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AN ENHANCED RESOURCE ALLOCATION SCHEME FOR LONG TERM EVOLUTION ADVANCED NETWORK

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ABSTRACT

The emerging Long-Term Evolution Advanced (LTE-A) is an extended version of Long-Term Evolution (LTE) fourth-generation (4G) wireless broadband technologies that supports high speed transmission of multimedia applications, like video streaming, multimedia online game, Voice over IP (VoIP), browsing over the web etc. The Third Generation Partnership Project (3GPP) does not define a standard packet scheduling strategy in LTE-A. Therefore, it is expected for researchers and network service providers to design efficient schemes. This paper proposed an Enhanced Resource Allocation Scheme (E-RAS) that improves the packet scheduling strategy of LTE-A by addressing issues related to delay and fairness of users with both high and low channel conditions, for both Real Time (RT) and Non-Real Time (NRT) flows. The aim was achieved by using a fair spectrum allocation mechanism that consider the priority of RT flows of cell-centre users, without neglecting the throughput requirements of edge-centre users. Moreover, the proposed algorithm introduces an efficient traffic load balancing mechanism to efficiently regulate traffic load in LTE-A network. To evaluate the proposed scheme, simulation was conducted using the MATLAB programming with LTE-A system level simulator. The result obtained shows that the proposed scheme achieves better delay for RT and NRT traffics by 7% and 11% respectively as against the Resource Allocation Scheme to Optimize the Throughput (RASOT) scheme.

Keywords: Downlink, Scheduling, LTE-A, QoS, Channel condition

INTRODUCTION

In recent years, due to the rapid development in cellular technological design, there has also been an exponential growth in its demands by users (Uyan & Gungor, 2019). Some types of wireless communication systems using Orthogonal Frequency Division Multiplexing (OFDM) and millimeter-wave spectrum, such as, Wireless Interoperability for Microwave Access (WIMAX), Long-Term Evolution (LTE), Long-Term Evolution Advanced (LTE-A) and Fifth Generation (5G) are evolving, to aid a wide variety of services and applications with different QoS requirements (Cong et al., 2018). LTE was developed by Third Generation Partnership Project (3GPP) to support higher data rate of 100 Mega-bits per second (Mbps) in the downlink and 50 Mbps in the uplink. The basic requirements of the LTE technology are; high date rate, high coverage and robust spectral efficiency (Moses & Karthikeyan, 2018). LTE-A is an extended version of LTE, and one of the fastest growing mobile technologies in the world. Further improvements of LTE-A are still on-going and its future releases have enhanced features such as; carrier aggregation, Multiple Input Multiple Output (MIMO), Coordinated Multipoint Transmission (CoMP), high data rates of 75 and 300 Mbps for both uplink and downlink respectively. Likewise, it guarantees high speed of up to three times faster than LTE in order to provide the best user experience for a complete Fourth Generation (4G) international mobile telecommunication requirement (Ramesh, 2019). 3GPP LTE-A introduces the concept of relay nodes to efficiently plan a heterogeneous network. The relay nodes are low power base station, which establishes wireless connection with radio access network using a donor cell to enhance coverage in targeted areas in lower costs without the need for a wired backhaul connection. Thus, increasing throughput, capacity at cell edges and group mobility (David, 2017).

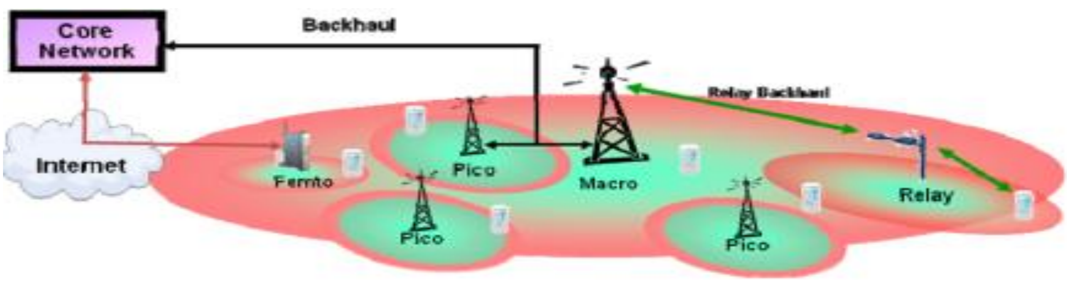

Figure 1: LTE-A Heterogeneous Networks (Elshennawy, 2020)

