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An Enhanced Downlink Scheduling Algorithm over LTE Network using Genetic Algorithm (EDSA-GA)

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Abstract

The emerging Long-Term Evolution (LTE) network is the type of fourth-generation (4G) wireless broadband technologies that supports high speed transmission of multimedia applications, such as video chat and streaming, Voice over IP (VoIP), multimedia online game, web browsing etc. It has a flexible bandwidth of 1.4 to 20 mega-herz (MHZ) and a diverse Quality of Service (QoS) requirements such as delay, jitter and throughput. It has been observed by recent researches that LTE downlink scheduling algorithms faces some major challenges while assigning available resources to contending users, such challenges such as low throughput, delay, packet drop, fairness leads to the reduction in the overall spectral efficiency of the network, some schedulers maximize throughput with a trade-off to fairness, while others reduce excessive delay of high priority users, but at the expense oflow priority users. Therefore, this research work addresses the challenging issues related to throughput and fairness of Real Time (RT) users, without sacrificing the performance of None Real Time (NRT) users. The aim was achieved by improving the performance in terms of throughput and fairness, which invariably reduces the delay of traffics using an ordering and filtering mechanism and an urgency factor that considers the QoS provisioning of LTE network. Likewise, the proposed scheme optimizes the overall spectral efficiency of the network. Simulation conducted using Vienna LTE system level simulator shows a remarkable improvement in terms of throughput and fairness of both users.

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I. Introduction

In recent years, due to the ever-growing demand for packet-based mobile broadband networks, there appear some kinds of wireless communication systems using Orthogonal Frequency Division Multiplexing (OFDM), such as, Wireless Interoperability for Microwave Access (WIMAX) and LTE to support a wide variety of services and applications with different QoS requirements [1]. LTE was developed by Third Generation Partnership Project (3GPP) to support higher data rate of 100 mega-bits (Mbps) in the downlink and 50 Mbps in the uplink, which was later extended to 300 and 75 Mbps for both downlink and uplink respectively [2]. The key requirements of the LTE technology are to double the spectral efficiency of 3G networks with a flexible bandwidth of 1.4 to 20 Megahertz (MHz), with a simplified architecture as compared to its predecessor such as Global System for Mobile Communications and Universal Mobile Communication Systems [3]. The high-level network architecture of LTE comprises of three (3) main components as illustrated in Figure 1. Namely the Evolved Packet Core (EPC), the Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the User Equipment (UE). The EPC communicates with packet data networks in the outside world such as the internet, IP multimedia subsystem, or the private corporate networks through the packet network gateway (P-GW). It is formed by multiple nodes, such as mobility management entity (MME), serving gateway (SGW), Home Subscriber Server (HSS) and P-GW. The functions of these nodes are user mobility management, routing, authentication, session management, setting up bearers and the application of different Quality of Services [7][8]. The E-UTRAN consists of evolved Node Bs (eNBs). It handles the radio communications between the mobile and the EPC. The base station that is communicating with a mobile is known as its serving eNB and each eNB can connect to multiple UEs. The UE comprises of Mobile Termination (MT), Terminal Equipment (TE) and Universal Integrated Circuit Card (UICC). The MT handles all communication functions, the TM terminates the data streams and UICC is a SIM card for LTE devices [9].

The LTE Radio Resource Management block located at eNBs is used to improve the utilization of radio resources of the LTE network by some techniques such as congestion control, call admission control, power saving scheme and scheduling [10]. The scheduler resides at the Medium Access Control (MAC) Layer of the eNB and perform the function of scheduling by deciding which group of Physical Resource Blocks (PRB) gets assigned to which UE at each Transmission Time Interval (TTI) of 1 milli-seconds, by ensuring that the QoS of different requirements are satisfied. PRB is the smallest element of resource allocation assigned by the eNB packet [11].

