FLOW BANDWIDTH MLWDF FOR LTE DOWNLINK TRANSMISSION

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ABSTRACT —*Long term evolution (LTE) Network is often faced with the challenge of meeting up with the quality of service (QoS) requirement of the different services supported in the Network. Maintaining a trade-off between system throughput and fairness among users when making radio resources scheduling decisions is very sensitive and problematic to most scheduling schemes. One of well-known packet schedulers known as Modified Largest weight delay first (MLWDF) algorithm is known to support both real time and non-real time services. This algorithm has been found not to support real time services at a sufficient level. This is due to the fact that head of line (HOL) delay and packet delay not sufficient to balance the scheduling decision to real time services thereby degrading its performance. This research work was an attempt to improve the performance of MLWDF by incorporating bandwidth of flow, β, which is directly proportional to flow weight and reserved rate .This approach used the uncertainty principle of fuzzy logic to calculate new weight for the different flows, by considering two input parameters from the network which are latency requirement for real time traffic and throughput for non-real time traffic .Results when compared with proportional fairness (PF),MLWDF, exponential proportional(EXP/PF) showed improved performance in Video and VOIP using throughput, packet loss rate, fairness index and delay as performance indices in an LTE simulator.*

Key words: LTE, VOIP, QOS, MLWDF, PF, MLWDF, Resource allocation, Scheduling.

I INTRODUCTION

Processes such as processor cycle, communication bandwidth are given access to system resources in computer science[1]. This process is known as scheduling. Scheduling algorithm arose from the need to satisfy the requirement of a fast computer system to perform multiple tasking simultaneously[2]. Scheduling is an important function of an operating system that regulates which function to execute when there are multiple runnable processes[3]. Scheduling in Central processing unit (CPU) is important because it enhances resource utilization and other performance parameters.

LTE is a mobile broadband network whose standard grew out of the global system for mobile communication (GSM) and universal mobile Telecommunication system (UMTS) technology. Scheduling plays an important role in LTE and is analogous to the scheduling seen in the computer system. Network resources are limited and as such efficient way of distributing these resources is essential in a way as to maintain trade-off between system throughput and fairness among users. In LTE the scheduler resides in the eNodeB to dynamically allocate uplink and downlink resources over the uplink and downlink shared channel U-SCH and D-SCH, respectively. Uplink scheduling is performed per SC-

FDMA while downlink is performed for OFDMA. The eNodeB calculates the time-frequency resources given the traffic volume and the QoS requirements of each radio bearer[4]. However, the resources are allocated per UE and not per radio bearer. The uplink and downlink schedulers are invoked to allocate resources every TTI. The minimum TTI duration is of one subframe length; that is, 1 ms. However, the LTE specification allows adaptive downlink TTI duration where multiple subframes can be concatenated to produce a longer TTI duration. This concatenation reduces the overhead for higher layers. The TTI length can be set dynamically by the eNodeB through defining the modulation and coding scheme used and the size of the resource blocks. Otherwise, it can be set semi-statically through higher layer signaling[5]. Adaptive TTI length can be used to improve the Hybrid Automatic Repeat Request (HARQ) performance or the support of lower data rates and quality of service. A. Resource allocation in LTE is described as the sharing of frequency, time, antenna ports and power between users which are aimed at achieving spectral efficiency, fairness and high/standard Quality of Service (QOS) [6]. Physical Resource Blocks (PRBs) are seen as the combined sharing of frequency and time to users (UEs) in the LTE network in order to meet a reasonable compromise amongst QOS, fairness, and spectral efficiency. Radio resources in LTE are composed of PRBs, Modulation and coding scheme (MCS) and power allocation. The MCS determines the bit rate and thus, the capacity of PRBs. Radio resource allocation is valid for one Transmission Time Interval (TTI) which is equal to 1ms [6].Fundamentally, LTE experiences great competition for resources considering the multiple but limited channels it supports in the presence of large number of users and their varied QoS requirements; hence the need for optimum resource allocation strategy. It is established that differences among resource allocation techniques are mainly based on trade-off between decision optimality and computational complexity. Key design aspects range from complexity and scalability, spectral efficiency, fairness to QoS provisioning [7]. The parameters for the evaluation of this optimality vary for different research goal. Despite these variations, users must be scheduled first before the assignment of resources [7]. As such, several schemes for scheduling users were developed considering the channel status of the user, the QoS demand by the user and other scheduling parameters. The parameters introduced in this work will focus attention on resource allocation in downlink system for real time services in LTE networks. An improved scheme will be developed by modifying one of the earlier algorithms known as MLWDF. The parameter introduced in this algorithm will be gotten by fuzzy means.The performance of the new algorithm will be compared with PF, MLWDF, EXP/PF algorithms using four performance metrics namely: throughput, packet loss rate, fairness index and delay. By incorporating bandwidth of flows (β) to MLWDF scheme, the MLWDF scheme was modified. Practically non-real time application has no constraint in delay and therefore has more packet in the buffer of eNodeB. This is also possible because it does not require the presence of the called party for communication to exist. Whereas it is not the same for real time application which has constraint in delay and has tendency of missing their deadline and therefore lost. This led to the considerable priority non-real time services get in accessing resources as can be seen from the original algorithm. The new algorithm considered bandwidth of flow in addition to delay which was incorporated to the old algorithm. By this, the scheme considered the bandwidth of the flow from the users to the buffer in the eNodeB for the different users. The aim is to improve the chances of real time services to access resources since they may exceed their deadline before the next transmission time interval (TTI).