The increased needs of mobile data request created a burden on existing LTE/LTE-A networks, which necessitated the investigation of the 5G cellular network by the European commission research and innovation program that supported 5G-Public private partnership to design 5G architectures with massive MIMO, full duplex communication, dense Heterogeneous Networks (HetNets), Device-to-Device (D2D) communication, massive Machine Type-

Communications (MTC), mm wave communication, energy-aware communication and energy harvesting, Cloud-Based Radio Access Networks (C-RANs), the virtualization of network resources, high density mobile broadband users etc. Despite the improved features in the architectural design of LTE-A network. The Radio Resource Management (RRM) techniques faces some hurdles such as; fairness in spectrum allocation, interference and power management due to the heterogeneity and dense deployment of wireless devices, the constraints of the fronthaul and backhaul capacities, and a large number of users and stakeholders with different objectives (Luong et al., 2019).

Scheduling is one of the RRM techniques used for the allocation of resources to users for the transmission of data. Some of the schedulers responsible for making scheduling decisions do not consider the channel status while making scheduling decision. Those schedulers are often referred to as channel-unaware schedulers. While the other category of schedulers, referred to as channel-aware schedulers gives resources to users based on their channel condition. The main aim of these schedulers is to maximize throughput. Normally, users that are close to Evolved Node Bs (eNBs), also known as the base station, have a higher Signal to Interference Plus Noise Ratio (SINR) which in turn means a higher Channel Quality Indicator (CQI) value, the higher the CQI value of a UE, the higher will be its Modulation and Coding Scheme (MCS), with will determine the number of bits to be transmitted. On the other hand, the edge users (i.e. users far away from the eNBs) faces some challenges such as, path loss, channel fading and bandwidth scarcity. Therefore, there is need for efficient RRM mechanisms to overcome the above mentioned limitations.

Alves & Roberto (2020) developed a novel channel-aware Resource Allocation Scheme to Optimize the Throughput (RASOT) of LTE-A and 5G HetNets. The scheme starts by comparing the SINR of contending users. If the SINR is less than a default value called *SINR_threshold,* then the algorithm inserts User Equipments (UEs) into the *edgeUE_list array.* However, if the SINR level is greater than *SINR_threshold,* then the algorithm inserts UEs into the *centreUE_list array.* The UE list is sorted in ascending order of their throughput, and the highest Spectral Efficiency (SE) Resource Blocks (RBs) are allocated to the cell edge UEs. When the cell edge UEs received RBs to transmit their data, the Centre UEs also gets a share of the RBs. RASOT improves the fairness index and cell edge throughput of HetNets users. However, the algorithm was not fair to RT traffics of Cell-Centre UEs. Likewise, the algorithm increases the delay and decreases the throughput of Cell-Centre UEs when the number of connected devices are many, due to the high priority given to Cell-Edge UEs.

In this paper, an Enhanced Resource Allocation Scheme (E-RAS) for LTE-A network is proposed with the main aim of increasing the fairness index and reducing excessive delay caused as a result of starvation of traffics of cell-centre UEs when the system is over loaded with request.

Related Works

Escheikh et al., (2014) proposed a novel channel-aware fair downlink scheduling algorithm to provide a significant system performance enhancement compared to the best channel quality indicator scheduler, time and frequency domain and round robin downlink scheduling algorithm. The scheduler receives CQI reports represented in vector format from each active UE in the current sector cell. It then sums the number of RBs assigned for each active UE over the time interval until the instant time $(t-1)$ and thus determines the corresponding scheduling metrics. Based on the determined metrics and their priority, the scheduler assigns the k^{th} RB to the i^{th} UE. The proposed algorithm is evaluated and comparison is made by means of simulation experiments with selected existing scheduling schemes, it demonstrated an improved performance in terms of fairness and throughput. However, the scheme is not efficient for RT traffics. Therefore, it causes delay and low throughput of RT flows.

Rahman et al., (2015) proposed an improved link level scheduler to improve the cell performance. The scheduler enhanced the performance of throughput by grouping the CQI level so as to distribute the RBs to respective UEs efficiently. The RR, PF and BCQI were carefully chosen and examined under different scenario with varying SNR value with the new scheduler. The result shows that the proposed algorithm improved the performance of the cell throughput and sustaining the fairness when there are several UEs placed at the cell edge. However, the QoS of RT flows faces an increase in delay.