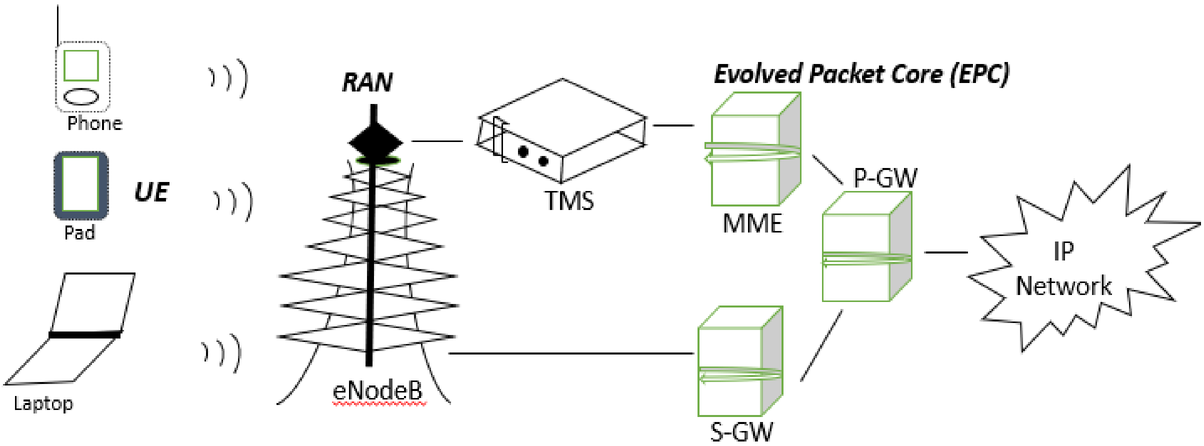


Figure 1: LTE System Architecture [7].

The 3GPP standard does not define any standard criteria for scheduling schemes in LTE networks, therefore it is left open for vendors and network operators to decide on how scheduling schemes are developed. Users are always demanding for a better service, as such, there is always the need for an effective radio resources management technique such as scheduling.

LTE downlink scheduling algorithms faces some major challenges while assigning available resources to contending users, such challenges include low throughput, delay, packet drop, fairness. Which in turn leads to the reduction in the overall spectral efficiency of the network [12].

Authors in [13] extended the work of [14] by incorporating a Genetic Algorithm (GA) into the scheme to improve the overall network throughput and decrease delay. After checking the channel status and QoS requirements of the users, the users are classified based on their priority, the high priority users received resources first before the low priority users. The GA will then be used to determine the order of transmission of packets. The scheme maximizes throughput, Spectral efficiency and causes a decrease in delay. However, when applied in a heavily loaded network, the scheme reduces the fairness index, due to its inability to properly define the fitness function that will consider the QoS provisioning of LTE network. There is also an increase in packet loss rate as a result of starvation of NRT packets, due to poor ordering and filtering mechanism of users in the GA algorithm. To address the aforementioned problems, this study proposed an enhanced downlink scheduling algorithm over LTE networks using genetic algorithm to improve QoS of users in LTE, by ensuring that resources are allocated to both high and low priority users based on their fitness function. It also introduces an ordering and filtering mechanism that arrange users based on their urgency and priority of resources, which will in turn, improve the transmission rate of varying traffic classes under heavy arrival of packets.

II. Literature Review

In this section, review of some related scheduling algorithms is presented, these comprises of some traditional algorithms in wireless networks, downlink scheduling algorithms in LTE networks and GA related algorithms. The operation, strengths and weaknesses for the schemes were also highlighted.

Round Robin (RR) was used for sharing of resources in equal manner among users over a fixed time. The algorithm is very basic, simple and fair when users contending for resources are not many. However, in wireless networks such as LTE, the user throughput also depends on experienced channel conditions, apart from the number of occupied resources. Hence, allocating radio resources to users with diverse QoS requirements is inefficient.

The behavior of this algorithm in LTE can thus be illustrated in Equation 1:

$$m_{i\,k}^{RR} = t_1 - t_2 \qquad 1$$

Where $m_{i\,k}^{RR}$ Is the metric of the i^{th}User on thek^{th} Resource Block (RB)

t_1 Is the current time and t_2 is the last time when the i^{th} user was served [15].

Blind Equal Throughput (BET) scheduling algorithm was proposed to provide fairness and improve efficiency of varying flows. It uses a memory to store past average throughput achieved by each user as a metric. In every TTI, low average throughput users in the past allocation are considered for RBs allocation. This scheduler is fair in providing throughput between users with both high and Low Channel Quality Indicator (CQI) values. Hence, it is called “blind”. However, it decreases the overall spectral efficiency. [16]

The BET scheduling priority metric is calculated using Equation 2:

$$M_n = \frac{1}{r_{n(t)}} \qquad 2$$

Where M_n is the metric of the n^{th}User
r_n (t) is the prior average throughput of the user.

