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Review of Downlink Scheduling Over LTE Cellular Network

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Abstract:
Many researchers interested in Long-term evaluation LTE and LTE advanced network, which considered one of the most important technical at networks and communication field, several issues have been studying in different approaches in target of enhancing the development of communications, and improves network performance for different types of traffic flows, which led to achieve higher user bit-rate, lower delays, increased spectrum efficiency, supported of diverse QoS requirements, and lower cost. Resource scheduling and mitigation is a key design to achieving these goals. LTE downlink scheduling considered as essential component in radio resource management, that support real-time and non-real-time traffic flow, such as video, VoIP, web browsing, and video calls, different algorithms have been provided for manage radio resource. Several approaches and algorithms have been proposed in the literature to address the needed of allocated the available resources efficiently; diversity and multiple algorithms are related to factors considered for optimum management of the radio resource, specifically the type of traffic flow and quality of service required. This article presents a review of various radio resource allocation strategies that proposed for downlink scheduling in LTE network, which have been studied under many factors and variables.

Keywords: *LTE; Radio Resource Allocation, Downlink Scheduling Algorithms*

I. INTRODUCTION

The Long Term Evolution (LTE) refers to E-UTRAN (Evolved Universal Terrestrial Access Network) that was introduced by 3GPP (3rd Generation Partnership Project) in R8, and considered as the access part of Evolved Packet System (EPS), which is IP based aims to supply high spectral efficiency, high data rates, and decrease delay, with flexibility in frequency and bandwidth, and with respect to previous 3G networks[1]object to answer the rising demand for different data services such as file sharing, Internet TV, and video telephony By taking advantage of various Radio Resource Management (RRM) procedures. Many key features are offered through LTE to serve subscribers and service providers. In addition, by targeting mobile broadband applications with improving mobility, user requirements are significantly satisfying[2]. According to the same reference,
LTE allows effective implementation of emerging Internet services in recent years. Packet switching are used same as in 3G networks, the difference is the use of Time Division multiplexing (TD) and Frequency Division multiplexing (FD) at the same time, which providing a higher productivity (in spectral efficiency) of 40%.

LTE is based on Orthogonal Frequency Division Multiple Access (OFDMA) as downlink transfer technology, provide higher-level modulation (up to 64QAM), large bandwidths, and spatial multiplexing that can be obtained at high downlink data rate, to support a wide range of multimedia and the Internet services even in high mobility scenarios[1][3]. The main thrust of research in LTE is to provide network services with 100 Mbps in downlink and 50 Mbps in uplink to deliver a peak data rate. However the exceeded in the final system, which delivered the peak data rate of 300 Mbps in downlink and 75 Mbps in the uplink [4].LTE access network support several system bandwidth configurations (from 1.4 MHz up to 20 MHz) that is divided into two parts via OFDMA to allow simultaneous downlink and uplink data transmissions based on QoS required by users[3], at the physical layer LTE supported two types of frame structure, known as Frequency Division Duplex FDD and Time Division Duplex TDD modes, two separate bands are used for uplink and downlink on FDD, and the same frequencies are used for both transfers downlink and uplink on TDD. For downlink transmissions in LTE a10ms frame is used and grouped in LTE downlink radio transmissions, each radio frame is created using 10 sub-frames of 1ms duration. Uplink and Downlink transmission use ten sub-frames, which split into two slots with 0.5 ms each[4].
LTE standard has not specifically defined the radio resource-distributing problem, which affects transmission flows over the

network, in this context, the scheduler consider as a initial element in the evolve node B eNB (LTE base station), and important area of researching study responsible to address and tackle the LTE downlink resource allocation issues in order to properly allocate the resources for users, a various of studied carry on this field, this paper proposed to review and discuss the various recent researches that have been addressed the LTE downlink scheduling the resource allocation strategies from eNB to UE.

II. LTE Architecture

LTE is designed to support Packet Switched (PS) services, in target of providing seamless IP communication between UE and Packet Data Network (PDN), without interference to the end users' application during mobility [9][5]. LTE with a flat IP architecture that requires a lower sharing node helps to improve system performance. Moreover, depending on the strategy of intelligence distributing between evolved NodeBs (eNB), which is LTE network's bases-stations, the connections and handover on the LTE network has been improved by ignoring of centralization controller that assisted to speed up the connection and making decisions between the user equipment UE and base-stations eNB. The LTE Medium Access Control (MAC) layer that accountable for packet scheduling located at eNB and considered as the main entity responsible for assigning portions of spectrum to shared them among users [6].

EPS uses the concept of EPS bearers to route IP traffic from a gateway in the PDN to the UE; these bearers are an IP packet flow with a specific Quality of Service (QoS)[5].

LTE system consists of a core network Known as Evolved Packet Core (EPC) and a Core Pack network known as E-UTRAN.The E-UTRAN and EPC together set up and release bearers as required by users' applications. The necessary QoS for the voice call will be provide via a VoIP bearer, and a best-effort bearer would be suitable for the web browsing or FTP [7].