Nguyen et al., (2016) proposed a new QoS-Aware scheduling algorithm for the downlink scheduling in LTE network to improve the QoS requirements of RT services. The algorithm considers the maximum queue size as an important factor for the priority metric value and the grouping of modified largest weighted delay first-based algorithms. The results of the simulation show that the proposed scheduler not only considers QoS requirements for RT services, but also improve the Modified Largest Weighted Delay First (M-LWDF), Virtual Token (VT-MLWDF) and Queue Head of Line (HOL-MLWDF) schedulers in terms of fairness, packet loss rate, spectral efficiency and cell throughput for video flows. The proposed algorithm significantly improves the delay in comparison with the Queue-HOL-MLWDF and VT-MLWDF scheduler's ones for both Video flows and Voice over IP (VoIP). However, the QoS requirement of best effort flow was neglected under a heterogeneous network traffic.

Deniz et al., (2018) proposed a new scheduling scheme to improve the edge throughput without losing the overall throughput. The scheduler provides the priority to the users to be assigned in time-frequency slots whose spectral efficiency is above the average of all users. This will aid the scheduler, maintain the MCS as high as possible for all users. It will also give priority to the users who have low channel status over the users with high channel status. RBs must not be allocated to the users if their CQIs are lesser than the average so as to keep the MCS higher. Results show that the proposed scheduler improves the fairness and edge throughput while controlling degradation in the cell throughput between 0 to 2 percent with respect to other schedulers. However, the scheme has a low spectral efficiency and fairness of both the best effort and other NRT of cell-centre users.

Elshennawy, (2020) presented a modified proportional fair scheduling algorithm for heterogeneous LTE-A network to improve its performance, the scheme modifies the proportional fair scheduler using arithmetic mean, geometric mean and root mean square to calculate the average throughput in its cost function. The performance of the proposed scheme was compared with the traditional proportional fair scheduler and best CQI algorithms at various UE velocities. The results expose that modified proportional fair scheduling algorithm for heterogeneous LTE-A networks have best improved values for energy per bit, spectral efficiency, and fairness of both the best effort and other NRT flows. However, the scheme did not consider the cell edge users, as a result, causes a decrease in throughput and an increase in delay.

Alves & Roberto (2020) proposed an enhanced channel-aware Resource Allocation Scheme to Optimize the Throughput (RASOT) of 5G HetNets and LTE-A. The algorithm starts by comparing the SINR of contending users. If the SINR is less than a default value called *SINR_threshold,* then the algorithm inserts UEs into the *edgeUE_list array.* However, if the SINR level is greater than *SINR_threshold,* then the algorithm inserts UEs into the *centreUE_list array.* The UE list is sorted in increasing order of their throughputs, and the highest Spectral Efficiency (SE) RBs are assigned to the cell edge UEs. When the cell edge UEs received RBs to transmit their data, the centre UEs also gets a share of the RBs. RASOT improves the cell edge throughput and fairness index of HetNets users. However, the algorithm was not fair to RT traffic of Cell-Centre UEs. Similarly, the algorithm increases the delay and decreases the throughput of Cell-Centre UEs, due to high priority given to the Cell-Edge UEs when the numbers of connected devices are numerous.
Therefore, the need for an effective algorithm that will improve the average throughput of GBR and NGBR traffics.

METHODOLOGY

Proposed Enhanced Resource Allocation Scheme for Long Term Evolution Advanced Network

A downlink packet scheduling strategy that accommodates both multimedia services and NRT services should be considered given their rapid and equal growth. Service classes concurrently, provides balanced Quality of service, and effectively makes use of the system radio resources. In other words, people increasingly want simultaneous use of messaging, internet surfing, best-effort services, and not just video and VoIP services.
The RASOT benchmark scheme begins by contrasting the SINR of competing users. UEs are added to the edgeUE_list array by the algorithm if the SINR is below a preset threshold value known as SINR_threshold. The technique instead adds UEs to the centreUE_list array, if the SINR level is higher than the SINR_threshold. The maximum Spectral Efficiency (SE) Resource Blocks (RBs) are allotted to the cell edge UEs, which are listed in increasing order of their throughputs. The center UEs also receive a portion of the RBs when the cell edge UEs use them to transmit data. Users of HetNets benefit from RASOT in terms of cell edge throughput and fairness index. However, RT was not treated fairly by the algorithm.