Proportional Equal Throughput (PET) was proposed to enhance the fairness of BET and user throughput by providing a balance between them. The scheme is a hybrid of PF and BET algorithms. In each TTI, it allocates the fraction of the RBs to the users. The algorithm improves fairness without causing a considerable decrease in throughput. However, the scheme is not suitable for RT traffics, due to its failure to consider the delay constraint in its metric [17].

Proportional Fair(PF) algorithm was first proposed to be used in time domain scheduling of code division multiple access systems [18]. The algorithm was improved in [19], so that it can be used in OFDM systems in both frequency and time domain. The main aim of the scheme was to improve fairness and average throughput for all active users. In each TTI, it selects the user with the best instantaneous data rate in relation to their average data rate. The algorithm has a high level of fairness. However, QoS of delay sensitive applications is ignored, thus, causing starvation of these applications. The metric of PF algorithm is calculated using equation 3.

$$p(t) = \frac{\mathrm{Rj(t)}}{\mathrm{Tj(t)}} \qquad \text{for } \mathrm{j} = 1{,}2 \dots\dots \mathrm{N} \qquad 3$$

Where $p(t)$ is the proportional fairness in a given time.R_j(t) and T_j(t) are achievable throughput and past average throughput respectively.

An Adaptive Exponential/Proportional Fair (EXP/PF) algorithm was proposed in [20] to improve the throughput of NRT users and guarantee the QoS requirements of RT users. The algorithm combines the functions of EXP and PF schedulers for resource allocation. The scheme increases the system throughput. However, at high system load, the scheme is unfair to RT users. Thereby, causing an increase in delay of RT users.

The authors in [21] proposed a Modified largest weighted delay first (M-LWDF) to improve the QoS of RT traffics. The algorithm takes the head of line (HoL) packet delay, average throughput and instantaneous data rate along all bandwidths into consideration, it prioritizes and serve the users based on a computed metric. It includes the probability of a user to exceed target delay requirements and user with highest probability receives highest data rate. Therefore, the scheme schedules RT and NRT differently. This is done by handling NRT with proportional fair and RT with delay weighted metric. The algorithm improves throughput in real-time services. However, it causes increase in packet drop of RT traffic due to the expiration of the delay budget. It also leads to delay of NRT traffics due to starvation caused as a result of strict priority given to RT traffics.

The authors in [22] proposed a service differentiated downlink flow scheduling algorithm to guarantee the QoS requirements of RT traffics and avoid starvation of NRT traffics, the algorithm uses α and β as adjustable values for fairness in resource blocks sharing, the remaining RB that was not used will be given to high priority users. However, a different load scenario was ignored in this algorithm.

Authors in [23] proposed an adaptive downlink packet scheduling in LTE networks, based on queue monitoring to reduce the packet loss from the queue of user at eNB when the network is congested and also improve fairness level among users. The algorithm divides each queue of an active user into different queues for different Quality of services and assigned threshold limit for both RT and NRT packets. In each TTI, the scheduler assigns RBs to the selected users based on the frequency domain scheduler metric (i.e., users selected with high scheduling metric). The result show that adaptive downlink packet scheduling improves fairness level and throughput, it also reduces packets transmission delay and improves packet delivery fraction. However, under heavy input traffic arrivals, the scheme causes delay of RT traffics due to its failure to maintain priority of the RT traffic. The scheme also increases packet drop due to expiration of their deadline as a result of starvation caused when NRT queues exceeds the threshold for a longer period.

A Maximum satisfied users (MSU) scheduler in LTE networks was proposed in [24] to increase the number of satisfied real-time video streaming users. The scheme divides the resource blocks into two, 10% and 90% respectively. The 10% is reserved in case of network congestion or users that have not been attended, while the remaining 90% is used to serve the active users that have good channel quality and maximum priority metric, but limit the number of bandwidths allocated to UEs using throughput threshold. In this scheme UEs that reached average throughput threshold will not be considered for resource allocation in the next TTI until all other UEs with throughput less than threshold have been served. The scheme maximizes the number of video streaming users and prevents starvation of RT packets. However, the scheme causes waste of resources under low input traffic arrival, it also causes starvation of NRT packets when applied in a network with varying traffics as a result of static resource allocation. Moreover, UEs will not have enough share of the RBs, due to the throughput threshold value set to control the allocation of bandwidth and the 10% RB reservation.