Fig1: represents a radio protocol stack of E-UTRAN control plane where The Radio Resource Control (RRC), being responsible for establishing the radio bearers between the UE and the eNodeB[7],these bearers are responsible for managing QoS on the E-UTRAN interface, a default bearer is created when UE joins the network for basic connectivity and exchange of control messages. Each bearer has a QoS class identifier (QCI) and each QoS is categorized by priority, packet loss, and allowed delay; depending on QoS requirements, these bearers can be classified as Guaranteed bit-rate (GBR) real-time or non-guaranteed bit rate (non-GBR) non-real time bearers [3]. In the access network, eNodeB is responsible for ensuring the quality of service required for the bearer on the radio interface[7].

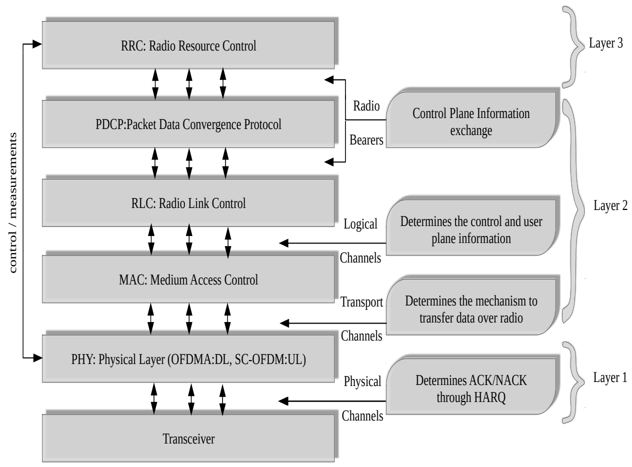

Fig.1. LTE E-UTRAN protocol architecture

The resource allocation issue considered as a significant challenge in charge of providing a satisfy QoS to active users by distributing available resources on the network among them, to serve their need. The packet scheduling is an essential element of radio resourcesmanagement, which have to be quickly and effectively modified to serve all LTE traffic[1][3].

III. Scheduling inLte

The scheduling techniques are used by LTE to make an effective use of resources in time and frequency bands[8], and satisfy the QoS requirements for multiple services[9].Packet scheduling mechanisms (both downlink and uplink) are implemented at eNBs, where the physical layer resources for uplink and downlink channel are allocated. The eNB are responsible for assigning parts of the shared spectrum to users, following specific policies, which means that parts of the spectrum should be distributed in each TTI among them. In order to support downlink data services at high transmission rates, eNB sends data using the LTE PDCCH channels (physical downlink control channel) that control the downlink control channel, and the content that comes from multiple users is transmitted in time and frequency domains [3]. The resources that are allocated for the uplink shared channel and the downlink-shared channel contains physical resources blocks (PRB) and modulation coding scheme (MCS). The bit rate is determined by MCS and the capacity is determined by PRBs. These allocations of MCS and PRBs are done for one or more TTIs and the duration for each interval for TTI is one sub-frame (1ms) [4].

Downlink control information (DCI) contains all PRBs assignment information, power control command, uplink grant, and MCS, etc. at high traffic scenarios the DCI messages in PDCCH will be scheduled for users in each TTI to notify the UEs of PRBs allocated for data transfer in downlink on PDCCH that increase overhead control[4][3].This scheduled technique known as **dynamic scheduling** which consider as a primary scheduling in eNB[10], using dynamic scheduling, large differences in the amount of data transmit can be

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processed at the expense of scheduling decisions sent on the downlink control channel, such as the PDCCH in each possible timetable[11]. For each VoIP packet was sent, the additional information will be added, this will led to PDCCH blockage and decrease VoIP capacity in case of limited resource, which impact the LTE QoS[10]. And because of voice data generated in small packets come in organized interval reliant on the network, in which case **persistent scheduling** is used, in aim to minimize the amount of control overhead signals resulting from the use of a fully dynamic scheduling strategy[12].Its technology is based on constant of frequency resource and temporal stability in the allocation of resources to the user while maintaining control information sent across sub-frame throughout the communication period, this scheduling algorithm significantly reduces overhead[13][4]. The user and the eNB aware of the TTI/ PRB allocation before start assignment, in addition the eNB has advance aware when and where PDSCH should be decoded, reducing additional PDCCH overhead. The main issue of persistent scheme is the difficult of determining exact number of resources needed to transmitted and retransmitted voice packets, which case the resources wastage, in addition to some other factors such as channel condition, user mobility, interference and Doppler effect, the TTI/PRB can't be determined in real time[4][10]. In aim to avoid drawback in using persistent allocation, **semi-persistent** scheduling for VoIP was improved taking the advantage of dynamic and persistent schemes. This scheduling algorithm allowed eNB to allocated packets resources periodically to the user equipment e.g. every 20 ms, and this procedure is done once at beginning of each data burst[14].