The RASOT technique, which was already detailed in the benchmark study, is modified in the proposed scheduler. The main idea and productive elements of the aforementioned scheduler are combined in this scheduler. In order to perform better than the benchmark scheduler when servicing both RT and NRT classes, the suggested E-RAS improves the performance in terms of fairness, while reducing delays of traffics using a fair spectrum allocation mechanism that consider the priority of RT flows of cell-centre users, without neglecting the throughput requirements of edge-centre users, RT traffics generally are delay intolerant in nature, therefore, in order not to exceed their delay budget, until packets starts dropping from their queue, an efficient traffic load balancing mechanism that efficiently regulate traffic load in LTE-A HetNet was introduced into the system. The mechanism uses queue size and the packet delay parameters in sharing of RBs to competing UEs. Traffics are given RBs to transmit their packets until the network becomes heavily loaded. Every flow that is transported over a different carrier has a buffer connected to it that stores the queue size. This option allows the scheduler to calculate and prioritize the admitted users by letting them know how many bits are available on each buffer. When the queue size of RT flows reaches 70% threshold value, then the scheduler gives higher priority to packets in RT queue. The parameter known as "packets delay" is determined by computing the HoL packet delay for each packet at each TTI. When the packet's delay approaches the target delay, this option is activated and packets that are about to exceed their delay budget are given higher priority for transmission. On the order hand, the priority will be revoked by 50% and given to NRT traffic when its queue size reaches 90% threshold value. This is to create fairness to both traffic and avoid starvation of NRT traffic. A queue size of NRT traffic will still tolerate a little delay, in as long as few packets are moving out of the queue.

Performance Evaluation

The proposed E-RAS scheme is compared with the RASOT in terms of delay and fairness of RT and NRT schemes. The proposed E-RAS was implemented and tested using MATLAB programming with LTE-A system level simulator. The simulator is an open-source software, released free for academic and non-commercial experiments.

Table 1: Simulation Parameters

Description	Value
DL channel BW	5 MHz
Number of UEs	10-70
UE distribution	Uniform
Number of RBs	25
Macroscopic path loss model	TS25814
Frame Structure	Frequency Division Duplexing
Packet Arrival	Poisson Process
Simulation period	100ms
Transmission scheme	2x2 MIMO, OLSM
Cyclic prefix used	Normal cyclic prefix
UE Speed	4.16 m/s
Node Mobility	Starburst uniform walking model

The simulation parameters shown in table 1 were used for conducting different simulation experiments for 10 to 70 UEs. In each experiment, RT and NRT traffics are generated using a Poisson distribution process. The experiment for both the benchmark and proposed E-RAS was conducted using the same traffic parameters.

The total bandwidth used for the simulation is 5 MHz with 25 RBs per slot of 12 subcarrier spacing. The simulation time used is 100ms while the results were obtained by taking the average over several times of simulation experiments.

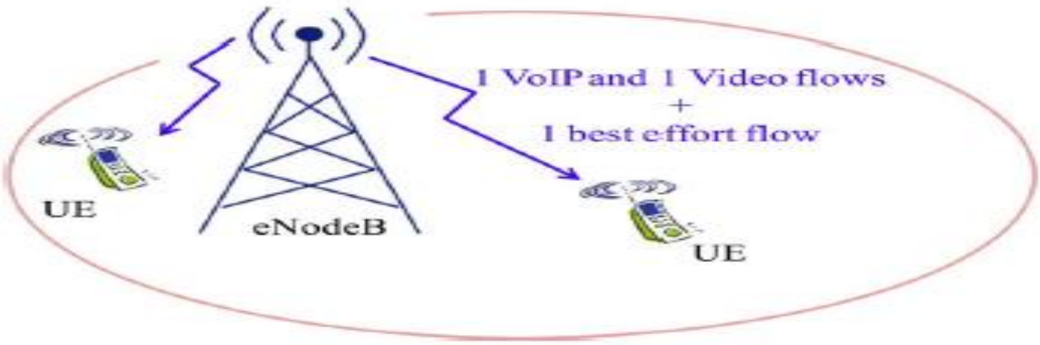

Figure 2: Simulation Experiment Topology

Performance Metrics

The performance metrics used to evaluate the performance of the proposed scheme are listed below:

i. ***Delay*****:** This is the time elapsed between the transmission of the packet and the reception of an acknowledgement.

$$D = t_2 - t_1 \quad (1)$$

where D is the delay, t_2 is the time elapsed between the transmission of the packet and t_1 is the time for reception of an acknowledgement.

ii. ***Jain Fairness Index:*** *It is* ***used to evaluate the fairness of resource allocation between traffic flows.*** Some UEs closer to the eNB have better channel condition, as such, they are given more RBs than the edge users, who are at the edge of the coverage area. This will result in greater throughput for the former and the later may suffer from higher packet delays and could even result to starvation.

$$F = \frac{[\sum_{i=1}^{n} x_i]^2}{n \sum_{i=1}^{n} x_i^2} \quad (2)$$

Where F is the Jain Fairness Index, n is the total number of users in the system, and x_i is the throughput of user i. Fairness index starting from 0 to 1, with 1 representing perfect fairness and 0 showing no fairness.