II STATE OF THE ART

In [8], the performance of exponential/proportional fair (EXP/PF) and maximum-largest weighted delay first (M-LWDF) scheduling algorithm in the downlink 3GPP LTE system was evaluated. They conducted performance evaluation in terms of system throughput, average real time (RT) and non-real time (NRT) throughput, packet loss for RT service and fairness for NRT service. Video streaming and web browsing traffic were used to model RT service and NRT service respectively. Results of the evaluation of the algorithms in downlink showed that at lower load, M-LWDF algorithm provides better performance than EXP/PF while as the load increases the EXP/PF gives better performance.[9] Investigates the performance of well-known packet scheduling algorithms developed for single carrier wireless systems from a real time video streaming perspective. The performance evaluation is conducted using the downlink third generation partnership project long term evolution (3GPP LTE) system as the simulation platform. This paper contributes to the identification of a suitable packet scheduling algorithm for use in the downlink 3GPP LTE system supporting video streaming services. Results show that in the downlink 3GPP LTE system supporting video streaming services, maximum-largest weighted delay first (M-LWDF) algorithm outperforms other packet scheduling algorithms by providing a higher system throughput, supporting a higher number of users and guaranteeing fairness at a satisfactory level. In [10] ,a QOS-guaranteed cross-layer resource allocation algorithm for multiclass services in downlink LTE system is proposed, which takes EXP rule, channel quality variance, real-time services and non-real-time services and Minimum transmission rate into account. The key features of the proposed algorithm are that all the users and resource blocks will be allocated step by step respectively. Numerical results demonstrate that the proposed algorithm effectively guarantees the user QoS requirement for multiclass services. At the same time, it mainly maintains the throughput and fairness performances in a high level.[11] Proposed a modified radio resource management-based scheduler with minimum guarantee in the downlink following network capacity and service class attributes defined in LTE standard. The complete service class-based scheduler design were divided into three discrete parts which are admission control, resource allocation and packet scheduling. Discrete event simulator 'LTE SIM' with LTE specifications was used as the modeling tool. The results showed that the proposed scheme performs better than the other schemes like M-LWDF, EXP-RULE etc. in terms of system throughput, user mobility and fairness. In[12], the proposed algorithm assumed that each eNode B receives channel feedback information in the form of CQI-feedback matrix. The method used in the proposed algorithm gives preferences to those users which uses less bandwidth than others and it evenly distributes the resources among the users during each TTI, therefore fairness is taken into consideration for users by the proposed algorithm and at the same time user's capacity was increased. The proposed algorithm provides fairness better than PF, RR and best CQI and also a better trade-off between fairness and throughput was obtained. In[13], analysis using mobility model was used to study the performance of four algorithms known as PF,MLWDF,EXP-rule and LOG rule. The key aspects that should be considered when designing new algorithm was stated. It was found that MLWDF, EXP-rule and LOG rule are better choice for real time services whereas PF algorithm is more suitable for non-real time services.