In [25], a heterogeneous network selection algorithm based on network attribute and user preference was proposed to improve the QoS and QoE. The algorithm comprises of three typical multiple attribute decision making methods, namely fuzzy analytic hierarchy process, entropy and technique for order preference by similarity to an ideal solution. fuzzy analytic hierarchy process was first used to calculate the subjective weights of network attributes and the subjective utility values of all alternatives for four typical traffic classes, entropy and technique for order preference by similarity to an ideal solution are then used to respectively get the objective weights of network attributes and the objective utility values of all alternatives. Lastly, it considers the utility value of every candidate network and a threshold, the selection is based on a network with the comprehensive utility value greater than the corresponding value of the current network of the mobile terminal. The proposed algorithm reduces the number of vertical handovers and enhances the QoS. However, the load balancing of the alternatives is not considered, which will invariably reduce the overall spectral efficiency of the network.

In [26], the authors proposed quality of service class identifier algorithm for LTE downlink networks to address the performance degradation problem. The scheme uses channel status and QoS requirements to allocate resources to contending users. The higher the priority of the users, the higher the number of RBs to be assigned. The proposed scheme increases the fairness of the network. However, in a network with varying traffics, it causes a decrease in the overall network throughput and an increase in delay, due to its failure to consider the GA before allowing user access to the RBs.

Authors in [24] extended the work of [23] by incorporating a GA into the scheme to improve the overall network throughput and decrease delay. After checking the channel status and QoS requirements of the users, the users are classified based on their priority, the high priority users received resources first before the low priority users. The GA will then be used to determine the order of transmission of packets. The scheme maximizes throughput, Spectral efficiency and causes a decrease in delay, however, when applied in a heavily loaded network, the scheme reduces the fairness index, due to its inability to properly define the fitness function that will consider the QoS provisioning of LTE networks. There is also an increase in packet loss rate as a result of starvation of NRT packets, due to poor ordering and filtering mechanism of users in the GA algorithm. To address the aforementioned problems, this study proposed an enhanced downlink scheduling algorithm over LTE networks using genetic algorithm to improve QoS of users in LTE, by ensuring that resources are allocated to both high and low priority users based on their fitness function. It also introduces an ordering and filtering mechanism that arrange users based on their urgency and priority of resources, which will in turn, improve the transmission rate of varying traffic classes under heavy arrival of packets.

III. Proposed Algorithm

Our proposed Strategic GA is capable of delivering optimal performance with low complexity with the following stepwise procedures. Step1: The foremost step in our algorithm is filtering and ordering of the users based on priority and urgency of the resources to be delivered.The urgency factor is calculated from the packet delay budget defined for each QoS Class Identifier (QCI) and the time interval the packet is waiting in the buffer.

In this section, a GA that uses a proper ordering and filtering mechanism to arrange users based on their urgency and priority of resources is introduced. The algorithm also uses fitness function to allocate resources to both high and low priority users. The scheme significantly improves network performance and increases fairness to users. The limitations of [14] (hereafter called the Downlink scheduling algorithm over LTE networks using genetic algorithm) are presented. Before radio resource allocation is granted, GA is used to determine the transmission order based on priority and urgency factor of users. The high priority users get resource blocks depending on their Quality of Service Class Identifier (QCI) value.The urgency factor is calculated from the packet delay budget and the time interval the packet is waiting in the buffer.

$$UF_i = \frac{Hl}{delay}$$

Where UF_i is the urgency factor of packet for ith user, Hl is the interval of time the packet waits in the buffer and $delay$ is the packet delay budget of the application the packet belongs to.

The priority factor is computed using equation

$$\text{PF} = \begin{cases} 2 \text{ if QCI of user packet is RT} \\ \\ 1 \text{if QCI of user packet is NRT} \end{cases}$$

RT applications are delay intolerant in nature, therefore, the algorithm gives higher priority to avoid the increase in packet drop rate of such applications. The urgency threshold is set to 70% of the packet delay budget to consider QoS requirements. When ui >=0.7, the demand of RBs for each user is calculated and contiguous allocation of RBs are carried out based on the priority. However, when ui < 0.7, each RB is given to a particular user in the form of vector representation.