IV. Downlink Scheduling in Lte

The packet scheduler is responsible for controls the assignment of RBs to UEs to avoid cells interference. Generally, the function of the schedule is to get the appropriate allocation of the basic physical resource unit (e.g., time, frequency, power, etc.) for User Equipment that serve the QoS requirements for users, based on specific scheduling criteria such as channel condition, traffic type, head of line packet delay, and queue status, depending on which packet scheduler prioritizes the users; and determined which UE to be scheduled and assigned the number of PRBs.[15]. The radio resource management modules for downlink packet scheduler functions in sequential operations thatrepeated every TTI, starting at users side where each UE calculates signal-to-noise (SNR) ratio based on its state of the channel and performed its CQI according to reference signals and send it back to eNB, where a buffer is set for each user [16]. On every TTI eNB uses CQI report to make a allocation decision based on scheduling algorithms and located a RB's mask, The AMC determines the best MCS that must be used to transfer data by scheduled users. Information about these users, customized RBs, and MCS is sent to the UEs on the PDCCH, then each user's equipment reads the PDCCH report and in case of scheduling, the payload for the (physical downlink shared channel) PDSCH packet can be reached[3][15].

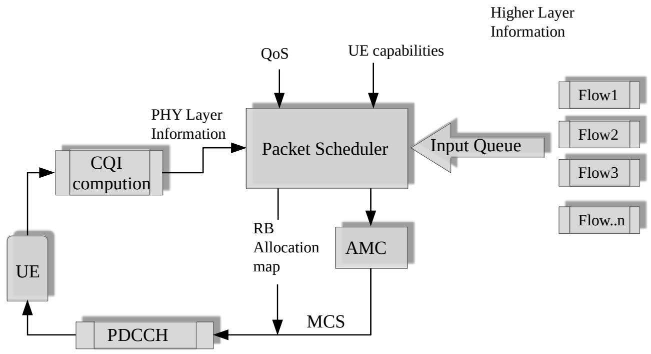

Fig.2. General Model of LTE Packet Scheduler

V. Downlink Scheduling Algorithms

For making resource allocation decision on downlink, the scheduler usually compares the metric value of each UE between each RB. Resources Block RB k_{th} are allocated to each UE depending on comparison between metrics for i_{th} user who has largest $M_{i,k}$ valueusing the following equitation:

$$M_{i,k} = max_i M_{i,k}$$

Nevertheless, different issues arise in design of a solutions of LTE system, and many downlink packet-scheduling algorithms have been developed to satisfy the QoS requirements and fairnes for various LTE service optimaization. Various factors in the literature have been addressed to meet the needs of users and optimize the use of available radio resources on LTE network.Different classifications of downlink algorithms have been identified in previous studies. Hereafter, different recnt resource allocation strategies introduced for LTE system will be illustrated, inaddition to well-know algorithm schemes that widely used in the literature are represented. In this review paper the scheduling classify according to their approch stratigy if its best effort or live multimedia scheduler.

VI. Best Effort Scheduler

The best effort scheduler describe the algorithms that don't provide any guarantee of achieving QoS requirements, and all network subscribers obtain best-effort service with unspecified bitrate, latency, packet loss ratio.

1) Round Robin (RR)

The resource block are fairly assigned to UEs for a time slot, channel condition and user throughput are unaware by RR scheduler[3].

$$M_{i,k}^{RR} = t - T_i$$

Where t refer to current time and T_i refer to the last time when UE served, i is a user on k RB.

2) Proportional Fair (PF)

PF algorithm assigns available radio resources to the users, takes into account the experienced channel quality and the past user throughput that can be act as a weighting factor of expected data rate; PF algorithm aims to maximize total bit rate and guarantee fairness among flows [3][17].

$$M_{i,k}^{PF} = \frac{d_{i,k}(t)}{R_i(t)}$$

This metric determined the proportion between the current available data rate $d_{i,k}(t)$ and the average past data rate $R_i(t), i$ refer to flow in k flow sub-channel.

3) Maximum Throughput Scheduler (MT)

This strategy aims to maximize the throughput of the system by assigning the available resource block to the UE that can maximize throughput at current TTI, MT performs unfair distribution of resources among users[3].

$$M_{i,k}^{MT} = d_k^i(t)$$

Where $d_k^i(t)$ is achievable throughput expected user i at t TTI and over k RB.

4) Throughput To Average (TTA)

This algorithm can be considered as a balance between MT and PF. The TTA guarantees a strong level of equity and provides better allocation of RBs per user in one TTI[3].

$$\mathrm{M_{i,k}^{TTA}} = \frac{\mathrm{d_k^i(t)}}{\mathrm{d^i(t)}}$$

$\mathrm{d_k^i(t)}$ And $\mathrm{d^i(t)}$ are achievable throughput for user i at t TTI,and over k RB, these differ from each other on how to get MCS [4].

VII. Live Multimedia Scheduler

For optimize the over all LTE system many scheduling algorithms have been introduce to serve real time flow and guarantee some required performance, in term of delivery delay or data rates considering CQI and user's application type.