III fuzzy processes Applied

The fuzzy approach proposed in this study takes as input two variables, latency requirement for real time and throughput for non-real time traffic. The output of the fuzzy inference system is weight, whose value will be utilized in the proposed algorithm for scheduling decisions. The respective membership functions for all the three variables were used. The fuzzy system is built over three linguistic variables for the input and output variables. The membership functions are defined as High, Medium, and Low. The range of all these variable is from 0 to 500ms for latency, 0 to 50Mb/s for throughput and 0 to 1 for flow weight. The rule base consist of 18 rules. The rule base has been defined considering the nature and dynamism of the input traffic.

The fuzzy system consist of three steps: fuzzification were the system reads in system input variables i.e. throughput and latency. Fuzzy reasoning were input state variables read in previous steps are manipulated on the rule base and provides an output value. Last step deffuzification employs center of gravity method to calculate a crisp value for output weight. The output weight is taken as the weight for real time traffic and weight of non-real time traffic is calculated by subtracting from 1 since the total weight for all queue shall satisfy the constraint defined in equation 5 below. The incorporated parameter which is a function of the weight of the flow is gotten from the fuzzy inference process using mamdani inference system shown from fig (1) to fig (5). The mamdani system using GUI was further converted to matlab code and then reconverted into C^{++} source code to be used in equation 4 while maintaining the constraint of equation 5, which when multiplied by the reserved rate of each user gives the value of the parameter β. On multiplying β with average throughput led to the modified scheme as seen in equation 2.