RESULTS AND DISCUSSIONS

The results obtained from the experiments are elaborated as follows: RT and NRT delay for the RASOT scheme and the proposed E-RAS scheme are depicted in Figures 3 and 4. The figures demonstrated the same value of delay when the number of users is low for the benchmark and proposed schemes, similarly, a slight improvement was observed when the number of UEs increases. However, as the network intensity becomes high, the available RBs are not proficient to serve traffics of all users in TTI. That is when the proposed E-RAS shows an enhanced performance compared to the benchmark scheme. This is achieved due to integration of an efficient load balancing traffic mechanism that efficiently regulate traffic load in the system. The mechanism uses queue size and the packet delay parameters in sharing of RBs to competing UEs. This prevents starvation of both traffics, as well as given RBs to UEs based on their delay budget and urgency.

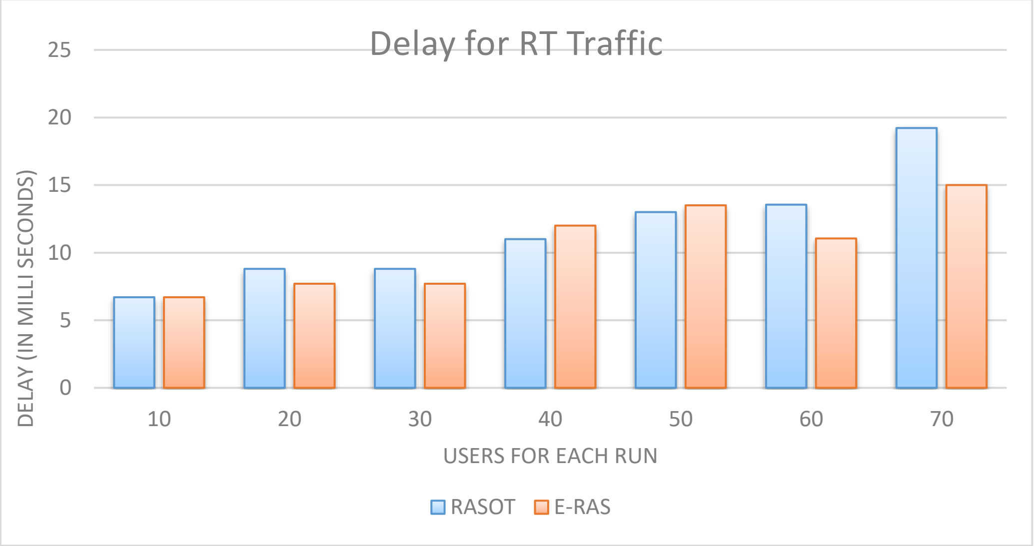

Figure 3: Delay for RT as the number of user's increases

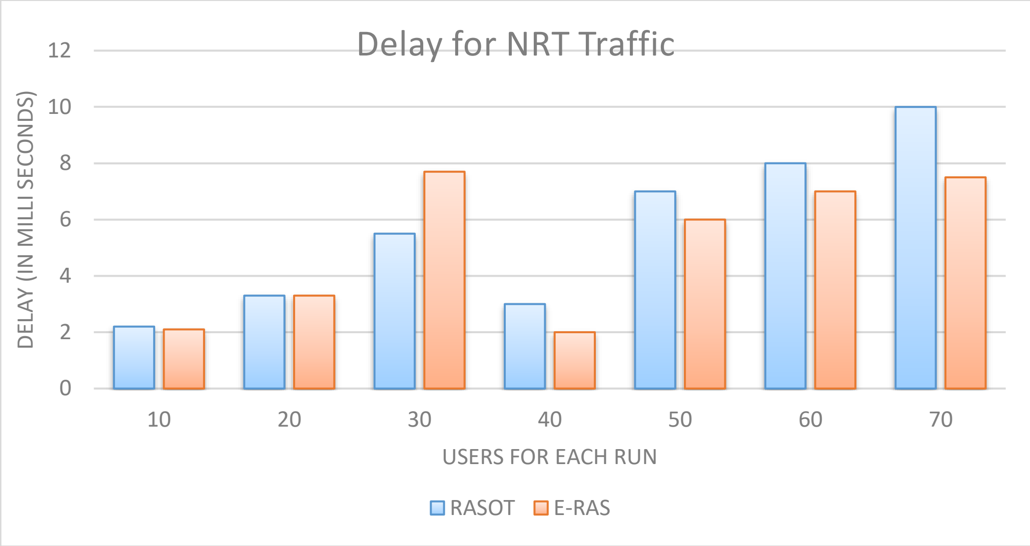

Figure 4: Delay for NRT as the number of user's increases

The fairness index parameter for the proposed scheme is depicted on Figure 5 for RT and NRT flows, respectively. The parameter demonstrates how the system is serving users fairly by assigning a fair share of system resources. Hence, the figure show that the proposed scheduler achieves a very good fairness for different types of services even when the network is heavily loaded.

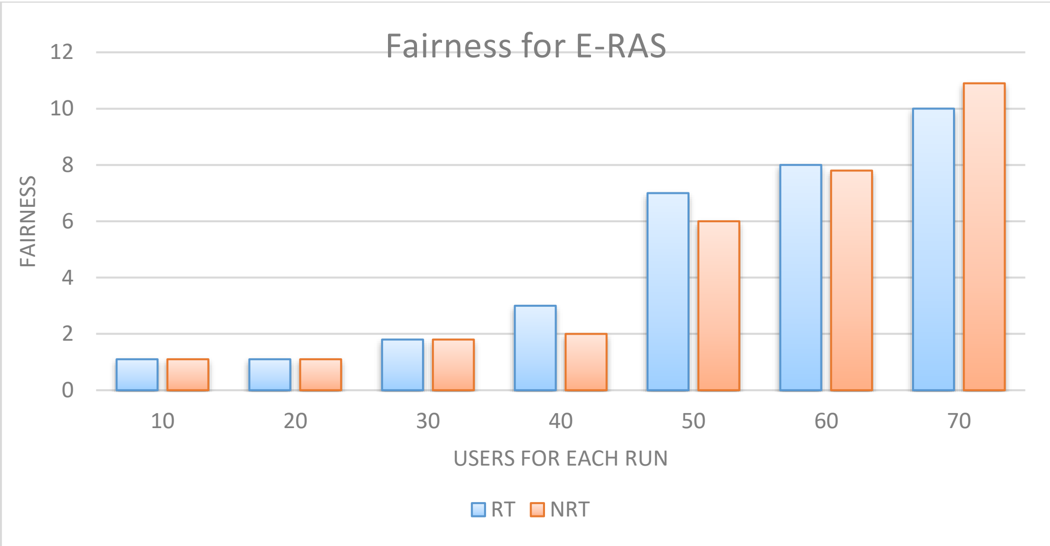

Figure 5: Jain Fairness Index for E-RAS