1) Maximum Largest Weighted Delay First (MLWDF)

It's a channel-aware algorithm supports multiple data user with various QoS requirements, MLWDF considers delay and fairness and guaranteed system throughput. Non real-time and real-time flow are addressed differently, where PF using for non-real time flow and for real time flow use weighting metric as follow:

$$M_{i,k}^{M-LDWF} = \propto_i D_{HOL,i} * M_{i,k}^{PF}$$

$$\propto_i = -\frac{\log \delta_i}{\tau_i}$$

Where $D_{HOL,i}$is head of line packet delay for useri at time t, τ_i represent the packet delay threshold for user i that consider for each real-time flow, δ_i indicates the maximum potentialthat the HOL packet delay thatmay cause the user ito exceed user's idelay threshold[16]. Note that, the HOL packet is the time contrast between the present time and the packet arrived time [16].

2) Exponential/Proportional Fairness (EXP/PF)

The EXP/PF algorithm was developed to support multimedia applications in time-multiplexed system [4]. It aims to increase the priority of real-time flows through non-real time flows, the number of user are multiplied every scheduling time due to available multiple sets of sub-carriers to be shared by all users within the system at same time[17]. EXP/PF takes into account the characteristics of the exponential function and PF for the end-to-end delay in the package to be sent, for best effort flows EXP/PF work as PF, else EXP/PF is applied in real time flow as:

$$M_{I,K}^{EXP/PF} = \exp\left(\frac{\alpha_i D_{HOL,i} - x}{1 + \sqrt{x}}\right) \cdot \frac{d_k^i(t)}{R^i(t-1)}$$

Where

$$x = \frac{1}{N_{rt}} \sum_{i=1}^{N_{rt}} \alpha_i \, D_{HOL,i}$$

N_{rt} is the number of active DL flows in real time.

3) Frame Level Scheduler (FLS)

The algorithm operates in a two-level framework that ensures specific delay intervals for real time flows. At the highest level, the total amount of data that should be sent in the actual time flow is calculated by applying a separate time-line control code in eachLTE frame, in order to meet their delay constraints. The lower layer works on each TTI, and is responsible for assigning RBs per flow. In particular, restricted delay flows are allocated using the same MT policy, take into account the bandwidth requirements that calcoulated at the upper level. there after, the PF algorithm is used to share the reserve spectrum among the best effort users[3]. The amount of transmitted data can be calculates by using following equation:

$$u_i(k) = h_i(k) * q_i(k)$$

$u_i(k)$ Represent the amount of data that will be transmitted by i flow during k LTE frame, which can be obtained by passing a signal $q_i(k)$ queue level, through a time invariant linear filter with plus response $h_i(k)$ or equivalently, $*$ is the discrete time convolution[17].

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4) EXP Rules

This algorithm are designed with the goal of increasing user channel allocation to the maximum with different channel condition, takes into account the overall network status. EXP rule specifies one user / queue to receive service at each scheduling moment. It uses channel information and stands in a queue without any prior knowledge of traffic access and statistics. Thus, the scale of priority in the EXP schedule can be expressed analytically as follows[17].

$$M_{i,k}^{EXPrlue} = b_i \exp\left(\frac{a_i D_{HOL,i}}{c + \sqrt{\left(1/_{N_{rt}}\right)\sum_j D_{HOL,j}}}\right).\Gamma_k^i$$

Where a_i, b_i and c are optimum parameters that required by system. N_{rt} Is the number of downlink flows at RT, $D_{HOL,i}$ id the head of line delay for i user, $\Gamma_k^i$is spectral efficiency on k resource block of user i[18].

5) LOG Rules

LOG Rule algorithm is designed to balance the QoS, considering average delay and durability. It uses logarithm rule for specified the delay, and PF metric for fairness. The resources are allocated to the users in the same way as an EXP rule, with the difference is that the LOG rule has prior knowledge of arrival and traffic channel statistics that led to maximize throughput [17].

$$M_{i,k}^{LOGrule} = b_i \log\left(c + a_i D_{HOL,i}\right).\Gamma_k^i$$

According to[3], Γ_k^i Represent the spectral efficiency for i user on k sub-channel

6) Delay sensitivity

[19]A channel- aware services with respect of QoS requirements was proposed, which specify the priority for GBR and non-GBR from various QoS Class Identifiers (QCIs), to reduce the maximum packet transfer delay, available bandwidth, transmission power, channel mode, and achievable transmission rate are factors that the scheduling algorithm used to assign bandwidth resource to the users based on channel quality indicator (CQI) reports. The approach that authors utilized depending on sorted the received packets at eNodeB in separate queue buffer for each user and the timer that obtain HOL packet delay started when the packet reaches the front of the queue; so each user assign one bearer to transport its data packets. The authors considered three cases, for GBR bearers a packet delay, QCI's and packet delay budget, for non-GBR bearers, a classical channel-aware scheduling policy was proposal, which aims at maximizing the sum of the concave (α-fair) utility function. If the PDB could not be fulfilled for all bearers, a novel algorithm that establishes relative precedence between QCIs was applied.