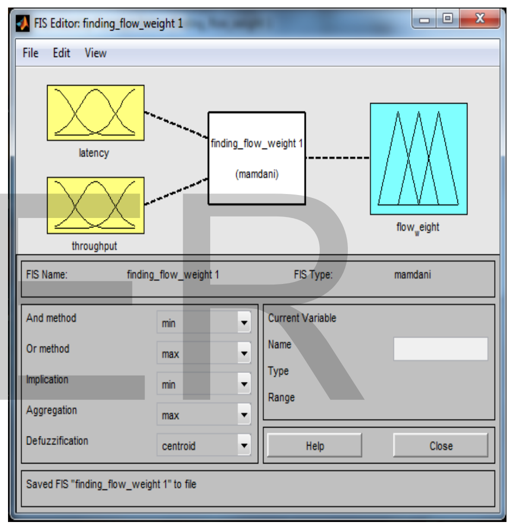


Figure 1: fuzzy inputs

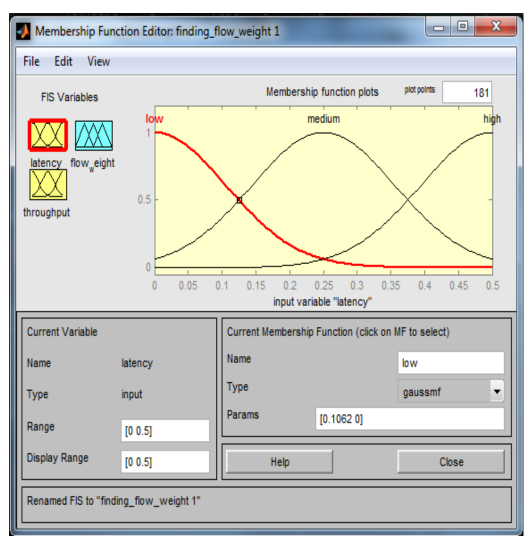


Figure 2: applying membership functions

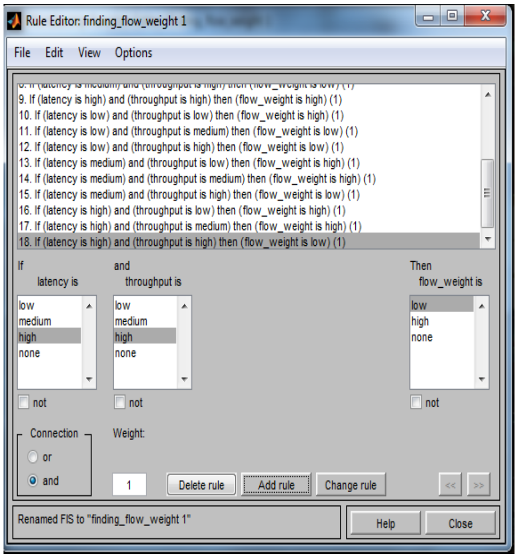


Figure 3: applying rules

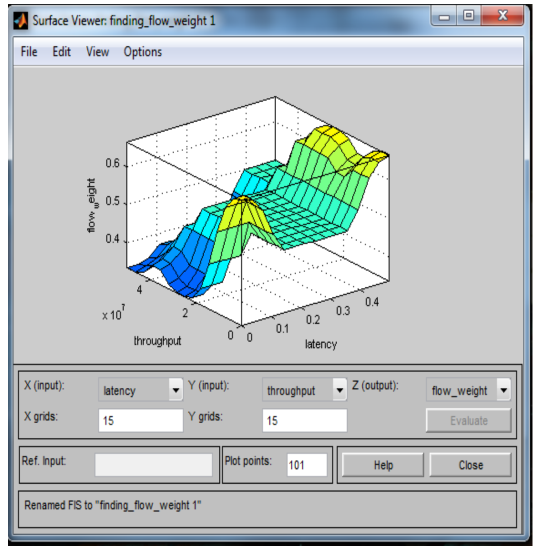


Figure 5: surface viewer

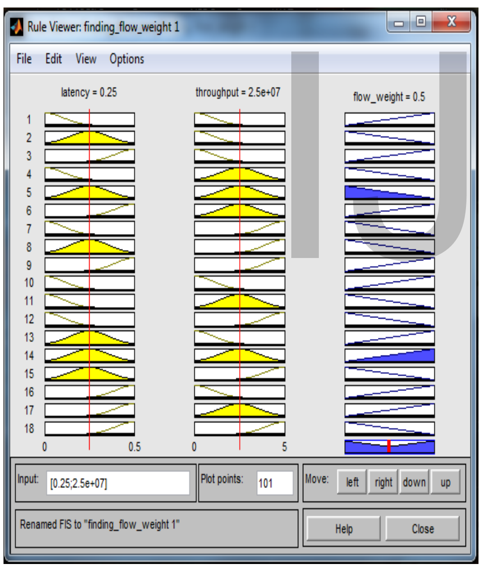


Figure 4: aggregating all outputs/deffuzification

IV PROPOSED SCHEDULING SCHEME

The MLWDF was modified to incorporate the parameters that will enhance the performance of the scheme. In this work another bandwidth of flow, β was introduced which is a function of buffer weight and reserved rate. This weight parameter β is multiplied by the average throughput in equation 1which lead to the modified form in equation 2. Equation I and equation 2 below show the M-LWDF and improved MLWDF respectively.

The scheduling problem in LTE has to satisfy a number of applications and these application tend to have different QOS satisfaction levels. This work tend to improve the M-LWDF algorithm by using a dynamic approach that is based on the principle of fuzzy logic.

$$m_{i,k}^{MLWDF} = \alpha_i D_{HOL,i} \frac{d_k^i(t)}{R_i(t-1)}$$

$m_{i,k}^{MLWDF}$

$= \alpha_i D_{HOL,i} \frac{d_k^i(t)}{R_i(t-1)\beta}$ (2)

Where

α_i =-$\frac{(log\delta_i)}{\tau_i}$

(3)

β=$R_{max} * \frac{w_i}{\sum_{i=0}^{n} w_i}$

(4)

$\sum_{i=0}^{n} w_i$=1 0.001 ≤w_i≤1

(5)

All flows shall satisfy the constraint given above.

