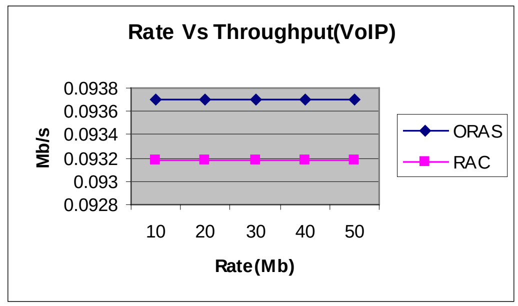

Figure.11: Rate Vs Received Bandwidth

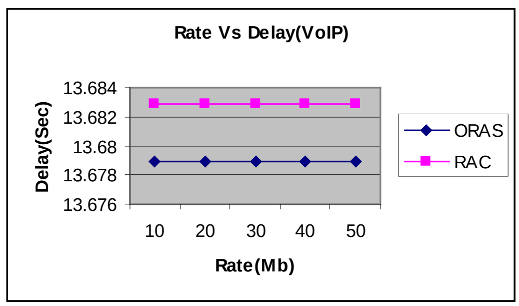

Figure. 12: Rate Vs Delay

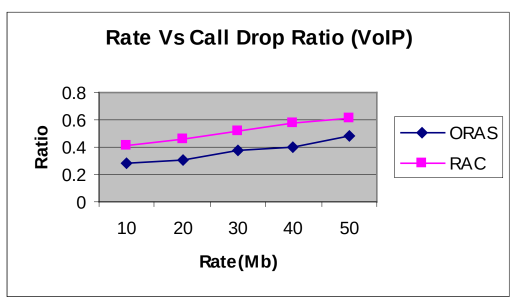

Figure. 13: Rate Vs Call Drop Ratio

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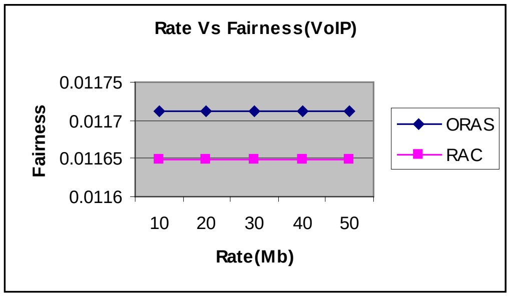

Figure.14: Rate Vs Fairness

From figure 11, we can see that the received bandwidth of our proposed ORAS is 0.5% higher than the existing RAC method.

From figure 12, we can see that the delay of our proposed ORAS is 0.02% less than the existing RAC method.

From figure 13, we can see that the packet drop of our proposed ORAS is 28.5% less than the existing RAC method.

From figure 14, we can see that the fairness of our proposed ORAS is 0.5% higher than the existing RAC method.

5. CONCLUSION

In this paper, we have proposed an Optimized Resource Block Allocation and Scheduling for Real-time Services in LTE systems. This approach considers both the resource block allocation and the scheduler process. The resource block allocation considers the instantaneous data rate and the average data rate. The RB algorithm will allocate the resources that are required to perform the real-time connection. If the resources are busy then we will schedule the user connection using the lower level of the scheduler. The scheduler has a timer based on the timer the user connections are updated. In the scheduling period, the available resources are assigned to the user. The advantage of this approach is that it is possible to assign the reserved RBs to real-time users so that average spectrum efficiency and average cell throughput will be improved and we are using the schedulers so that we can assign the resource to the users more effectively.

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