GA imitates the natural biological development process. DNA system has many chromosomes, and people assume the chromosomes as the arrangement of tasks or jobs, the genes inside chromosomes are referred to as the individual task, and people rearrange them in a different sequence to obtain a better sequence. The procedure of arrangement is called the Crossover and Mutation. The process is iterated several times to obtain better solution from previous results. Therefore, as it is used for task scheduling in different sectors, including the networks industries. The methodology of this research work incorporated GA in order to achieve a sub-optimal solution and maximize the QoS of different flows of QCI users. The following steps are used in GA processing for the distribution of resource blocks and packets transmission in LTE network:

1. Forming chromosomes

In this study, due to the diversity and large number of users contending for resources in each TTI, a single chromosome contains several genes which is also called a task, twenty genes are arranged in a single chromosome, which implies a completion of an operation by twenty tasks. Half of the operations are tested in order to form parent chromosome,$t_{i,x,y}$Where $t$represent a task, x = 1,2,3………20,i= 1,2,3………10 and y = 1,2,3………10. While x,i *and* y represents the operations, total number of tasks and UEs. The first parent chromosome is formed by arranging the UEs because the sequence will be rearranged in the following process. However, the sequence will be dependent on some number of operations. Therefore, it could be deduced that $t_{i,x,y}$ represents the first task done by UE1.

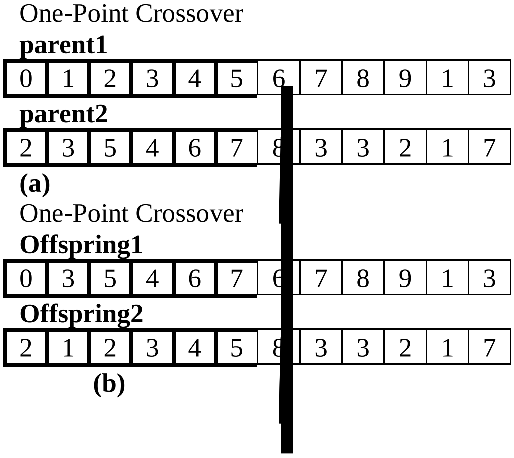
2. Crossover stage

The crossover/ evolutionary computation process combines two parent chromosomes to produce new offspring chromosomes, also referred to as genetic operator. For the crossover process, at least two chromosomes are needed, and there is possibility of getting better chromosomes if the child chromosomes takes best characteristics from both the parents. Figure 2 demonstrates an example (as used in the simulation scenario) of twelve genes in a single chromosomes, two parents are obtained and in order to get the offspring from both parent chromosomes, One-Point Crossover is applied. A cut-off and exchange of the genes with each other will occur at any place during the process.

0	1	2	3	4	5	6	7	8	9	1	3

2	3	5	4	6	7	8	3	3	2	1	7

Figure 2: Parent before processing



One-Point Crossover

parent1

0	1	2	3	4	5	6	7	8	9	1	3

parent2

2	3	5	4	6	7	8	3	3	2	1	7

(a)

One-Point Crossover

Offspring1

0	3	5	4	6	7	6	7	8	9	1	3

Offspring2

2	1	2	3	4	5	8	3	3	2	1	7

(b)

Figure 3: chromosomes (a) before and (b) after crossover process

The difference in the coordination of chromosomes after a crossover process occur is shown on figure3.The rate of crossover is a determinant factor in controlling the capability of the GA in exploiting a located hill to reach a local optimum. Let's consider a scenario of a set of crossover at a higher rate, the quicker the exploitation proceeds. Therefore, crossover rate is not to be set too larger, because it would disrupt individuals faster than they could be exploited. Normally, the value of a crossover rate is between "0.3 to 0.7".