Where: α_i=weight parameter, $D_{HOL,i}$=head-of-line packet delay, $d_k^i(t)$=expected data rate for i^{th} user at time t on k^{th}resource block, $R^i(t-1)$=average throughput up to time slot t-1, β=bandwidth of flow

δ_i=maximum probability for HOL packet delay of user i to exceed the delay threshold of user i.

τ_i=delay threshold of user I, R_{max}=user's maximum reserved rate, w_i=weight of the flow

SIMULATION PARAMETERS

Number of users	100
Bandwidth	10MHz
Number of resource blocks	50
Number of OFDM symbols per slot	7
Carrier frequency	2GHz
Simulation duration	150s
Flow duration	120s
Cell Radius	500m
Video bit rate(mp4 high quality video trace(Jurassic park 1)[14]	242kbps
VOIP bitrate	8.4kbps
NRT bit rate[FTP]	20kbps

V SIMULATION RESULTS AND ANALYSIS

The simulation was carried out using LTE-sim with the configured parameters as listed above and results obtained. Throughput, packet loss rate, delay and fairness index were used as performance indices which were compared with some existing schemes.

MLWDF scheme has been chosen and respectively modified to use the incorporated weight parameter β to improve their performance when using multimedia services such as video and VOIP. To make an evaluation of result, the following notation is used: 'PF' represents the proportional fair algorithm, 'MLWDF' represents the classic modified largest weight delay first algorithm, 'EXP/PF' represents the classic Exponential proportional rule, and 'I-MLWDF' represents the improved MLWDF. In this analysis, a percentage value is used to compare modified algorithms result to the results of non-modified algorithms.

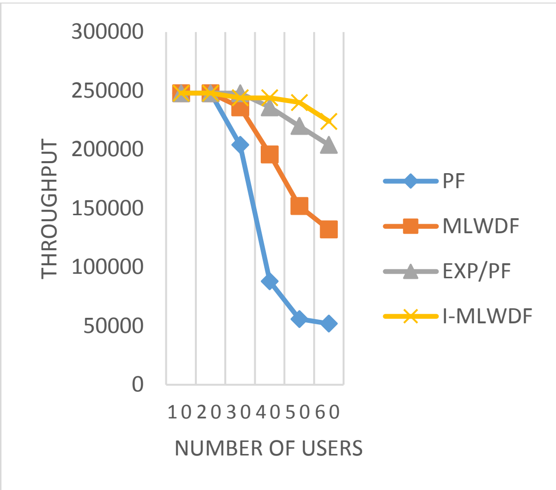
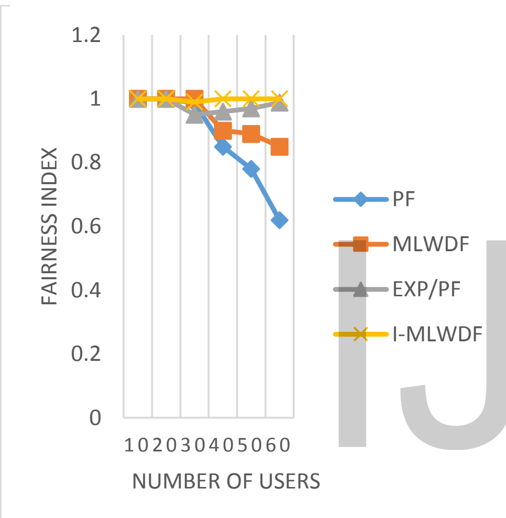
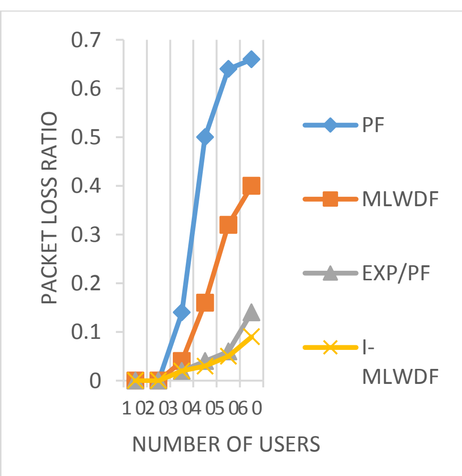