CONCLUSION

An E-RAS for LTE-A HetNets is developed to improve the performance RT and NRT users. To efficiently regulate traffic load in LTE-A. An efficient traffic load balancing mechanism was introduced that uses queue size and packet delay parameters in sharing of RBs to competing UEs. The mechanism ensures that RT flows do not exceed their delay budget and gives higher priority to packets in the RT queue when the queue size reaches 70%. Additionally, packets that are about to exceed their delay budget are given higher priority for transmission when the packet's delay approaches the target delay. The mechanism also creates fairness to both traffic and avoids starvation of NRT traffic by revoking 50% of priority given to NRT traffic when its queue size reaches 90%. The simulation experiment was conducted using MATLAB system-level simulator to evaluate the performance of the benchmark scheme (RASOT) with the proposed scheme (E-RAS). The results obtained show that E-RAS scheme achieves an improved delay for RT and NRT traffics by 7% and 11% respectively as against the benchmark scheme (RASOT). The proposed scheme also demonstrates a good fairness for RBs distribution of both RT and NRT traffics. The improvement is as a result of incorporation of an efficient traffic load balancing mechanism that efficiently regulate traffic load in the system. The mechanism uses queue size and the packet delay parameters in sharing of RBs to competing UEs. This prevents starvation of both traffics, as well as given RBs to UEs based on their delay budget and urgency.

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