3. Mutation Stage

The chromosomes from the previous process need to go for the Mutation process with a method called 'Boundary'. The boundary is a mutation operator that simply exchanges one gene with another chromosome. Let's say the problems are represented with X as the RB and y as the MCS, New solutions are generated by applying f(X, y) in which either x_i or y_i is uniformly randomly selectedto be processed once. If x_i is selected, then a particular column of X, say j, is randomly chosen to assign the kth RB to one randomly selected user, say

i. Moreover, if kth column $x_k = (x_{0,k}, ..., x_{i,k}, ..., x_{w,k}, ..., x_{N,k})^T$ is $(0, ..., 0, ..., 1, ..., 0)^T$ then the new solution $x'_j = (x_{0,k}, ..., x'_{I,j}, ..., x'_{k,j}, ..., x_{,N,j})^T$ will be $(0, ..., 1, ..., 0, ..., 0)^T$. However, if the selected decision variable is b, then $y_i = (y_{i,0}, ..., y_{i,j}, ..., y_{i,k}, ..., y_i,Q_{max}(i))$ with a possible value of (0, ..., 0, ..., 1, ..., 0) will be randomly chosen to be operated for producing the next state subject. Then the resulted state will be $y_i' = (y_i,0, ..., y'_{i,j}, ..., y'_{i,k}, ..., y_i,Q_{max}(i))$ with a possible value of (0, ..., 1, ..., 0, ..., 0). This mutation procedure performed efficiently in the work of

IV. Performance Evaluation

In this section, in order to evaluate the performance of the proposed enhanced downlink scheduling algorithm over LTE network using genetic algorithm against the benchmark algorithm [14]. Vienna LTE system-level simulator is used, it is an open source software released for academic and non-commercial purpose. The simulation parameters in table (1) are adopted from the benchmark work. However, as against the range of UEsstarting from 10 to 100 with an interval of 10 after each simulation experiment, our own scenario started from 10 UEs in the first experiment, 20 UEs in the second experiment and their after, an interval of 20 number UEs is applied until the last run that will contain 100 UEs.

Table 1: Simulation Parameters

Parameter	**Value**
System Bandwidth	5 MHz (25 RBs)
Number of UEs	10-100
UE distribution	Random
Number of RBs	50
Frame Structure	Frequency Division Duplexing
Packet Arrival	Poisson Process
Simulation period	1000ms
Transmission scheme	2x2 MIMO, OLSM
Cyclic prefix used	Normal cyclic prefix
UE Speed	4.16 m/s
Node Mobility	eNB position is fixed and UE position is random

1. Simulation Scenario

In this research work, the high rate of UEs mobility is considered, the interest is for the moving user scenario, where the users are 10, 20, . . ., 100, starting from the first, second to the last simulation experiment respectively. In this experiment, 5 MHz spectrum is assigned to each sector with 500m distance between inter base station. Users are uniformly distributed with a moving speed of 4.16 m/s.

2. Performance Metrics

The following performance metrics are used to evaluate the performance of the proposed algorithm.

i. Throughput: This is the total number of calls successfully admitted into the network within a given time.

$$\boldsymbol{Throughput = \frac{Tp}{t}} \qquad (1)$$

Where**Tp**, is the total number of successful transmitted packets, and $\boldsymbol{t}$ is the time taken for the successful transmission of the packets.

ii. Jain Fairness Index: This is a known performance metric used for evaluating the fairness of resource allocation among traffic flows**.** SomeUEs closer to the eNB have good channel condition and are therefore given more RBs than the edge users, who are at the edge of the coverage area. This will result in higher throughput for the former and the later may suffer from long packet delays and could even lead to starvation.

$$\text{Jain Fairness Index} = \frac{[\sum_{i=1}^{n} x_i]^2}{n\sum_{i=1}^{n} x_i^2} \qquad (2)$$

Where n is the total number of users in the system, x_i is the throughput of user i.

Fairness index ranges from 0 to 1, with 1 indicating perfect fairness and 0 indicating no fairness.

V. Experimental Results and Discussions

In this section, the experimental results obtained are discussed as follows: Figures 4 and 5 represent throughput and fairness respectively, for both the DSA-GA and EDSA-GA. It is demonstrated on Figure 4 that the throughput of users for both the benchmark and proposed scheme is the same when the number of users is low, likewise, a little improvement is observed when the number of UEs increases to 40 and 60. However, as the network intensity increases (i.e. 80 and 100 UEs), the available RBs are not capable of serving traffics of all users in each and every TTI, that is when the proposed EDSA-GA demonstrates an improved performance over the benchmark work. The improvement is as a result of incorporation of a proper ordering and filtering mechanism and an urgency factor that considers the QoS provisioning of different users and their need for RBs.It is also demonstrated on Figure 5 that thejain fairness index for 10 and 20 UEs is almost the same for both the benchmark and the proposed scheme. This is because the traffic load is low and as such, the available resources are enough to serve all users without delaying them or causing starvation. But when the number of users increase, then the proposed scheme shows a better performance.