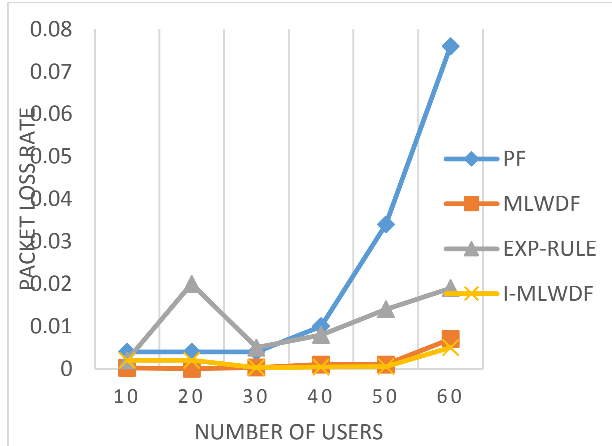
Figure 6: Average throughput Per Video



Fiaure 7:Packet Loss Rate for Video Flows



Fiaure 11:Fairness index for video flows



Fiaure 8: Packet Loss Rate for VOIP Flows

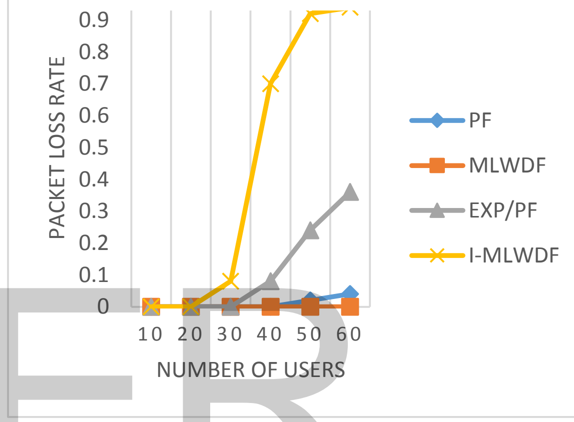


Figure 9: Packet Loss Rate for NRT

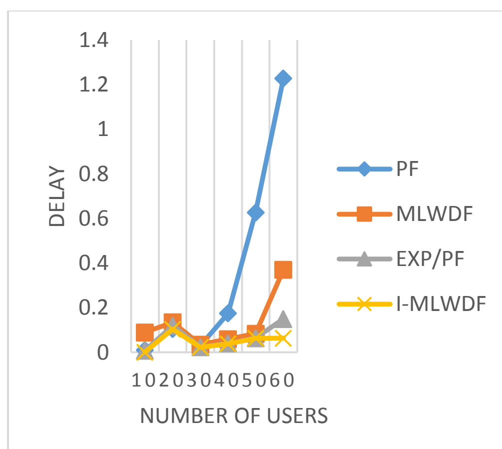


Figure 10: Delay for Video Flow

In figure 3, there was an increase in the overall throughput by about 9.8% for 60 users using the modified algorithm(I-MLWDF) as compared to the non-modified algorithm(MLWDF).An explanation for this is by using the incorporated weighty parameter, the video service having a high bit rate occupy a weighter flow in the network and therefore larger video flow bandwidth(β),which justify the considerable priority they get as we saw in fig (3). The worst results are obtained by PF.

In figure(4), The accepted packet loss rate for VOIP flows is under 3%.In this senario all schedulers shows accepted loss rate under 3% as shown in figure(4).

In figure(5),The best packet loss ratio performance for non-real time is shown by MLWDF whose packet loss ratio is under 1% when the cell is loaded by 60 users.PF also shows an acceptable packet loss rate when the cell is loaded up to 50 users. EXP/PF shows a packet loss rate under 3% when the cell is loaded up to 32 users. I-MLWDF shows a sharp increase of packet loss ratio. This can be explained that because non-real time flow will be the smallest one, Therefore NRT flows will perform high packet losses caused by buffer overflows. However, it should be noted that LTE-sim works under UDP traffic, so considering that FTP is normally implemented under TCP, the packet loss rate could be lower than shown in figure (h) due to the TCP retransmission control.