EXP-MLWDF new downlink scheduling that has been evolved in [20], and evaluated the performance of it, the proposed algorithm was suggested for the high mobility scenario with a large number of active users, in order to avoid congestion in the network, which may occur due to the large increase in bandwidth requirements. This algorithm considers some parameters to serve user with good channel condition with considering to users with bad channel condition these parameters include user channel condition, average transmitted data rate, head of line delay, and the difference between HOL delay and packet delay time at buffer queue. UE's with better channel condition will obtain higher priority for sending their packets; and for users who have bad channel condition, estimated average transmission data rate and head of line delay at each TTI have to be considered for transfer their packets.

[27] Presented a method to improve PF LTE downlink scheduler, took in account latency Rate and LTE standard characterize. The proposed scheduling Proportional Fair - Latency Rate Scheduler (PFLR) depended on two main scheduling, (Latency-Rate LR scheduler providing a customizable rate per user, and token bucket algorithm scheduling for restricting input traffic). The token bucket size and rate are calculated based on the properties of the data entry traffic, and the LR Scheduler can provide a specific delay as requested by users. In proposed scheduler, queuing delay relies upon parameters on token bucket scheduler for each session, network latency and rate allocation. For modifying original PF scheduler, the service rate per session will be considered with channel condition and delay required by each user.

Real time applications data traffic was consider by [32] to serve a higher demand for RT services and fulfill the different sorts of their QoS requirements, a downlink algorithm DP-VT-MLWDF was designed, in aim to evolve the QoS performance for real time flows and keep non real time services performance in a fair level, to achieve their aim, PLR and delay were taken into account beside CQI, flow buffer size and past time average throughput. The proposed scheduling depending on kept a delay and PLR at lower level, and give the highest priority to packets flow that their delay closer to value of threshold, and it has to be transmitted first.

The proposed scheduling in [35] is delay aware and resource block management algorithm joined with PF algorithm, the proposed algorithm used to control queue length and packet delay in aim of satisfies QoS requirements, with considered the delay threshold and RB

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ratio of real time and non-real time traffic. The goal of this algorithm is reduce the average packet delay for RT traffic and maintain the fairness for non-RT traffic. The simulation results illustrate better performance for average packet delay, the packet loss ratio and the system throughput compared with PF algorithm.

An effective Delay-based and QoS-Aware Scheduling (DQAS) algorithm was proposed [36] in aim to solve the resource allocation issue in MAC layer; that reduce real time traffic delay and increase the system throughput with keeping the QoS at a good level for real time and non real time flows. Two mechanisms were comprised for the proposed algorithm, EDC algorithm to analysis Delay-oriented flows that determine and LDI that used for QoS-aware procedure for throughput-oriented flows, and the resource allocated decision made based on delay-derived rules to meet QoS requirements for real time flows. The performance evolution of the proposed algorithm DQAS showed it maintained a low-latency and strong behavior for independent RT traffic for increased network load. In addition, it returns the highest amount of throughput with low data drop ratio.

7) Buffer-aware schedulers

A resource allocation algorithm was proposed by [24], which makes an adaptive multifractal envelope process and minimum service curve for LTE downlink. This algorithm with QoS guarantees aims to improve network parameters taken into account backlog, channel condition and user traffic behavior for real time implementation, to provide a maximum throughput and a minimum delay; an adaptive minimum service curve was proposed to estimate LTE delay bounds. For describe network flow an adaptive algorithm was proposed channels spectral efficiency; in addition to computing the users' priorities to scheduling blocks SBs in each TTI, and the decision was taken depending on spectral efficiency of users and buffer state.

[25] Illustrated a new LTE downlink-scheduling scheme, which satisfies the quality of services (QoS) requirements of the real time traffic, with consideration of different elements for delay requirements. The approach of this algorithm confirms receiving the transmitted packet with in limited time to avoid discard them when reach deadline, the deadline is assign for each flow has eNB's packet queue via scheduler; different parameters have been taken into account to compute the deadlines include queue size, waiting time of the packet in the queue, and maximum delay.

The lack of recourses that cause burst user data rate traffic was considered in [30], which led to the eNodeB buffer overflow. For user queue overflow problem that accord at the base station a queue monitoring and resource scheduling are illustrated, that reduce packet transmission time and improve the system throughput with fairness distributing available resources among users. The algorithms strategies follow sequence steps, start at eNodeB where users queue level, channel condition, packet QoS, and history of resource allocation is checked. Next, they use three proposed mechanisms for resource allocation and the allocated decision made up depending on two factors (user priority metric and status of user's queue at a base station).

[31] Proposed a service-differentiated downlink flow-scheduling S-DFS algorithm for the different downlink flows in aim to solve the flow scheduling problem over the LTE by distinguishing between the flows depending on their QoS requirements, taking into account HOL packet delay, channel quality, QCI, and data packet queue length, to ensure quality of service for GBR flows and to prevent starvation for non-GBR flows. For each UE the CQI and queue status will be collected every TTI, and based on CQI the eNB transmitted PRBs to UEs then according to QCI and status of the queue every UE assign the gaining PRBs to its flows, which guaranteed the QoS for GBR flows. Adjustable α and β is used to deny some flows gather a giant range of PRBs. additionally; unused PRBs are reallocated to a flow with excessive demand. Nevertheless, the proposed algorithm ignored various load scenarios.