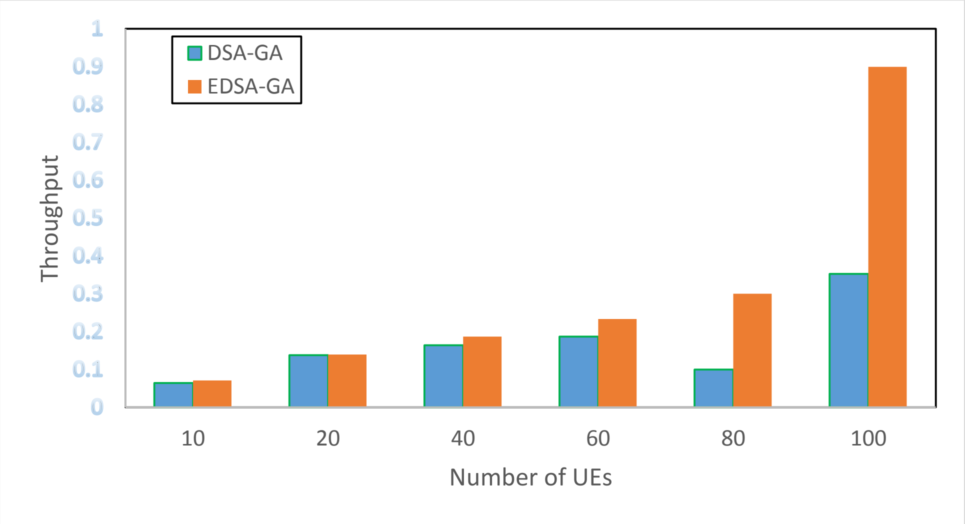


Figure4: Throughput as the number of users increases

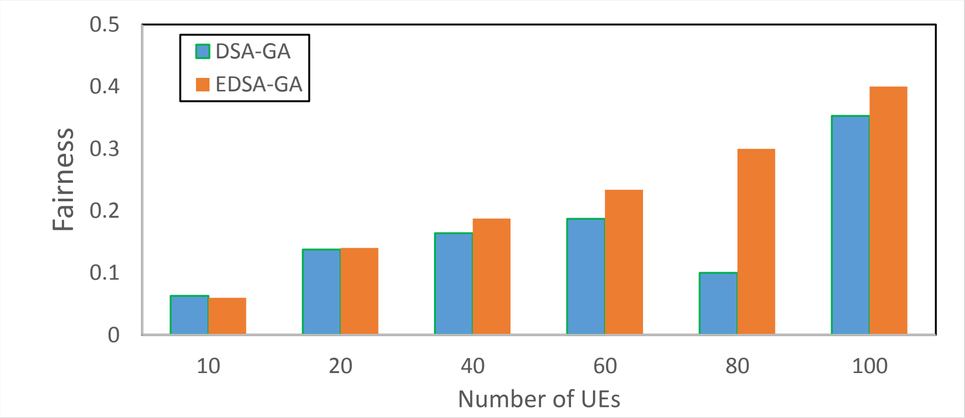


Figure 5: Jain Fairness Index

VI. Conclusion

An enhanced downlink scheduling algorithm over LTE network using genetic algorithm is proposed for LTE network to improve the performance of both RT and NRT users. The scheme allocates RBs to UEs based on their channel conditions, priority and urgency of the resources. RT are delay intolerant applications, therefore, in most cases, priority is given to them to transmit their packets, Simulation experiments were carried out using Vienna LTE system-level simulator to evaluate the performance of the benchmark scheme with the new proposed scheme. The result obtained show that proposed scheme achieves better average throughput for RT and NRT traffics. The improved performance is as a result of the incorporation of the GA with good filtering and ordering of the users based on priority and urgency of the resources. Which causes more RT packets to be transmitted, which in turn, translates to higher average throughput. Further performance evaluation should be conducted to assess the performance of the scheme based on other performance metrics like packet drop ratio and overall increase in spectral efficiency.

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