In figure (6), Video delays are illustrated in figure (i). The best performance is shown by I-MLWDF with its delay under 0.05s. The other schedulers are under 0.07s except PF which presents the worst performance.

In figure(7),Video delays are illustrated in figure (j).the shortest delays are performed by I-MLWDF (under 0.007s when the cell is loaded by 60 users) the other schedulers show similar packet delays, all of them under 0.02s, except PF (0.08s) when the cell is loaded up to 60 users.

In figure (8), Figure (m) shows the fairness index for VOIP flows. Since the VOIP flows are created by an ON/OFF method, the curves show ups and downs. All algorithms show a fairness index performance between 98.5% and 99.5%.

VI CONCLUSION

The work highlighted the limitation of the existing MLWDF Algorithm used in making scheduling decisions in LTE network. It identified bandwidth of flow as a necessary parameter, which was introduced to the MLWDF algorithm to further add to the delay parameter as seen in the original scheme in trying to favour scheduling decisions to real time services. The bandwidth of flow has been gotten by fuzzy means, making use of parameters from the network. Result of the new algorithm showed better result in throughput, delay, packet loss rate, and fairness index as compared to the other algorithm.

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REFERENCES

[1] W. Stallings, *operating systems internal and design principles*, 5th ed. 2006.

[2] I. S. Rajput, "A Priority based Round Robin CPU Scheduling Algorithm for Real Time Systems," vol. 1, no. 3, pp. 1–11, 2012.

[3] E. O. Onyetunji and A. E. Oluleye, "Performance assessment of some cpu scheduling algorithm," *Res. J. Inf. Technol.*, pp. 22–26, 2009.

[4] M. Abd-Elhamid, H. Taha, and N. A. A. Hassanein, *LTE,LTE-ADVANCED AND WIMAX TOWARDS IMT-ADVANCED NETWORK*, First. united kingdom: wiley and sons, LTD, 2011.

[5] C. Science, "Dynamic Resource Allocation in a LTE / WLAN Heterogeneous Network," pp. 96–102, 2015.

[6] "Free scale semiconductor. Inc, Long term evolution protocol overview,White paper." 2008.

[7] F. Capozzi, G. Piro, S. Member, L. A. Grieco, G. Boggia, S. Member, P. Camarda, and R. Robin, "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.

[8] R. Basukala, H. A. M. Ramli, and K. Sandrasegaran, "Performance Analysis of EXP / PF and M-LWDF in Downlink 3GPP LTE System," *IEEE First Asian Himalyas Conf.*, vol. 1, pp. 1–5, 2009.

[9] H. Adibah, M. Ramli, R. Basukala, K. Sandrasegaran, and R. Patachaianand, "Performance of Well Known Packet Scheduling Algorithms in the Downlink 3GPP LTE System," *Proc. 2009 IEEE 9th Malaysia Int. Conf. Commun.*, vol. 1, pp. 815–820, 2009.

[10] Q. Ai, P. Wang, F. Liu, Y. Wang, F. Yang, and J. Xu, "QoS-Guaranteed Cross-Layer Resource Allocation Algorithm for Multiclass Services in Downlink LTE System," *Int. Conf. Wirel. Commun. signal Process.*, vol. 2, pp. 1–4, 2010.

[11] Y. Zaki, T. Weerawardane, C. Görg, and A. Timm-giel, "Multi-QoS-aware Fair Scheduling for LTE," *IEEE 73rd,vehicular Technol. Conf. spring)*, vol. 1, pp. 1–5, 2011.

[12] M. S. Bahreyni and V. Sattari-naeini, "Fairness Aware Downlink Scheduling Algorithm for LTE Networks," *J. Math. Comput. Sci.*, vol. 11, no. 2, pp. 53–63, 2014.

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

[14] C. O. Nnamani, C.L.Anioke, and C. I. Ani, "Improved MLWDF scheduler for LTE downlink transmission.," *Int. J. Electron.*, 2016.