A downlink link scheduling was proposed [34] in aim to enhance the PF algorithm in term of fair delay distribution among users in the cell based on buffer state for each user instead of minimizing time of delay. The available resources will be allocated to user, whose buffer state is not empty with considering the previous scheduling interval, taking into account the different traffic volumes for users in the cell. The proposed algorithm was compared with PF and MT algorithms and the simulation results showed it has better delay fairness so it achieves the fairness of implementation rate, however the throughput fairness slightly loss.

8) Throughput sensitivity

[22] Illustrated a modified strategy that maximize the LTE system throughput while achieving justice for users, this method improve existing downlink scheduling algorithms EXP/PF by saving resource blocks, with a consideration to the users on a bad channel condition without impact users in good channel condition. The presented method based on the actual process of scheduling, if the RBs for users in good channel condition can be saved with guaranteed QoS, the users who have not good channel condition can get access to more RBs.

[23] Addressing a varying of channel condition challenge, in LTE resource allocation. Bandwidth prediction method is used through statistical information

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to evolve system throughput supporting QoS requirements based on collecting and analyzing channel quality information during resource allocation to predict future channel state, according to these data the resource allocation vectors will be configured. This approach split network nodes into various sets based on channel condition and QoS requirements, nodes with no require for QoS can be spate into groups according to their channel condition. The opportunities for transmission decision will be made according to nodes' channel condition and QoS requirements in each frequency period of time.

[26] A new algorithm in downlink LTE network was presented in this paper, named Extended-PF, which enhances the PF algorithms in term of throughput and spectral efficiency. With investigation of its performance at managing multi-service flows in real time and non real time, to provide higher spectrum efficiency and Quality of Service (QoS) over LTE network. The proposed algorithm takes into account the modulation of the traffic rate according to the state of the channel and ignores the delay in the proposed algorithm. The frame channel shared between the flexible motion users within the system's network must be stable with fairness of values. Flexible traffic is a service that has the ability to adjust its rate according to the status of the channel. By controlling the stability between supply and demand, the maximum productivity value can be achieved.

The work in [33] a multi-Level Queue scheduling algorithm was proposed in aiming of evolving the network's throughput taking into account users mobility. The active users on the network are distributed based on their channel condition to several queues. UEs with a better channel condition will be assigned to higher priority queues and perform their resource allocation, UEs with lesser channel condition will gain lesser priority queues and their resource allocation will be perfumed after end off higher priority queues, the better results gain for system throughput for UEs in good channel state, and guarantee fairness for UEs in bad channel state, although the QoS requirements are ignored.

[37]A mathematical model named DSA-QoS for VoIP over LTE that proposed to reducing average waiting time to allocate resources and increase average throughput for real time and non-real time users taken into account balancing between channel quality and application type. The scheduling priority assigned to the users according to CQI classification and application classification. The proposed algorithm was simulated and compared with other algorithms include MY_SCH_Fair, EDF, and M-LWDF in term of average waiting time, average throughput and average spectral efficiency. The results showed higher-level performance of DSA-QoS.

9) Energy aware

Data rate and energy efficiency (EE) was concentrated in [29] aims to answer the expanding requests in cellular traffic. An efficient algorithm was proposed called Quality of Service (QoS) and Energy Efficient Aware (QEEA); aims to control energy consumption that need to achieve high data rates to meet LTE requirements. The HOL delay, achievable throughput, past average throughput, and transmitted power, are considered in proposed algorithm, which evolve EE and use low transmitted power to increase network throughput, without affecting the QoS. (The minimums power of 45 dBm(20 W) according to LTE specifications). QEEA scheduler is based on Frequency Domain and Time Domain scheduling, that considers the QoS requirements for resources allocation.

[21]Presented a LTE downlink scheduling, considered QoS requirements and CQIs reports for end users' equipment, to ensure the maximum delay in the package delay budget PDB of any of them. The overall scheduling design to collect QCIs describing the data flows present in the cell with their priorities and calculate average throughput values, next, estimate instantaneous throughput values, and checked the bearers, considering three cases for bearers: for GBR bearers the proposal scheduling aims to ensure a (PDB); for non-GBR bearers, the PDB was guaranteed for delay-dependent traffic (e.g. IMS signaling, voice, live streaming, interactive gaming, etc.), and for non-GBR bearers for elastic traffic (e.g. www, email, ftp, progressive video, etc.) the proposal aims to provide a minimum data rate.

As mentioned by [28]The current algorithms experience performance degradation caused by prioritized conditions due to the base data rate used to decide the transmission request. For that, new radio resource algorithm has been proposed for LTE downlink scheduling in a target of enhancing objectives of proportional fair PF LTE algorithms, and consider as bearer class quality of service control algorithm. It decides resources location based on (QoS channel Indictor) QCI in the aim of fulfilling the QoS constraints, beside that, by using QoS requirements and user’s channel conditions the need for minimum data rate will be compensated. This algorithm depends on the sorting technique for users channel based on their QoS requirements, in case a user request several services with different QoS requirements at one time.

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VIII. References

[1] N. Magdalena, "LTE, the Mobile brodband standard, 3GPP," *3GPP*. [Online]. Available: http://www.3gpp.org/technologies/keywords-acronyms/98-lte. [Accessed: 23-Oct-2018].

[2] F. Bendaoud, M. Abdennebi, and F. Didi, "Survey on Scheduling and Radio Resources Allocation in LTE," *Int. J. Next-Generation Networks*, vol. 6, no. 1, pp. 17–29, 2014.

[3] F. Capozzi, G. Piro, L. a. Grieco, G. Boggia, and P. Camarda, "Downlink Packet Scheduling in LTE Cellular Networks : Key Design Issues and a Survey," *IEEE Commun. Surv. Tutorials*, vol. 15, no. 2, pp. 678–700, 2013.

[4] R. Subramanian *et al.*, "Survey of LTE Downlink Schedulers Algorithms in Open Access Simulation Tools NS-3 and LTE-SIM," *Int. J. Wirel. Mob. Networks*, vol. 7, no. 2, pp. 01–16, 2015.

[5] S. Kitanov and T. Janevski, "Performance Evaluation of Scheduling Strategies for LTE Networks in Downlink Direction," *XI Int. Conf. ETAI 2013*, no. September, 2013.

[6] D. Singh and P. Singh, "Radio Resource Scheduling in 3GPP LTE : A Review," *Int. J. Eng. Trends Technol.*, vol. 4, no. 6, pp. 2405–2411, 2013.

[7] S. Sesia *et al.*, *LTE– The UMTS Long Term Evolution*, Second Edi. Chichester, UK: John Wiley & Sons, Ltd, 2011.

[8] P. Kumar, S. Kumar, and C. Dabas, "Comparative Analysis of Downlink Scheduling Algorithms for a Cell Affected by Interference in LTE Network," *Annals of Data Science*. Springer Berlin Heidelberg, 2016.

[9] M. Salah, N. Ali, and A. Taha, "Designing Standard-Compliant LTE Schedulers," *Bmec.Queenstrl.Ca*, no. August 2016, 2011.

[10] D. H. Nguyen, "Enhancing and improving voice transmission quality over LTE network : challenges and solutions," Institut National des Télécommunications, 2017.

[11] J. Rune and E. Eriksson, "Methods and Arrangements for semi-persistent Scheduling," US 9,681,430 B2, 2017.

[12] M. R. Tabany, C. G. Guy, and R. S. Sherratt, "A novel downlink semi-persistent packet scheduling scheme for VoLTE traffic over heterogeneous wireless networks," *Eurasip J. Wirel. Commun. Netw.*, vol. 2017, no. 1, 2017.

[13] A. Patra and L. Y. Volker Pauli, "Packet Scheduling for Real-Time Communication over LTE Systems A Comparative Study of Dynamic and Semi-Persistent Scheduling Schemes," 2013, pp. 1–6.

[14] R. Ratasuk, D. Bhatoolaul, N. Mangalvedhe, and A. Ghosh, "Performance Analysis of Voice over LTE using Low-Complexity eMTC Devices," 2017.

[15] S. Fouziya Sulthana and R. Nakkeeran, "Study of Downlink Scheduling Algorithms in LTE Networks," *J. Networks*, vol. 9, no. 12, pp. 3381–3391, 2014.

[16] F. Afroz, K. Sandrasegaran, and P. Ghosal, "Performance Analysis of PF, M-LWDF and EXP / PF Packet Scheduling Algorithms in 3GPP LTE Downlink," *Australas. Telecommun. Networks Appl. Conf.*, pp. 87–92, 2014.

[17] U. N.Nwawelu, C. Ani, and M. A. Ahaneku, "Comparative Analysis of the Performance of Resource Allocation Algorithms in Long Term Evolution Network.," *Niger. J. Technol.*, vol. 36, no. 1, pp. 163–171, 2017.

[18] R. Khdhir *et al.*, "Downlink Packet Scheduling Algorithm Using Tabu Method in LTE Systems," in *Wired/Wireless Internet Communications*, 2018, pp. 0–13.

[19] P. Ameigeiras *et al.*, "3GPP QoS-based scheduling framework for LTE," *Eurasip J. Wirel. Commun. Netw.*, vol. 2016, no. 1, 2016.

[20] I. Angri, M. Mahfoudi, A. Najid, and M. El Bekkali, "Exponential MLWDF (EXP-MLWDF) Downlink Scheduling Algorithm Evaluated in LTE for High Mobility and Dense Area Scenario," *Int. J. Electr. Comput. Eng.*, vol. 8, no. 3, pp. 1618–1628, 2018.

[21] A. Gutierrez, J. N. Ortiz, J. M. L. Soler, R. G. Perez, J. Manuel, and J. L. Hernando, "Method and a system for scheduling the downlink in long term evolution (lte) networks based on quality of service (qos)," PCT/EP2013/053324, 2017.

[22] Z. Jiang, W. Zhang, S. Gao, and L. Zhou, "An improving strategy for LTE downlink scheduling algorithms based on QoS requirement," *Proc. - CQR 2015 2015 IEEE Int. Work. Tech. Comm. Commun. Qual. Reliab.*, no. 1, 2015.

[23] S. Gayathri and R. Sabitha, "Resource Allocation in downlink of LTE using Bandwidth prediction through Statistical Information," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 10, no. 2, pp. 680–686, 2018.

[24] D. C. Abrahão and F. H. T. Vieira, "Adaptive envelope process and minimum service curve applied to resource block allocation in the LTE downlink," *Int. J. Commun. Syst.*, vol. 32, no. 1, p. e3829, Jan. 2019.

[25] D. Samia and B. Ridha, "A New Scheduling Algorithm for Real-Time Communication in LTE Networks," in *2015 IEEE 29th International Conference on Advanced Information Networking and Applications Workshops*, 2015, pp. 267–271.

[26] I. Nurcahyani and S. Adinandra, "A novel packet scheduling with channel-aware algorithm for multi-

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ISSN: 0193 - 4120 Page No. 10047 - 10055

service flow in the LTE network," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 8, no. 3, pp. 749–755, 2018.

[27] R. P. de Oliveira, L. A. de Góis, and A. Foronda, "Enhanced PF Scheduling Algorithm for LTE Networks," *Int. J. Commun. Networks Inf. Secur.*, vol. 10, no. 1, pp. 49–56, 2018.

[28] M. Mamman, Z. M. Hanapi, A. Abdullah, and A. Muhammed, "Quality of Service Class Identifier (QCI) radio resource allocation algorithm for LTE downlink," *PLoS One*, vol. 14, no. 1, p. e0210310, Jan. 2019.

[29] N. M. Yusoff, D. M. Ali, A. Idris, S. Ismail, and K. S. S. K. M. Noh, "QEEA algorithm for throughput improvement in the LTE networks," in *2017 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)*, 2017, vol. 10, no. 1, pp. 54–58.

[30] N. D. Adesh and A. Renuka, "Adaptive downlink packet scheduling in LTE networks based on queue monitoring," *Wirel. Networks*, vol. 1, pp. 1–18, 2018.

[31] Y. C. Wang and S. Y. Hsieh, "Service-differentiated downlink flow scheduling to support QoS in long term evolution," *Comput. Networks*, vol. 94, pp. 344–359, 2016.

[32] Y. P. Li, B. J. Hu, H. Zhu, Z. H. Wei, and W. Gao, "A delay priority scheduling algorithm for downlink real-time traffic in LTE networks," *Proc. 2016 IEEE Inf. Technol. Networking, Electron. Autom. Control Conf. ITNEC 2016*, pp. 706–709, 2016.

[33] S. Gayathri and R. Sabitha, "Multi-level queue based resource allocation in downlink of OFDMA wireless cellular networks," *Indian J. Sci. Technol.*, vol. 9, no. 10, 2016.

[34] S. Liu, C. Zhang, Y. Zhou, and Y. Zhang, "Delay-Based Weighted Proportional Fair Algorithm for LTE Downlink Packet Scheduling," *Wirel. Pers. Commun.*, vol. 82, no. 3, pp. 1955–1965, 2015.

[35] K. Kaewmongkol, A. Jansang, and A. Phonphoem, "Delay-aware with resource block management scheduling algorithm in LTE," *ICSEC 2015 - 19th Int. Comput. Sci. Eng. Conf. Hybrid Cloud Comput. A New Approach Big Data Era*, 2016.

[36] N. Madi, "Delay-based and QoS-aware packet scheduling for RT and NRT multimedia services in LTE downlink systems," *Madi al. EURASIP J. onWireless Commun. Netw.*, vol. 180, pp. 1–21, 2018.

[37] K. Ramkumar and P. Calduwel Newton, "DSA-QoS: Delay based scheduling algorithm to enhance the QoS in mobile networks," *Int. J. Pure Appl. Math.*, vol. 118, no. Special Issue 9, pp. 93–101, 2018.

[38] Gapar, M., & Ruzi, B. (2013). Toward Measuring of E-Learning Usability through User Interface. Advanced Applied Informatics (IIAIAAI), 2013 IIAI International Conference, 192-194

[39] R. A. Abbas, "Improving time series forecast errors by Using Recurrent Neural Networks," Australian Journal of Forensic Sciences, 2018

[40] M. H. Alkawaz, Automated Kinship verifcation and identifcation through human facial images, vol. 76 of Multimedia Tools and Applications, Kluwer Academic Publishers, 2017.

[41] M. H. Alkawaz, Detection of Copy-move Image forgery based on discrete Cosine transform, Neural Computing and Applications, Springer verlag, 2018.

[42] Y. H. A. Falah, "A Survey and Analysis of Image Encryption Methods," International Journal of Applied Engineering Research, 2017, Research India Publications.